Vol. 10 No. 3 AUTUMN 2024

THE MAGAZINE FOR THE METAL ADDITIVE MANUFACTURING INDUSTRY

METAL AM

in this issue

SPACEX'S RAPTOR 3 | NORSK TITANIUM
BEAM SHAPING | TUNGSTEN PBF-EB
MINING PATENT DATA & MORE

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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 MAGAZINE

"SpaceX has the most advanced 3D metal printing technology in the world."

Whether or not you agree with this recent but rare statement on metal Additive Manufacturing by Elon Musk, when high-profile companies and individuals talk about their successes with the technology, everybody wins.

Within our industry, it is no secret that AM technology has underpinned much of SpaceX's progress, yet public information is frustratingly scarce. Many of us are, of course, complicit in the safe harbouring of information, be it about SpaceX or other companies, out of professional courtesy and respecting confidentiality.

Whilst the silence around some metal AM applications could in some instances be ascribed to national security interests, the biggest driver is retaining a competitive advantage. The vast floorspaces dedicated to the production of medical implants by Powder Bed Fusion come to mind.

Whether it is for the production of end-use parts or improving the performance of conventional manufacturing processes, such as injection moulding through the use of AM-enabled conformally cooled tooling, AM often delivers results that are, unfortunately, just too good to share publicly.

Of course, there are exceptions to every rule. The use of AM in commercial aviation, for example, is widely publicised, in part because of the huge advantages that the technology enables in terms of improving the operational and manufacturing efficiency of a new generation of engines.

If you're new to AM, don't be fooled into thinking that the technology isn't being adopted at scale by highly successful companies. It is – just too few are shouting about it.

Nick Williams
Managing Director

Cover image
Three generations of Raptor engines (Courtesy SpaceX)


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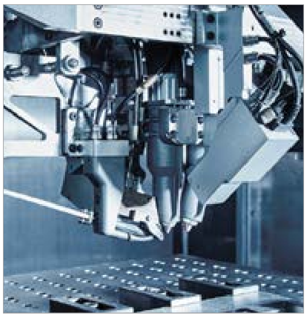

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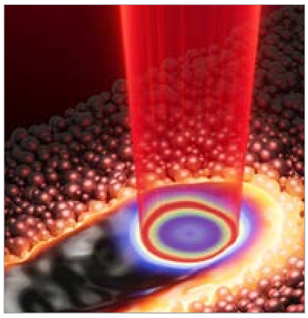

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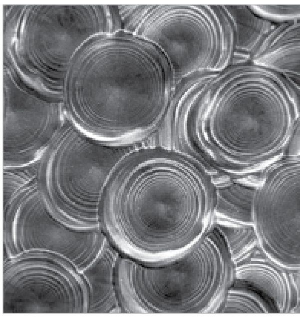

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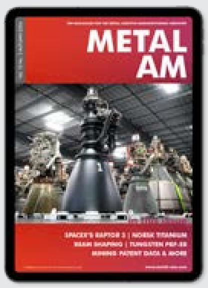

185 **Enabling the fusion energy revolution: Mastering tungsten with PBF-EB Additive Manufacturing**

There is a growing interest in additively manufactured pure tungsten, primarily propelled by the expected demand for tungsten components in future fusion power plants.

Here, Additive Manufacturing veterans and PBF-EB enthusiasts, Ulf Ackelid and Ulric Ljungblad – both of Sweden's Freemelt AB – provide insights into the AM of tungsten and the benefits of using an electron beam as the energy source.

This article is a standalone continuation of previous PBF-EB articles in *Metal AM*, published in the Summer 2020, Autumn 2022, and Summer 2023 issues. >>>

199 **Patents and Additive Manufacturing: What insights can mining PBF-EB data reveal about the industry and the technology?**

Patents have had a major impact on the evolution of the Additive Manufacturing industry. They offer intellectual property protection, yet they also force the disclosure of expertise. Registering a patent also comes at a high cost, yet for those who are found to infringe a patent, the costs are even higher. But what can the data generated by the global patenting process tell us about AM?

Here, Joseph Kowen and Gil Perlberg use Electron Beam Powder Bed Fusion (PBF-EB) technology as a case study to discover what patent data can reveal. >>>

209 **Additive Manufacturing for Semiconductor Capital Equipment: Unlocking critical supply chains**

The global semiconductor supply chain is under immense strain as a result of geopolitical and economic factors, putting significant pressure on Semiconductor Capital Equipment (SCE) manufacturers.

In this article, Emily Godsey interviews Texas A&M's Prof Alaa Elwany and Jiahui Ye, and Veeco Instruments Inc's Dr Ahmed El Desouky, to explore the benefits of metal Additive Manufacturing technologies for semiconductor manufacturing and the SCE supply chain. >>>


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Industry news

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SpaceX reveals its Raptor 3 engine, further enhanced with metal AM; secures access to Velo3D technology

SpaceX, Hawthorne, California, USA, revealed its Raptor 3 engine for the first time in early August. Produced using advanced manufacturing technologies including – extensively – metal Additive Manufacturing, the company reports that its engineers have been able to move many external parts inward, consolidating and simplifying the design.

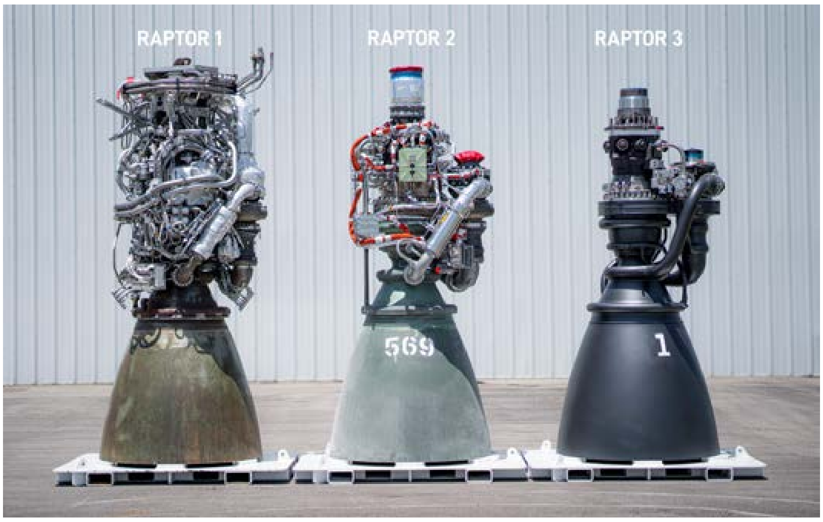
Elon Musk, SpaceX founder, stated on X, "The amount of work required to simplify the Raptor engine, internalise secondary flow paths and add regenerative cooling for exposed components was staggering. As a result, Raptor 3 doesn't require any heat shield, eliminating heat shield mass and complexity, as well as the fire suppression system. It's also lighter, has more thrust and has higher efficiency than Raptor 2." The sea-level variant of Raptor 3 has been reported as having 21% more thrust than Raptor 2 whilst being 7% lighter.

Whilst historically tight-lipped about the specifics of its Additive Manufacturing technology, Musk highlighted SpaceX's expertise in this area, stating, "It is not widely understood that SpaceX has the most advanced 3D metal printing technology in the world."

Laser Beam Powder Bed Fusion (PBF-LB) is believed to be the most widely used metal AM process at SpaceX. Whilst it has been publicly reported that the company has purchased more than twenty Velo3D Sapphire PBF-LB metal Additive Manufacturing machines, SpaceX has in the past been linked to a number of AM technology suppliers. Other metal AM processes, such as Directed Energy Deposition, are used widely in the space industry.

SpaceX is believed to operate highly-customised variants of commercially available Additive Manufacturing and post-processing technologies, as well as in-house developed solutions.

In line with the publicly reported activities of other commercial space companies, it can be expected that SpaceX's development activities in Additive Manufacturing have focused on large scale AM part production, part consolidation, advanced surface finishing, inspection and monitoring, multi-material AM, alloy development, and optimising machine productivity.



Comparisons of the three generations of Raptor engine (Courtesy SpaceX)

SpaceX's new Raptor 3 engine undergoing an initial 30 second hot fire test at the company's McGregor test site in Texas (Courtesy SpaceX)

The latest Sapphire XC Additive Manufacturing machine from Velo3D (Courtesy Velo3D)

Metal Additive Manufacturing was the catalyst that shifted space exploration from state enterprises to private enterprises by significantly reducing cost-barriers and speeding up the development time of space technology. "This is a fantastic example of how Additive Manufacturing fits with innovation. By eliminating numerous labour and inspection steps, reducing the need for technicians, and significantly enhancing safety through radically optimised designs, Elon Musk and his brilliant team of creative minds at SpaceX demonstrate what true innovation looks like. Respect!," commented one high-profile European AM industry leader on *Metal AM* magazine's Linkedin page.

SpaceX secures Velo3D licensing and service agreement in $8 million deal

In September it was announced that Velo3D had entered into a licensing and support agreement with SpaceX, in a deal totalling $8 million. As stated in a Form 8-K, published by the United States Securities and Exchange Commission, Space Exploration Technologies Corp (SpaceX) is granted a licence to Velo3D's Additive Manufacturing technology and will also receive a range of engineering and support services. The agreement states that SpaceX will pay Velo3D a fee of $5 million for the technology licence and a further $3 million for the provision of related engineering and other support services.

Regarding Velo3D's technology, SpaceX has been granted a worldwide, non-exclusive, royalty-free, and perpetual licence. The licence will allow SpaceX to use, manufacture, modify, and develop Velo3D's technology for its own internal operations. The licence covers not only the existing technology as of the agreement date, but also any improvements or modifications made to the technology by Velo3D over the next twelve months.

The licence agreement confirmed that all IP embodied in the Velo3D technology, including any improvements made by Velo3D, shall remain the sole and exclusive property of Velo3D. Any such improvements made by SpaceX shall be owned entirely by SpaceX, with no obligation to provide Velo3D with any source code, executable copy or documentation comprising any such improvements. It was added that Velo3D shall give SpaceX all assistance reasonably required to perfect such rights to any such improvements made by SpaceX, at SpaceX's expense.

Clauses regarding bankruptcy were included in the document. Here, it was stated that all rights and licences granted by Velo3D to SpaceX under the agreement will follow Section 365(n) of the United States Bankruptcy Code. Subject to SpaceX's rights under this code, all rights, licences, and privileges granted to SpaceX would continue, subject to the respective terms and conditions. SpaceX would also be entitled to complete access to all IP, subject to the licence, if not already in SpaceX's possession.

Velo3D delivered its first Sapphire AM machine in 2018 and has been a strategic partner to companies such as SpaceX, Aerojet Rocketdyne, Lockheed Martin, Avio, and General Motors.

www.velo3d.com
www.spacex.com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Nano Dimension to acquire Markforged in $115 million deal; Desktop Metal stakeholders approve takeover

Nano Dimension, based in Waltham, Massachusetts, USA, has announced a $115 million deal to acquire Markforged Holding Corporation, based in Watertown, Massachusetts, USA. Entering into a definitive agreement, the all-cash transaction will see Nano Dimension purchase all outstanding Markforged shares for $5.00 per share.

The news follows Nano Dimension's agreement to acquire Desktop Metal in July 2024 - a deal which has now been approved by Desktop Metal's stakeholders. The combined Nano Dimension-Desktop Metal-Markforged company would have revenue of $340 million based on fiscal year 2023. Post-closing, the combined company is expected to have a strong balance sheet with a total expected cash and cash equivalents, which includes marketable securities, of $475 million.

In purchasing Markforged, Nano Dimension said it is acquiring a company with scale and efficiency. In 2023, Markforged's revenue was $93.8 million with a 47.4% gross margin and 48.6% non-GAAP gross margin, and a second quarter of 2024 gross margin of 48.3% and non-GAAP gross margin of 51.9%. This had the potential to expand further, added Nano Dimension.

As of June 30th, 2024, Markforged had cash and cash equivalents, including restricted cash, of $93.9 million. Restricted cash includes $19.1 million to cover certain liabilities associated with the Continuous Composites lawsuit.

The total payable to Markforged's shareholders of $115 million, based on $5 per share, was said to represent a 71.8% premium to Markforged's September 24th, 2024 VWAP and a 67.8% premium to Markforged's ninety-day VWAP as of September 24th, 2024.

"In combining with Markforged, Nano Dimension is taking bold action in its journey towards becoming a digital manufacturing leader and being a foundational pillar of Industry 4.0," stated Yoav Stern, Chief Executive Officer and member of the board of directors of Nano Dimension. "Markforged is an exceptional company with innovative AM materials and solutions for true production. Their prowess is validated by their more than fifteen thousand installed and connected systems in the field with many leading names across key industry verticals."

"I am excited to work with Shai Terem and his team, who have done an exceptional job developing their cutting-edge solutions. This is all the more substantial when we think about the anticipated closing of our deal with Desktop Metal. We believe the combination of Nano Dimension, Desktop Metal, and Markforged further strengthens our unique opportunity in creating value for our shareholders, customers, and employees as we work to deliver profitable growth, exceptional services, and notable career development opportunities," continued Stern.

Shai Terem, Chief Executive Officer, president, and member of the board of directors of Markforged, added, "We're excited to bring together our pioneering, complementary product portfolios that will further enhance our ability to serve our customers in high-growth industries with a more complete offering of highly innovative solutions used on the factory floor. Not only is our product offering unique, but together we will have the scale and balance sheet strength to become an even more trusted partner to our customers, who are leaders across several industries. We look forward to working with Nano Dimension to join great companies and their devoted teams that can serve our stakeholders to the maximum extent possible."

Completing the transaction is subject to certain closing conditions, including the approval of Markforged's stockholders, and required regulatory approvals. The transaction is not subject to a financing condition, it was added, with Nano Dimension intending to finance the transaction using its cash on hand.

www.markforged.com
www.desktopmetal.com
www.nano-di.com

Markforged offers a complete range of industrial Additive Manufacturing machines (Courtesy Markforged)

ADDMAN's acquisition of KAM set to create largest metal AM service provider in North America

ADDMAN Group, headquartered in Fort Myers, Florida, USA, has acquired Keselowski Advanced Manufacturing (KAM) based in Statesville, North Carolina, USA. The move is reported to have resulted in the largest and fastest-growing metal Additive Manufacturing provider in the United States, with the combined company now operating over fifty metal Additive Manufacturing machines. The expanded ADDMAN Group offers around 28,000 m^2 of Additive Manufacturing capacity, boosted by KAM's 6,500 m^2 Statesville facility.

"ADDMAN's integration marks a pivotal moment for the additive industry. Combining these companies brings a powerful combination with KAM's world-class processes and systems, and ADDMAN's abundant resources and R&D," stated Brad Keselowski, founder of KAM. "Together, we set a new standard for innovation and excellence in the Additive Manufacturing industry."

It was added that Keselowski will remain deeply committed and invested in the operation's success, assuming the role of Commercial Advisor on ADDMAN's Board of Directors and ensuring a seamless transition and continued expansion.

ADDMAN has acquired Keselowski Advanced Manufacturing in a move reported to have resulted in the largest and fastest-growing metal Additive Manufacturing provider in the United States (Courtesy ADDMAN Group)

KAM joins Castheon, ADDMAN's metal AM research and production facility in Thousand Oaks, California. By combining the strengths of both locations, the teams will work together to provide enhanced solutions with industry-leading capability and lead times in refractory alloy production and material science. This collaboration ensures coast-to-coast support from engineering design to full-scale production, leveraging the expertise and capabilities of both facilities.

ADDMAN's CEO, Joe Calmese, commented, "We hold immense respect for the legacies of the companies we integrate into our fold. Brad and the exceptional team at KAM have built an impressive, profitable, and sustainable 3D printing enterprise in a remarkably short time. This is yet another proof point that ADDMAN is dedicated to assembling the industry's finest under our banner. I look forward to seeing the new era of our combined company unfold."

With KAM and ADDMAN both serving the defence and commercial space markets, the merger is expected to strengthen their combined Manufacturing Readiness Level (MRL) and Technology Readiness Level (TRL). Backed by American Industrial Partners (AIP), this will enable them to deliver advanced, market-ready solutions and innovative technologies to the defence industry.

www.kamsolutions.com
www.addmangroup.com

US to control export of metal Additive Manufacturing technologies

The US Bureau of Industry and Security (BIS), a government entity focused on export control and treaty compliance, has issued a ruling regarding the exportation of advanced manufacturing technologies, including AM equipment and software.

Within its 'Commerce Control List Additions and Revisions; Implementation of Controls on Advanced Technologies Consistent with Controls Implemented by International Partners' ruling, the BIS states that a licence will henceforth be required to export or re-export Additive Manufacturing machines intended for metal or metal alloys and "specially designed components thereof."

The licencing rule also includes software for the "development, production, operation, or maintenance" of metal AM machines.

"Today, metal AM equipment is used to produce parts and components in military devices, such as aircraft, missiles and propulsion systems," the ruling explains. "Ultimately, next-generation metal AM equipment with high levels of precision and control will enable significant improvements in part performance properties and advanced military capabilities not yet realistically achievable with current standard metal AM equipment."

www.federalregister.gov

Lockheed Martin optimises hypersonic Mako missile with Additive Manufacturing

Lockheed Martin has reported that its multi-mission hypersonic Mako missile, unveiled in April 2024, is among the company's first generation of missiles designed entirely in a digital engineering ecosystem. Whilst Mako leverages existing components that reduce cost, Lockheed Martin said it explored ways to innovate, to make it more quickly and more affordable.

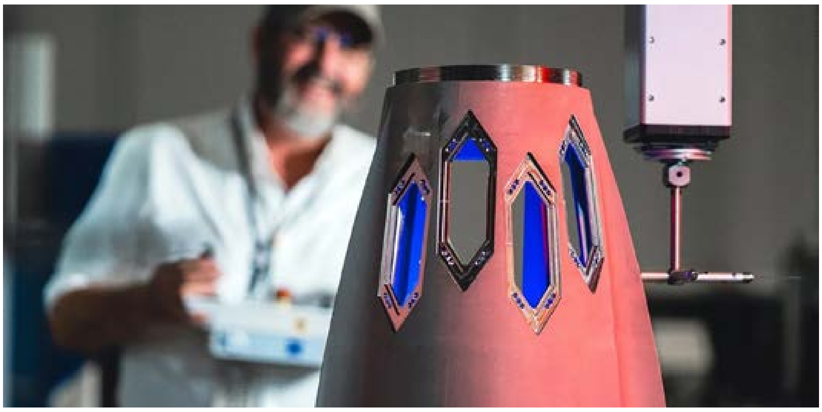
To this end, transformational processes such as an all-digital design and Additive Manufacturing significantly reduce cost and schedule. The company reports using Additive Manufacturing for a number of components, including the guidance section and fins.

The additively manufactured guidance section reportedly met all engineering requirements. It was produced at one-tenth the cost of traditional manufacturing and ten times faster.

The missile is also said to benefit from model-based systems engineering best practices and an integrated, model-based enterprise that supports the weapons' life cycle. Because it has been digitally developed with producibility in mind, manufacturing engineers have been in the loop from the start to ensure a seamless transition into production, Lockheed Martin states.

At 560 kg, the missile is 33 cm in diameter and 4 m long. It has been physically fit-checked externally on a variety of aircraft, including F-35, F/A-18, F-16, F-15 and P-8, and internally on the F-22 and F-35C.

www.lockheedmartin.com



The Mako missile's guidance section was optimised via Additive Manufacturing (Courtesy Lockheed Martin)

Morf3D relaunched as Nikon AM Synergy as it focuses on defence and aerospace sectors

Nikon Corporation, headquartered in Tokyo, Japan, has announced that subsidiary Morf3D Inc will be relaunching under the name Nikon AM Synergy Inc. Following Nikon's full acquisition of Morf3D in July 2023, the company has undergone a significant realignment to support Nikon's advanced manufacturing business strategy.

This transformation includes new leadership and a refreshed mission, said to align with Nikon's broader goals. The reorganisation involves a decisive shift from the former general-purpose contract manufacturing (CM) service bureau business, leading to the closure of the El Segundo, California, location and the divestment of non-essential equipment.

Now operating from Nikon's advanced manufacturing business unit facility in Long Beach, California, Nikon AM Synergy is dedicated to accelerating the adoption and scaling of metal Additive Manufacturing for cutting-edge applications, with a particular focus on the defence and aerospace sectors. This will be achieved through the integration of Nikon SLM Solutions AG's Laser Beam Powder Bed Fusion (PBF-LB) technology and Nikon's internally developed Directed Energy Deposition (DED) solutions, enhanced by premier metallurgy and metrology capabilities.

Nikon AM Synergy will offer specialised capabilities within an ultra-secure environment in the United States, meeting the stringent security requirements of defence and aerospace clients. These capabilities are bolstered by a newly revitalised business development team that is reportedly well-versed in industry knowledge and already delivering results for strategic customers.

Hamid Zarringhalam, CEO of Nikon Advanced Manufacturing Inc, global headquarters of advanced manufacturing business unit, stated, "Our strategic realignment has sharpened our focus and optimised our global resources to drive the Nikon Vision 2030 plan forward. By facilitating the adoption, enablement, and scaling of advanced manufacturing solutions, we are positioning Nikon as a leader in on-shore industrial manufacturing. We look forward to announcing the next significant phase of our plan to transform the manufacturing landscape."

www.nikon.com

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6K closes $82 million funding round and names Saurabh Ullal as CEO

6K Inc, located in North Andover, Massachusetts, USA, announced that it has raised $82 million as part of its Series E funding round. The capital is expected to enable the company to scale up production for battery cathode active materials (CAM) and expansion for producing Additive Manufacturing metal powders.

In addition to the funding round, 6K announced that Dr Saurabh Ullal has assumed the role of CEO, replacing Dr Aaron Bent. The company has also appointed LaunchCapital's Chief Investment Officer Bill McCullen as chairman of the board, with Volta's CEO Dr Jeff Chamberlain and auto industry veteran Beda Bolzenius also joining the board.

"Thanks to Aaron, 6K is well-positioned today as a leader for sustainable, critical material production for lithium-ion batteries and additive manufacturing. Saurabh's expertise in technology and operations ensures the company's scaling strategy while meeting the material specifications and reliability levels customers demand," McCullen stated. "The $82 million raised underscores the confidence investors have in 6K, the UniMelt platform, and the leadership team."

Incoming board member Beda Bolzenius has over thirty years of experience in leadership roles across the global automotive industry in Germany, United States, Mexico, South Africa, China, and Japan. Beda has an automotive technical background with operational experience in engineering, manufacturing, logistics, and supply chain management. He served as CEO of global manufacturer Marelli and held leadership positions in market-leading companies such as Bosch and Johnson Controls. He is expected to bring corporate, operational and automotive industry insights to his role on the board.

Dr Chamberlain is the CEO of Volta Energy Technologies, LLC, a venture capital firm launched out of Argonne National Laboratory. Chamberlain has a long record of industrial product R&D and commercialisation in energy, integrated circuit, and water treatment technology.

In addition to these activities, Chamberlain spent ten years leading energy storage initiatives at Argonne National Laboratory. In collaboration with the US Department of Energy, he led the effort to successfully transfer advanced battery technology from Argonne to organisations such as LG Chem, BASF, General Motors, Toda Kogyo, and General Electric.

www.6KInc.com

MELD awarded $975 million contract by the US Air Force

US Army, Air Force, NAVAIR, and NAVSEA have acquired multiple L3, K2 (pictured), and CD-14 machines (Courtesy MELD)

MELD Manufacturing Corporation, based in Christiansburg, Virginia, USA, has announced that it has been awarded a $975 million contract by the United States Air Force to support the Rapid Sustainment Office (RSO) in optimising the operational readiness of deployed assets.

The RSO, focused on enhancing readiness and sustainability across the US Air Force, has selected MELD for its solid-state metal Additive Manufacturing process. MELD's technology enables the production of large-scale components using aerospace-grade materials. The company has successfully additively manufactured flight-critical components, achieving forging-level quality with materials such as Al-7075, Al-6061, and Ti-64.

This contract is in addition to the DoD and DoE investment in MELD machines. To date, the US Army, Air Force, NAVAIR, and NAVSEA have invested in MELD technology with the acquisition of multiple L3, K2, and CD-14 machines to support various government initiatives.

MELD is reportedly the only large-scale, solid-state metal Additive Manufacturing machine chosen by the RSO.

www.meldmanufacturing.com ■

Additive Industries sells first two MetalFab 300 Flex machines to K3D

K3D, based in Bergeijk, the Netherlands, has been announced as the launch customer for the new MetalFab 300 Flex machine from Additive Industries, headquartered in Eindhoven, the Netherlands. The company is reported to have ordered two machines.

Mark Massey, CEO of Additive Industries, commented, "We are delighted to partner with K3D as our launch customer for the MetalFab 300 Flex. Their decision to invest in our latest system highlights their confidence in our technology and their forward-thinking approach to business growth. The flexibility and scalability of the MetalFab 300 Flex will support K3D in meeting their expanding production demands while managing financial risk effectively."

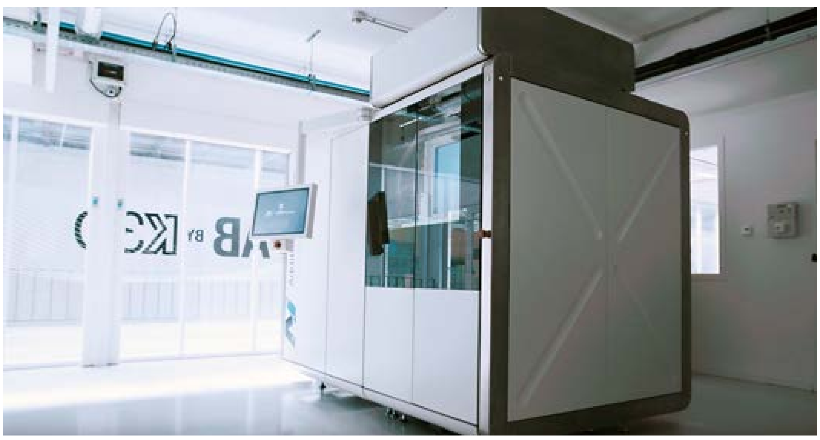
The MetalFab 300 Flex, said to be the only metal Additive Manufacturing machine with a flexible build area, was launched at the RAPID+TCT exhibition in Los Angeles, USA.

K3D became one of the first customers of Additive Industries in 2016, acquiring a MetalFab machine. As the company continues to target a broad range of industries, including aerospace, automotive, tooling, energy (including Oil & Gas), and defence, the need to expand its production capacity has increased significantly.

The investment in the MetalFab 300 Flex is seen as a strategic move to accommodate this growth, particularly for stainless steel (316L) and titanium (Ti-6Al-4V) applications.

Luuk Wissink, CEO of K3D, added, "We are very pleased to be the launching customer for the MetalFab 300 Flex. This new business model approach from Additive Industries enables us to invest our capital in smaller increments, reducing our financial, commercial, and operational risks. The ability to expand our capacity and manage our footprint as our business grows is crucial, and the MetalFab 300 Flex provides the perfect solution."

www.additiveindustries.com
www.k3d.nl ■■■



Additive Industries has sold its first two MetalFab 300 Flex machines to K3D (Courtesy Additive Industries)

Ipsen USA introduces regional Service HUBs to expand customer service and support

Ipsen USA has formally launched its regional Service HUB model for US customers (Courtesy Ipsen USA)

Ipsen USA, Cherry Valley, Illinois, USA, has formally launched its Service HUB model, marking a shift in how the company will deliver service and support to customers in the US. To support the rollout of the Service Hub model, Ipsen also introduced its Technical Development Center (TDC) training initiative.

Over the past two years, Ipsen has developed the regional HUB model concept under the direction of Ipsen Global CEO Geoffrey Somary. Now, led by CSO John Dykstra, the HUBs will provide services across a large portion of the American Midwest and Southeast, particularly in areas with a high density of Ipsen customers.

This move to regional service centres is intended to enable quicker response times, dedicated support teams and thorough knowledge of each customer's facility. This more tailored response is expected to reduce customer downtime and optimise heat-treating operation performance whilst also improving the quality of life of its Field Service Engineers (FSEs).

The Ipsen Technical Development Center (TDC), is an initiative led by Darci Johnson, Program and Transformation Manager, and Cavan Cardenas, Technical Training Lead. The TDC is focused on training and developing new Field Service Engineers (FSEs), including the launch of the Field Service Engineer Academy, a specialised programme intended to equip new and current technicians with the skills and knowledge to best serve customers within the HUB model.

www.ipsenglobal.com

BOFA rebrands as Donaldson BOFA

Portable industrial fume and dust extraction company BOFA, headquartered in Poole, Dorset, UK, has announced a name change to Donaldson BOFA. The rebranding is said to reflect a closer alignment with its parent company, Donaldson. Additionally, the company announced the merger of BOFA International and BOFA Americas into Donaldson Filtration (GB) and Donaldson Company Inc, respectively.

"It was BOFA's world leadership in industrial fume and dust filtration that first attracted Donaldson to invest in our business in 2018," stated Tony Lockwood, Donaldson BOFA Managing Director. "There was already strong synergy in terms of technology, but now we're seeing growing market traction as a result of ever-closer integration of business processes, administration and marketing coordination."

"Specifically, the scientific and research facilities now at our disposal, coupled with Donaldson's global reach, are driving competitive advantage in new territories and in growth and established sectors, including laser, electronics, 3D printing and Additive Manufacturing, ink printing, mechanical engineering, dental, medical and pharmaceutical," Lockwood continued. "This collaboration is delivering technology innovations which will further extend our market leadership in portable fume and dust extraction."

Donaldson BOFA, with offices in the UK, US, and Germany, said it is eyeing growing market opportunities thanks to the parent company's presence in more than forty countries. It has access to over 100 technical laboratories, and an R&D spend standing at more than $78 million.

With this resource, Donaldson BOFA is able to test new materials and processes more cost-effectively and anticipates potential reductions in the time to market of new products and system evolutions.

Although Donaldson BOFA products are already sold to customers in 120 countries around the world, this closer alignment opens up new market opportunities for the business across a broader range of industries and applications.

www.donaldsonbofa.com

Donaldson BOFA offers a range of fume extraction for AM including the 3D PrintPRO 2, 3D PrintPRO 4 and AM 400 (Courtesy Donaldson BOFA)

McLaren to use Divergent Additive Manufacturing for next-generation chassis components

McLaren Automotive, based in Woking, UK, has announced a multi-year collaboration with Divergent Technologies, Inc, located in Torrance, California, USA, that will see Additive Manufacturing used to produce chassis components for its next-generation supercars. The technology will allow McLaren to integrate new and more complex designs into its vehicle architecture, enhancing vehicle performance, sustainability, and production efficiency.

Divergent has developed the Divergent Adaptive Production System (DAPS), a complete software-hardware solution using AI-driven generative design software and Additive Manufacturing to replace traditional vehicle manufacturing techniques.

"We're excited to work with Divergent who, like McLaren, have demonstrated a commitment to manufacturing and engineering innovation," stated Michael Leiters, CEO, McLaren Automotive. "This technology will help us to further reduce weight in our complex structures, which will ultimately benefit the driving experience of our customers and support McLaren's mission to push the boundaries of performance."

Initially, McLaren Automotive will utilise DAPS to additively manufacture chassis components, allowing the company to further reduce weight and improve dynamic performance – all areas seen as 'core to the McLaren DNA.'

Kevin Czinger, CEO, Divergent, added, "Our collaboration speaks to McLaren's commitment to adopting the highest performance technology to push the envelope on customer experience. DAPS offers automotive manufacturers the means to harness computing power to deliver fully optimised, digitally manufactured structures with unparalleled design freedom."

www.divergent3d.com
www.cars.mclaren.com

McLaren plans to use Divergent's Additive Manufacturing technology to produce chassis components for its next-generation of supercars (Courtesy McLaren Automotive)

3D Lab receives Chinese patent for ATO atomiser technology

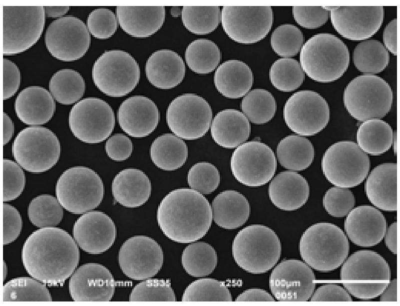
3D Lab sp zoo, based in Warsaw, Poland, has been granted a Chinese patent for the technology incorporated into its ATO atomisers. 3D Lab has stated that this patent – 'A Method for Evacuation of Powder Produced by Ultrasonic Atomization and a Device for Implementing This Method' – represents the next in a series of developments from the company.

Atomisation with 3D Lab's ATO technology is said to allow for the production of high-quality metal powders with characteristics required in Additive Manufacturing. The company states that the use of its technology enables:

- Good flowability and sphericity of powder
- Precise, controllable size distribution
- Low oxygen content

The now-patented technology is the basis of ATO Lab Plus, 3D Lab's ultrasonic atomiser designed for metal powder production. The ATO Lab Plus allows users to create spherical metal powders from multiple feedstock form options at a consistent quality that is optimised for Additive Manufacturing and Powder Metallurgy in a variety of industries such as aerospace, automotive, and medical.

www.metalatomizer.com



3D Lab has received a Chinese patent for the technology centring its ATO atomisers (Courtesy 3D Lab)

3DEO secures $3.5 million investment from Mizuho Bank

3DEO, Los Angeles, California, USA, has announced a $3.5 million strategic investment from Mizuho Bank, Ltd, Chiyoda City, Tokyo, Japan.

Earlier this year, 3DEO also announced investments from IHI Aerospace as well as the Development Bank of Japan (DBJ) and Seiko Epson Corporation. Mizuho Bank's involvement further enhances 3DEO's capabilities and continues to accelerate collaboration with DBJ and Epson.

"We are honoured to receive this investment from Mizuho Bank, a partner that recognises the transformative potential of our technology," said Scott Dennis, CEO of 3DEO. "This collaboration will not only accelerate our growth but also enable us to further integrate advanced AM capabilities into critical manufacturing sectors."

www.mizuhogroup.com/bank
www.3deo.co

Mantle secures $20 million in Series C funding to support market expansion

Mantle Inc, San Francisco, California, USA, has announced that it has secured $20 million in Series C funding, raising the company's total funding to more than $61.5 million. Led by private investment firm Schooner Capital, the round was also joined by the Mantle's largest existing investors, including Fine Structure Ventures, Foundation Capital, Corazon Capital, 11.2 Capital, and Build Collective.

"Mantle is poised to revolutionise the global tooling industry," stated Alexandra Manick, Principal of Schooner Capital. "The company's advanced manufacturing platform, TrueShape, is proven to deliver significant cost savings and, more importantly, unprecedented speed for its customers. This paradigm-shifting solution is readily adoptable and sorely needed to address persistent skilled labour shortages and accelerate product development timelines for industrial toolmakers and OEMs worldwide."

Reshoring with Additive Manufacturing

The recent push towards reshoring manufacturing back to the United States has highlighted the need for solutions which address labour shortages, whilst reducing costs and improving production efficiencies.

"The fragile state of the global supply chain has triggered a massive reshoring initiative that sharply increased the demand for moulded parts and thus toolmaking," stated Ted Sorom, CEO and co-founder of Mantle. "We're navigating a twin set of hurdles: a toolmaking workforce in the US that has shrunk by half over the past quarter-century, coupled with the rising costs and extended lead times brought on by constrained toolmaking capacities. This has driven manufacturers to seek out groundbreaking solutions. For our innovative customers, the adoption of Mantle's tooling technology has emerged as a key strategy to enhance labour productivity, cut expenses, and drastically shorten lead times."

Easing labour scarcity of toolmakers

Amid a severe labour shortage of toolmakers and skilled tradespeople plaguing the manufacturing industry – fuelled by a workforce nearing retirement and surging demand for the tooling essential for everyday products – manufacturers are turning towards automation and technology to navigate these workforce obstacles.

Heyco Products, a US-based manufacturer of wire protection products and electrical components, deployed Mantle technology for its in-house moulding and toolmaking capabilities.

"We purchased a Mantle system for two reasons: to reduce time-to-market for our products and to make our toolroom more efficient while attracting next-generation talent to Heyco," commented Danny Anthony, Heyco's Vice President of Operations. "By using Mantle to print mould tooling, we have already brought a new product to market two months faster than we would have otherwise. We also increased the throughput in our toolroom by giving our toolmakers access to the latest technology that makes them significantly more productive."

Positioned for growth in tooling needs

Mantle has had a year marked by double-digit growth in shipments. The company's metal Additive Manufacturing technology is designed specifically to build injection moulding tools, and is said to reduce the time and cost needed to fabricate high-quality mould and dies whilst automating tool production and reducing the dependence on scarce skilled labour.

By focusing on building tools for mass production rather than the parts themselves, Mantle has worked to tackle the issues of high costs and lengthy production times associated with tool creation for mass production. This strategic shift has resulted in cost reductions for customers reportedly exceeding 65% and accelerated manufacturers' development cycles by up to 90%.

www.mantle3d.com

Mantle's TrueShape process in action (Courtesy Mantle)

Heyco Products operating its Mantle machine (left). Heyco-printed tool for a deep-ribbed consumer product (right). (Courtesy Heyco Products)

EOS to expand US production of its EOS M290 metal AM machine


EOS GmbH has announced plans to expand the assembly of its EOS M 290 metal AM machine at its Texas facility to fulfil North American machine orders (Courtesy EOS GmbH)

EOS GmbH, headquartered in Krailling, Germany, has announced plans to expand the assembly of its EOS M 290 metal Additive Manufacturing machine at its Pflugerville, Texas, USA, facility. Set to begin during the first quarter of 2025, the move is due to increased demand from its North American customers.

"EOS is not new to producing AM products in the US, we have been doing so for 14 years. The high demand for our popular EOS M 290 – as well as governmental policies encouraging procurement of manufacturing technologies from domestic and US-friendly sources – made our decision easy to expand production to our growing Texas facility," Kent Firestone, senior vice president of operations, EOS North America, stated.

EOS has been producing AM hardware, software and materials in North America for nearly two decades. It already has a well-established procurement process, QA process and ISO 9000 certification in place.

"We already produce the INTEGRA P 450 polymer AM system in our Pflugerville facility and have been engineering and manufacturing polymer materials through our Advanced Laser Materials (ALM) group in Temple, Texas. Our years of proven quality and manufacturing expertise will help ensure we continue to meet our customers' high expectations for both quality and performance of the EOS M 290," Firestone continued.

"In-region production is becoming more important to the end-users of our technology. The 'Texas Built' EOS M 290 will be another step in our fulfilment of that requirement, and we plan to expand on our US-based manufacturing in the next few years," shared Glynn Fletcher, president of EOS North America.

www.eos.info

CNPC gains SCS certification for recycled aluminium and titanium powders

CNPC Powder, headquartered in Vancouver, Canada, has achieved a Certificate of Carbon Footprint for Aluminium and a Certificate of Achievement for Aluminium made from recycled materials from SCS Global Services, said to demonstrate sustainable development at scale. The company is reported to be the first manufacturer of titanium and aluminium alloy powders with production based in China to achieve SCS certification.

"Our technologies are focused on ensuring that we can sustainably scale for large applications in AM without compromising the environment," stated Paul Shen, CEO of CNPC Powder. "Our mission is rooted in transforming the industry by implementing eco-friendly practices and promoting the recycling and reuse of critical materials, including aluminium alloys, titanium alloy powders, and beyond. This milestone is merely the first step on our path to carbon neutrality."

CNPC has been producing metal powders for Additive Manufacturing in China for more than a decade, over which time it has developed a proprietary Additive Manufacturing Production (AMP) technology. AMP is said to have a better composition ratio, less gas consumption and lower cost than other powder production methods, aiding the production team in achieving up to a 400% reduction in the carbon footprint of materials produced whilst tailoring properties to better suit Additive Manufacturing.

CNPC has finalised the facility expansion at its Anhui Additive Manufacturing Campus (Courtesy CNPC)

In expanding its research and development of green technologies, including refining recycling processes and enhancing product performance, CNPC has also finalised the facility expansion at its Anhui AM Campus. The additional floor space will be used for the production of 45 tons of recycled Al powder per month.

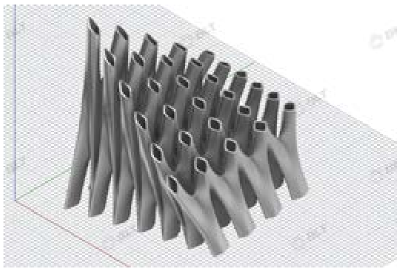
At the same time CNPC says that it has been an active participant in developing industrial standards that promote the ecological advancement of the entire Additive Manufacturing industry, including partnerships with leading local Universities and global companies in the electronics, automotive and aerospace sectors.

"Our journey to 100% recycled materials has begun with the most reactive and high-value applications, meeting rigorous aviation and automotive standards without compromising quality," said Kathy Liu, Global Sales Manager. Currently, CNPC has a resource utilisation rate of over 90% for recycled aluminium and titanium.

By utilising recycled raw materials, CNPC states that it is contributing to both environmental sustainability and potential cost savings for customers. "Our efforts are geared toward reducing carbon emissions, lessening the impact of global warming, and setting a new standard for sustainability in the metal powder industry," it was added. "Through sustainable practices and innovative technologies, we are committed to reducing the carbon footprint of metal manufacturing and contributing to a greener future."

www.cnpcpowder.com

BLT unveils high-precision metal PBF-LB technology for micro-sized parts



To demonstrate the capabilities of its micro PBF-LB technology, BLT used algorithmic digital design to create F-RD topology structure models (Courtesy BLT)

This medical component has a maximum diameter of 3 mm, with eight 0.3 mm fluid channels (Courtesy BLT)

MicroNeuro and BLT developed an advanced structural component with a minimum wall thickness of just 0.15 mm (Courtesy BLT)

This stainless steel threaded part had a minimum thickness of 0.1 mm and a forming angle of 30° (Courtesy BLT)

Xi'an Bright Laser Technologies Co, Ltd (BLT), based in Xi'an, China, has announced the development of a high-precision Laser Beam Powder Bed Fusion (PBF-LB) metal Additive Manufacturing process for the production of micro-sized parts. The new process is reported to be capable of achieving surface roughness as low as Ra 2-3 µm and precision below 0.05 mm.

BLT explains that traditional metal PBF-LB technology generally excels at producing parts with larger feature sizes, where surface roughness ranges from 5-20 µm and manufacturing precision is above 0.1 mm. Recognising the growing demand for smaller and more precise components, the BLT team embarked on a multi-year project to optimise equipment, processes, software, and raw materials.

To demonstrate the capabilities of this technology, the BLT team used algorithmic digital design to create an F-RD topology structure model. The F-RD structure is a type of periodic minimal surface characterised by distinct hyperbolic features and complex curvature variations. With principal curvature radii ranging from approximately 0.5 mm to +∞ (straight line), the algorithm-generated model exhibits rich curvature dynamics. The final formed part showcases the effects of different inclinations on the local surface texture within the same layer thickness.

By comparing parts formed with traditional 60, 40 and 20 µm layers against those produced with BLT's 10 µm high-precision metal PBF-LB technology, the results were striking. The surface quality improved significantly, with roughness decreasing from Ra 7, 6 and 5 µm to Ra 2.6 µm. The high-precision parts exhibited a smooth, refined surface free from the layer lines typically associated with Additive Manufacturing.

BLT's high-precision metal PBF-LB technology has reportedly already been successfully applied in various industries, showcasing its versatility and effectiveness. These include the following components:

Case Study 1: Medical component
This medical structural component has a maximum diameter of 3 mm, with eight 0.3 mm fluid channels and a minimum wall thickness of 0.09 mm between them. Traditional metal PBF-LB technology is unable to achieve the precision required for such intricate internal channels. Utilising BLT's high-precision metal PBF-LB technology, the part was successfully manufactured with all fluid channels intact and no wall breaches. The dimensional accuracy deviation was within 0.05 mm, meeting stringent quality standards and eliminating the risk of cracks or deformations during use.

Case Study 2: Advanced structural component
In collaboration with the MicroNeuro project team, BLT developed an advanced structural component with a minimum wall thickness of just 0.15 mm. Traditional manufacturing faced difficulties in positioning, processing, and stability. BLT's high-precision metal PBF-LB technology overcame these challenges, significantly reducing development time, lowering material costs, and improving material utilisation efficiency. The resulting parts exhibited superior surface finish and flatness, meeting all surface roughness requirements and ensuring consistent quality in batch production.

Case Study 3: Stainless steel threaded part
This stainless steel threaded part with a minimum thickness of 0.1 mm and a forming angle of 30° posed a challenge for conventional metal PBF-LB methods, which required additional support structures for the threads. BLT's high-precision metal PBF-LB technology successfully formed the part without the need for support structures, achieving a surface roughness of Ra⩽1.6µm through simple sandblasting.

www.xa-blt.com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implantcast adds further PBF-EB AM machines from Colibrium Additive

implantcast has successfully installed its new PBF-EB machines from Colibrium Additive (Courtesy implantcast)

implantcast GmbH, based in Buxtehude, Germany, has reported the installation of new Q10plus Electron Beam Powder Bed Fusion (PBF-EB) machines from Colibrium Additive. Now operational, the machines have passed Acceptance Testing (SAT) jobs, verifying their functionality and ensuring that they meet the requirements for integration into the company's production line.

To adhere to implantcast's quality standards, and comply with national and international regulations, numerous test specimens were repeatedly manufactured, examined, and statistically analysed. To ensure operator and environmental safety, including electrical safety and radiation protection, the company reported it engaged specialised firms to certify the safety of its systems.

The new machines are scheduled to transition into regular series production and be integrated into implantcast's specially developed powder handling system.

"We're proud of the seamless process, the excellent collaboration with both Colibrium Additive and internal teams, and the smooth integration of the new systems into our facility and production line. We extend our gratitude to everyone involved in the project," implantcast shared on LinkedIn.

Jens Sass, Managing Director stated, "We recognised the potential of 3D printing right from the start and tried to take advantage of it. After intensive market research, we opted for ARCAM (now GE), from whom we purchased our first 3D printer back in 2015. Since then, new possibilities for implants have opened up for us in the areas of custom-made products, shaping and bone structures. It is also a very sustainable process because the unmelted powder can be reused for the next jobs. This is very much in line with our forward-looking corporate strategy."

"3D printed implants are becoming increasingly popular with users. For this reason, our new printing centre was built in 2023 to bundle our 3D capacities. With the newly acquired equipment, we now have eight titanium printers. This makes us one of the leading users in Germany. The production and capacity for our eight systems is up to 40,000 parts per year," added Sass.

www.implantcast.de

IDEX to acquire Mott Corporation for $1 billion

IDEX Corporation, Northbrook, Illinois, USA, announced in July that it has entered into a definitive agreement to acquire Mott Corporation, headquartered in Farmington, Connecticut, USA, and its subsidiaries for cash consideration of $1 billion, subject to customary adjustments.

When adjusted for the present value of expected tax benefits of approximately $100 million, the net transaction value is approximately $900 million. This represents approximately 19x Mott's forecasted full-year 2024 EBITDA and a mid-teens multiple based on forecasted 2025 EBITDA. The transaction is expected to be accretive to adjusted earnings per share in fiscal year 2026.

Mott Corporation produces a range of sintered filters, amongst other products (Courtesy Mott Corporation)

"Mott's business fits the IDEX sweet spot of highly engineered, configurable mission-critical components focused on scalable select applications. The addition of Mott represents an important step in our evolution, as we continue building our differentiated capabilities in applied materials technologies. Mott brings advanced technical and application expertise that will expand our capabilities in high-value end markets and open new organic growth opportunities. Our focus on driving profitable growth through the enterprise-wide application of 80/20 is expected to yield material benefits," said Eric D Ashleman, Chief Executive Officer and President of IDEX.

"The addition of Mott supports our strategy to deliver long-term, compounding value to our customers, employees, and shareholders, which includes targeted inorganic growth funded by strong cash flow generation. With shared cultural values, including a deep passion for solving customer challenges through technical capabilities and innovative solutions, our great teams combine to offer meaningful go-to-market opportunities. We look forward to welcoming the over 500 Mott employees to IDEX," Ashleman continued.

In 2024, Mott is expected to generate approximately $200 million of revenue, with an EBITDA margin in the low 20s. Mott will join IDEX's Health & Science Technologies segment. The transaction will be funded through a combination of cash on hand, borrowings from IDEX's current credit facility, and potential debt issuance.

"We're excited to join an industry leader with a strong record of helping customers solve their toughest problems. Mott brings applied material science, chemistry, and application expertise, an additive and complementary customer base, and a growing pipeline of opportunities. When combined with the scale of IDEX, industry-leading positions, and deep technological know-how, this will yield meaningful synergies and benefits. Our culture and capabilities align with IDEX, and our employees will add tremendous value to the company, just as they've driven Mott's growth for generations," stated Boris Levin, president and Chief Executive Officer of Mott.

The deal was expected to close by the end of the third quarter of 2024, subject to regulatory conditions.

www.idexcorp.com
www.mottcorp.com

Sandvik revises Additive Manufacturing strategy as it divests BEAMIT

Sandvik AB, based in Stockholm, Sweden, has announced a revised Additive Manufacturing strategy, with its focus returning to metal powder production. As a result, it has announced the decision to exit its minority stake (approximately 30%) in the Italian Additive Manufacturing service provider BEAMIT. Sandvik has been a shareholder in BEAMIT since 2019. As part of a wider strategic shift, the engineer-to-order business of DWFritz Automation (DWFritz) has also been divested.

Charges totalling approximately SEK 390 million will be accounted for in the third quarter and reported as items affecting comparability. Out of the total charges, approximately SEK 250 million relates to a capital loss, including transactional costs, from the divestment of DWFritz, and about SEK 140 million relates to a write-down of the stake in BEAMIT.

Sandvik has sold DWFritz's engineer-to-order business to the US-based private equity firm Balmoral Funds. It bought DWFritz in 2021 to expand its ZeroTouch business. The ZeroTouch platform is a unique inspection gauging equipment that enables near-line and in-line metrology and is an important part of Sandvik's closed-loop strategy. Since acquiring DWFritz, Sandvik has developed and started to commercialise ZeroTouch. ZeroTouch will not be part of the divestment but will remain a part of Sandvik.

DWFritz and the BEAMIT holding were part of the Sandvik Manufacturing and Machining Solutions business area.

www.home.sandvik

Tekna offers coarse titanium powders developed for PBF-LB Additive Manufacturing

Tekna Holding ASA, Sherbrooke, Quebec, Canada, reports it is now offering coarse titanium alloy (Ti-6Al-4V) powders for Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing.

The company states that the advancement of PBF-LB machines has opened new possibilities for using larger powder sizes, marking a transformative shift in the market. Addressing this emerging demand, Tekna has developed a range of Ti64 coarse powders specifically engineered for PBF-LB applications. The powders are optimised for use with varying layer thicknesses, including 60 µm, 90 µm, and above.

By leveraging its proprietary plasma atomisation technology, Tekna produces Ti64 powders that are reported to be spherical and free from internal porosity. This results in powders with higher density and flowability, which translates into superior mechanical properties in the final manufactured parts. Consequently, this enhances the end-user production yield and part reliability, the company states.

Economic and safety advantages

The use of thicker deposition layers leads to reduced production times, which enhances productivity and lowers the end-user overall production costs. This economic advantage, combined with the reduction in powder costs, makes the process more cost-effective. Furthermore, the ability of the end-user to procure Ti64 coarse powders and finer PBF-LB size fractions manufactured from the same dedicated plasma atomisers accelerates the industrial qualification.

From a safety perspective, finer powders commonly used in PBF-LB applications are often classified as flammable. In contrast, Ti64 coarse powders produced by Tekna have a lower sensitivity to oxygen thus reducing risks related to powder handling and recycling as well as costs associated with storage and transport.

"Our commitment to safety is essential, both for users and the environment. Thanks to their reduced reactivity, Ti64 coarse powders are not classified as flammable and are not sensitive to static electricity, making them safer to handle. This also simplifies logistics, allowing for easier transportation and compliance with local storage regulations. Ultimately, these advancements reflect our dedication to delivering high-quality products that prioritise safety and efficiency at every stage," shared Rémy Pontone, VP Sales & Marketing at Tekna.

Productivity boost

Ti64 coarse powders can significantly improve productivity. Based on recent qualifications performed on well-known manufacturing platforms, the productivity for a given part increased from 123 cm^3/hr at a 60 µm layer thickness to 254 cm^3/hr at a 90 µm layer thickness. Manufacturing thicker layers provides better energy dissipation, which contributes to fewer deformations. This reduces the number and complexity of part supports required during manufacturing. It, therefore, contributes to decreased post-processing time and costs.

Compliance with industry standards

Parts manufactured using Tekna's Ti64 coarse powders reportedly fulfil critical industry standards, including B348-21, F3001, and F136. These compliances highlight the quality and reliability of the produced parts.

Comparison between actual values measured on parts manufactured with Tekna's Ti64 coarse powders and ASTM B348-21, F3001-14, and F136-13 standards.

Outlook

Tekna's development of Ti64 coarse powders marks a significant milestone in the Additive Manufacturing industry. As the market continues to evolve, Tekna remains committed to pioneering innovations that drive economic, safety, and productivity advancements, setting new benchmarks for quality and performance.

www.tekna.com

		Tekna	B348-21 Standard Ti64 Alloy Bars and Billets	F136-13 Standard Ti64 Alloy Surgical Implant Applications	F3001-14 Standard Ti64 Alloy Powder Bed Fusion
Ultimate Tensile Strength	Vertical Direction	1036 MPa	828 MPa	860 MPa	860 MPa
Yield Strength	Vertical Direction	964 MPa	759 MPa	795 MPa	795 MPa
Elongation After Fracture	Vertical Direction	18.80%	10%	10%	10%

Comparison between actual values measured on parts manufactured with Tekna's Ti64 coarse powders and ASTM B348-21, F3001-14, and F136-13 standards (Courtesy Tekna Holding ASA)


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LASERTEC 30 SLM
More information
dmgmori.com

Sakuú and SK On collaborate to advance Additive Manufacturing of EV batteries

Sakuú Corporation, San Jose, California, USA, has announced a joint development agreement with EV battery supplier SK On, Seoul, South Korea. Central to the agreement is the industrialisation of the dry-process Kavian platform. The platform uses Additive Manufacturing to produce next-generation batteries, including solid-state chemistries, for commercial-scale production.

Following Sakuú's announcement of early access to its Kavian platform in December 2023, SK On, the fifth largest battery manufacturer in the world, is among the first to partner with Sakuú in developing the platform. SK On currently operates two EV battery plants in Commerce, Georgia, and is further expanding its presence in the southern US by constructing additional EV battery plants through joint ventures with Ford Motor Co and Hyundai Motor Group.

"We are pleased to announce this strategic partnership with Sakuú," said Dr Rhee Jang-weon, Chief Technology Officer of SK On. "We look forward to working closely with Sakuú to accelerate innovations in the manufacturing processes for EV battery electrodes."

Sakuú's work in dry-process manufacturing and the Additive Manufacturing of electrodes is able to eliminate the use of solvents and enables the use of new processes in battery manufacturing that can enable cost-effective, higher-performance batteries that are also environmentally-friendly.

"Together, SK On and Sakuú are ushering in a new era in battery manufacturing technology, advancing safety, sustainability, and innovation in battery technology," stated Robert Bagheri, founder and CEO of Sakuú. "With Sakuú's pioneering technology and SK On's best-in-class EV battery manufacturing expertise, we're addressing the core issues facing battery makers today."

www.sakuu.com

www.eng.sk.com

Sakuú has partnered with SK On to develop its Kavian Additive Manufacturing platform for the industrialised production of EV batteries (Courtesy Sakuú)

Apollo Future Mobility divests share in Divergent Technologies amidst US national security concerns

Divergent Technologies is the parent company of performance automotive brand Czinger Vehicles, maker of the Czinger 21C hypercar (Courtesy Czinger Vehicles)

Caixin Global has reported that Apollo Future Mobility Group, a Hong Kong-traded investment company with Chinese backing, has announced the sale of its holding in US-based Additive Manufacturing company Divergent Technologies. The company cited concerns over US national security scrutiny.

Divergent Technologies, located in Torrance, California, USA, developed the Divergent Adaptive Production System (DAPS) and is the parent company of performance automotive brand Czinger Vehicles, maker of the Czinger 21C hypercar featuring over 350 AM components.

Apollo Future Mobility stated that it will sell its entire 12.87% stake in Divergent Technologies in a deal expected to cost it a record loss of approximately $13.6 million.

Apollo Future Mobility's stake in Divergent Technologies surpasses the maximum limit for foreign ownership established by US regulations. This prevents the company from obtaining US-classified defence contracts. As a result, Divergent Technologies has reportedly requested that Apollo Future Mobility and other foreign shareholders who exceed the ownership limit divest, according to the Hong Kong-based firm.

Formerly known as WE Solutions, Apollo Future Mobility counts high-profile businesspeople from the Chinese mainland, Hong Kong and Macao as major backers. Its business focuses on investments and expands to designing, developing, manufacturing and electric vehicle sales. The company also operates in jewellery and watch sales, as well as lending services.

Citing its major shareholders' connection with the Chinese government, Apollo Future Mobility reportedly stated that the holding in a US military supplier could expose the company and its shareholders to potential US regulatory scrutiny and penalties.

www.apollofmg.com
www.divergent3d.com

EU grants consortium €7.3 million for sustainable titanium extraction project

An EU project coordinated by the European Powder Metallurgy Association (EPMA) has been granted €7.3 million. The funding, divided between thirteen partners under the REPTiS project, is intended to support the responsible extraction and processing of titanium and other primary raw materials for sourcing EU industrial value chains and strategic sectors.

Together, the companies are required to use the grant to demonstrate the feasibility of titanium extraction, processing, and utilisation within the EU through a partnership with Ukraine.

In addition to the EPMA, key participants include Ukrainian titanium producer Velta and global aerospace manufacturer GKN Aerospace.

The majority of the funding is reportedly designated for Velta and the EPMA; other recipients include companies specialising in Metal Injection Moulding and Additive Manufacturing, research centres, and universities. However, the current allocation of funding does not cover the entire €7.3 million budget.

The aim of the project is to demonstrate solutions for extracting and processing titanium across the value chain – including open-pit ilmenite ore mining at Velta's Byrzulivske deposit – and the production of low-carbon titanium powder and use of other technologies including Additive Manufacturing and Metal Injection Moulding.

The collaboration will focus on areas such as energy efficiency and environmental impact, titanium powder production and final product manufacturing. For example, Sweden's University West will manufacture an aerospace demonstrator component, defined by GKN, using Powder Bed Fusion Additive Manufacturing and titanium powder from Velta. Other final products include medical implants and watch casings.

A life cycle assessment will be carried out from the extraction of raw materials to the final products in order to evaluate the differences between the methods used in the REPTiS project and conventional practices.

"The substantial funding for our consortium project underscores the EU's recognition of Ukraine as a strategic partner — one capable of establishing a secure titanium supply chain from raw materials to final titanium products, which are critical globally," Velta chief executive Andriy Brodsky said.

Ukrainian state-owned property fund SPFU manages various titanium assets in Ukraine and it has been pushing for international investment into the country's titanium industry. One of SPFU's key assets is titanium minerals mining firm UMCC, which manages and operates the Vilnohirsk and Irshansk mining and ore processing complexes.

The project is funded under the EU's Horizon Europe programme and is scheduled to run for four years, with a planned end date of August 31, 2028.

www.european-union.europa.eu
www.epma.com
www.velta.us

Kymera International secures $775M for debt refinancing and acquisitions

Kymera International, a specialty materials company headquartered in Raleigh, North Carolina, USA, has received a private credit loan of $775 million to refinance its existing debt and provide capital for add-on acquisitions, including its recent acquisition of Fiven, reports PitchBook, a financial data and software provider.

According to market sources, HPS provided the entirety of the facility and syndicated a small portion of the debt to other lenders. The facility included a term loan as well as a delayed-draw term loan. The company also has a separate Asset-Based Lending (ABL) facility held by KeyBanc and M&T.

Piper Sandler and Goldman Sachs served as financial advisors on the transaction, which was reported to have been dual tracked between the syndicated market and the private credit market.

"When you have a good credit like Kymera, with a history of growth and strong free cash flow conversion, you have financing options. Private credit has raised so much capital that it does create a viable alternative to the syndicated market, a dynamic that benefits the issuers," Adam Shebitz, Palladium's Head of Industrials, told PitchBook LCD.

Palladium first invested in Kymera in 2018, and since the buyout, the company's EBITDA has reportedly tripled.

The company announced its agreement to acquire silicon carbide developer Fiven from OpenGate Capital on June 4.

"Given the fact that Kymera had an acquisition under LOI, we wanted a timely close and we wanted to avoid market flex on terms," added Shebitz.

www.kymerainternational.com

Kymera International is a specialty materials company providing a wide range of metal powders (Courtesy Kymera International)


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Cooksongold launches Cookson Industrial division to pioneer precious metal Additive Manufacturing

Cooksongold, Birmingham, UK, has launched a new industrial division — Cookson Industrial — focused on pioneering precious metal Additive Manufacturing for a range of performance-critical applications. Part of HM Precious Metals, Cookson Industrial aims to provide an end-to-end service covering consultancy, R&D, NPD and production for Additive Manufacturing as well as traditional manufacturing. All of these services will be managed from the Birmingham head office and manufacturing site.

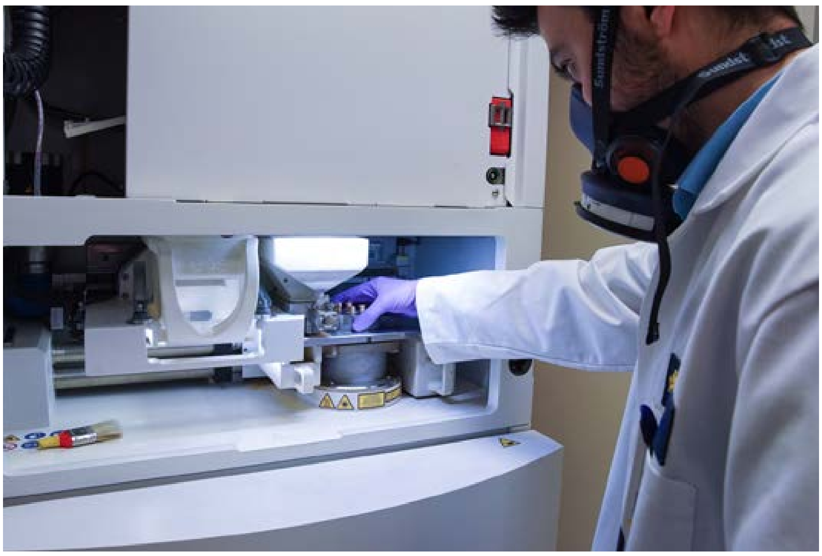
The use of precious metals in Additive Manufacturing expands the performance ability of AM in extreme environments, where traditional alloys have failed to meet the thermal and material application challenges. Cookson Industrial aims to help organisations looking to explore the technology to de-risk their development, simplify their supply chains and shorten time-to-market.

The company develops and manufactures a broad range of gas atomised precious metal powders on site, including gold, silver, platinum and palladium powders; all of which are refined from recycled sources where possible.

All precious metal powders are available for purchase in small batches up to 15 kg, or for use in Cookson Industrial's Additive Manufacturing facility in Birmingham. This currently comprises six EOS Precious M 080 and M 100 machines, alongside a Renishaw AM 500S Flex single laser AM machine.

Cookson Industrial has already partnered with the University of Birmingham to explore the development of precious metal alloys for Additive Manufacturing applications across the aerospace, healthcare and glass fibre manufacturing industries. Both organisations were jointly awarded a £750,000 Early-stage Prosperity Partnership funding from the Engineering & Physical Sciences Research Council (EPSRC).

Leveraging Cooksongold's 100-year heritage in jewellery and luxury product manufacturing, the company is also currently working with Bentley Motors to manufacture a series of components for its Batur by Mulliner line.



The new company will offer a range of services including consultancy, R&D, NPD and production for Additive Manufacturing as well as traditional manufacturing (Courtesy Cooksongold)

Cookson Industrial will focus on pioneering precious metal Additive Manufacturing for a range of performance-critical applications (Courtesy Cooksongold)

Nikesh Patel, Head of Cookson Industrial, commented, "While the use of precious metals in Additive Manufacturing has largely been confined to the jewellery, luxury lifestyle industries, many more organisations are beginning to explore its potential for use in critical applications."

Aerospace is seen as a key growth market for Cookson Industrial. The company is actively exploring new developments in satellite thruster design to help lightweight parts and reduce the volume of hazardous materials used in the manufacturing process compared to chemical thruster design.

"For extreme environments such as aerospace, where there is no room for compromise, the performance characteristics of precious metals can offer a whole new world of design parameters compared to traditional alloys," added Patel.

"There is also a lot of dynamism in the UK aerospace sector with many legacy processes set for disruption. However, given the significant cost of the powders themselves – a full hopper often outweighs the purchase price of the AM machine – many organisations have struggled to fully commit to R&D. As we produce and print with our own powder supply, we can help derisk the process by offering the optimum parameters for powder production, storage and use. This will help reduce powder loss and the associated impact on project costs, while giving organisations access to one of the most innovative production environments in the UK."

www.cookson-industrial.com

nTop advances computational design with NVIDIA collaboration

nTop (formerly known as nTopology), headquartered in New York City, USA, has announced a collaboration with NVIDIA that looks to harness the power of accelerated computing to enable engineering teams to deliver advanced products to market at unprecedented speeds. This includes an investment from NVentures, NVIDIA's venture capital arm.

The initial focus of this collaboration will be to integrate nTop's computational design software with the NVIDIA Omniverse technologies to create new tools that help engineering teams accelerate and better visualise their designs. Omniverse is a platform for developing OpenUSD applications for industrial digitalisation and generative physical AI.

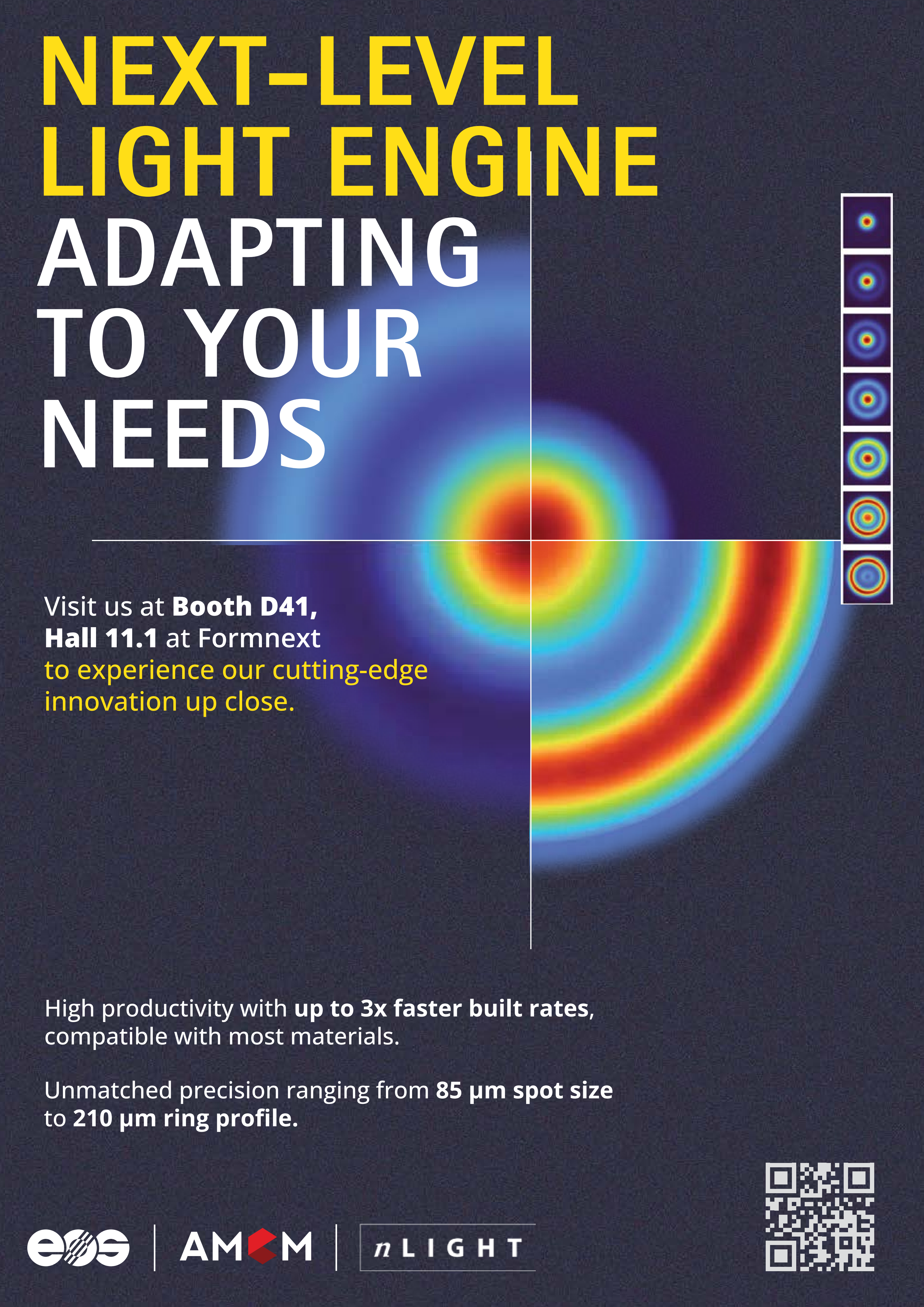
"Our goal in collaborating with NVIDIA is to provide the fastest computing solutions to our customers so they can iterate even faster through design options," said Bradley Rothenberg, co-founder and CEO, nTop. "We are seeing strong interest from customers and partners and are looking forward to sharing more capabilities later this year."

Computational design is the process of creating algorithms that use engineering design logic to generate solutions to engineering problems. nTop's software automates design and optimisation processes while integrating with engineering teams' existing design, analysis, and simulation tools and workflows. nTop's integration with NVIDIA's accelerated computing platform looks to allow engineering teams to accelerate product design and bring high-performance products to market faster and with less effort.

The first proof of concept integrates the NVIDIA OptiX ray-tracing framework in an effort to provide more realistic rendering in nTop. Omniverse SDKs and APIs will also be used to integrate nTop implicits into the Omniverse and OpenUSD ecosystem to provide engineering teams with a collaboration environment wherein they can see and interact with live digital twins of their parts and assemblies. As changes are made to designs in nTop, they can be reflected in OpenUSD applications developed on the Omniverse platform, with no meshing necessary for the transfer. nTop is a member of NVIDIA Inception, a programme that looks to nurture companies believed to be revolutionising industries with technological advancements.

"Product engineering and development teams working in every industry need powerful simulation capabilities to design their work in a physically accurate manner," stated Mohamed 'Sid' Siddeek, corporate vice president at NVIDIA and head of NVentures. "In collaboration with NVIDIA, the team at nTop is showcasing the benefits of accelerated computing in computational design by building incredible tools for engineering teams to design and deliver innovative products."

www.ntop.com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Collins Aerospace, Pratt & Whitney and TU Delft collaborate for sustainable aviation

Collins Aerospace, Pratt & Whitney and Delft University of Technology, have signed a Master Research Agreement (MRA) enabling bilateral collaboration across a range of sustainable aviation research opportunities, including advanced materials, hydrogen propulsion, advanced manufacturing and industrial design.

Through the agreement's strategic framework, Collins Aerospace and Pratt & Whitney will initiate multiple research projects involving TU Delft graduate research facilities, students and staff over the next five years.

"Collaboration between RTX engineers and university research institutions plays an important role in developing our understanding of emerging technologies, while also supporting the next generation of talent that will drive our industry forward," said Michael Winter, RTX Chief Science Officer. "Our MRA with TU Delft – our first agreement of its kind with a European university institution – will focus on advancing technologies to support more sustainable aviation, which is key to the future of our industry."

Among the first projects initiated as part of the MRA, Collins and TU Delft are collaborating on a high-speed intelligent inspection system to enhance manufacturing processes for lightweight and recyclable aircraft materials. Pratt & Whitney and TU Delft will work on developing novel engine configurations that utilise thermal energy recovery technologies to improve fuel efficiency and reduce CO_2 emissions for commercial aircraft.

"We're excited and very happy to sign this new agreement. It gives us the opportunity to step up our collaboration on sustainable aviation with the engineering teams of Collins Aerospace and Pratt & Whitney," said Professor Henri Werij, Dean of the Faculty of Aerospace Engineering at TU Delft. "Collaboration with leading aerospace companies is absolutely crucial to take the necessary steps towards reaching the goal of climate-neutral aviation by 2050."

www.collinsaerospace.com
www.prattwhitney.com
www.tudelft.nl

Leading titanium bike manufacturer looks to produce 50,000 metal AM parts annually

Following the introduction of China's first titanium alloy bike under the Hi-Light brand in 1992, Hanglun Technology is now reported to be the world's largest manufacturer of titanium alloy bikes. With an annual production capacity of nearly 20,000 titanium alloy frames, Hanglun supplies a number of leading global brands.

With a strong presence in high-end bicycle markets across North America, Europe, and Southeast Asia, Hanglun Technology also dominates the Chinese sports cycling market. With custom-engineered titanium alloy bike frames, handlebars, and other key components, the company reportedly captures 80% of the Chinese domestic market.

In 2023, Hanglun Technology made a strategic investment in the FS350M four-laser metal Additive Manufacturing machine from Farsoon Technologies, based in Changsha, China. The company stated that it aims to additively manufacture over 50,000 titanium bicycle components annually, for use in both high-volume production and custom models.

"3D printing is a game-changer in our industry and is leading the way in innovation. It pairs perfectly with traditional precision casting," stated Yanpeng Yang, Vice General Manager, Hanglun Technology. "Right now, we use precision casting for big production runs and 3D printing for those smaller, custom projects. This mix lets us create lighter, more complex, and highly customised bicycle parts. Plus, it helps us cut down on costs and environmental impact for small-batch production, speeds up delivery times, and makes the whole process smoother and more efficient."

In the product design and development phase, Additive Manufacturing enables rapid iterations of titanium alloy bicycle components to be produced, significantly speeding up the design process. AM technology also leads to higher quality, enhanced performance, and more reliable components, explains Hanglun.

For example, the technology allows for the seamless integration of complex structures into a single piece. To further minimise air resistance, the company has also integrated cables and components for braking and shifting directly into the AM frame, enhancing overall efficiency.

The AM process also has significant advantages over traditional welding methods, which can cause issues such as deformation, fatigue damage from residual stresses, and problems with size accuracy and poor connections. Welding can also lead to slightly heavier titanium alloy frames due to the added weight of welding materials.

Performance tests on titanium bicycle components produced with the FS350M-4 machine have also shown improved mechanical properties, with a tensile strength of 1,035 MPa, a yield strength of 998 MPa, and an elongation at break of 13.5%. These enhancements significantly extend the lifespan of the components, underscoring the advanced capabilities of AM technology in producing high-performance parts.

Hanglun aims to additively manufacture over 50,000 titanium bicycle components annually, for use in both high-volume production and custom models (Courtesy Farsoon/Hanglun)

By combining topology optimisation with Additive Manufacturing, Hanglun can achieve a reduction in full-frame weight to just 1.4 kg. For cyclists, this means increased speed and reduced turbulence during long-distance rides, offering smoother, faster, and more efficient cycling.

According to Farsoon, by embracing Additive Manufacturing, Hanglun not only elevates the performance, efficiency, and design of its bicycles, but also strengthens the legacy of the Hi-Light brand with its continuous technological advancements.

www.tibicycle.com
www.farsoon.com

Additive Manufacturing allows for the seamless integration of complex structures into a single piece (Courtesy Farsoon/Hanglun)

ORNL leads $15 million project to revolutionise large-scale AM for hydropower component

The US Department of Energy's Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee, USA, has announced a manufacturing programme for large metal parts. The approach could greatly reduce waiting times for critical components and enable economic growth in the manufacturing sector for energy, according to scientists at the Department of Energy's Oak Ridge National laboratory.

The project, "Rapid Research on Universal Near Net Shape Fabrication Strategies for Expedited Runner Systems" (Rapid RUNNERS), has received $15 million in funding from the DOE over three years. The project aims to develop a system for producing the large runners (the rotating part of a turbine that converts water pressure and movement into electricity) used in hydropower dam turbines. The runners will be produced using Additive Manufacturing combined with conventional tools. The process will use robotic welders to deposit metal layer by layer to form the runners.


ORNL's Jay Tiley inspects a hydroelectric runner from TVA's Cherokee Dam. ORNL is partnering with TVA and others to develop a process to produce large metal components like this for clean energy applications (Courtesy Jim Tobin/ORNL, US Dept. of Energy)

"This has the potential to transform forging and casting of large-scale metal components," said Adam Stevens, an R&D staff member at ORNL and technical lead for the project.

These large metal components are predominantly manufactured overseas. When they fail, it can take years to fabricate and receive replacements, resulting in lost time, money, and renewable energy. "Right now, it takes around 18 months to produce one of these. If you can't operate a hydropower turbine because you're waiting for a part, that's 18 months of clean energy you're not generating. This approach can fill the gap in the domestic industrial base," Stevens added.

Brian Post, leader of ORNL's Disruptive Manufacturing Systems Development group, and Jay Tiley, head of the lab's Materials Structures and Processing Section, are project principal investigators for systems and materials, respectively. The Manufacturing Demonstration Facility at ORNL is providing resources and expertise. The MDF, supported by DOE's Advanced Materials and Manufacturing Technologies Office, is the hub for a nationwide consortium of collaborators working with ORNL to innovate, inspire and catalyse the transformation of US manufacturing.

To demonstrate the capability of the manufacturing system, the team will fabricate three Francis runners, a particular style of large stainless-steel turbines used in dams to generate hydropower. The first runner is a prototype to be used for testing. The second, about 1.5 metres in diameter, is being made for potential installation in the Tennessee Valley Authority's Ocoee Dam in Parksville, Tennessee. The hydropower dam, spanning the Ocoee River, has five generating units that produce 24 megawatts of electricity.

The third Francis runner will be manufactured for potential installation in TVA's Wilson Dam, which has 21 generating units producing 653 megawatts of electricity. The turbine will be about 4.5 m in diameter, 2.4 m tall and weigh around 42 tonnes. TVA, based in Knoxville, Tennessee, is the largest public power company in the nation, operating 113 power generators in 29 dams.

"We are always looking for new ways to do things better. Innovation is a part of TVA's DNA, and it's something that we focus on in all things we do," said Joe Hoagland, TVA's vice president of innovation and research. "This programme offers an innovative way for us to fulfil TVA's mission summarised by three 'E's: for Energy, it improves reliability, for the Environment, it maximises renewable energy produced, and for Economic development, it brings great jobs back to the US."

The programme covers developing the software, hardware, robotics and manufacturing strategies necessary to produce these large components. In addition to TVA, several organisations partner with ORNL on development. These include Huntington Ingalls-Newport News Shipbuilding, where the largest Francis runner will be additively manufactured; the Electric Power Research Institute, contributing to techno-economic analyses; Open Mind Technologies, assisting with manufacturing strategy development; ARC Specialties, providing robotic hardware and integration; and Voith Group-Hydropower, a hydro unit manufacturer.

At the end of the three-year term, the project will have created a new distributed hybrid-manufacturing platform that could be used by many industries.

www.ornl.gov

Amaero completes qualification of Addman's Niobium C103 powder

Amaero International Limited, based in McDonald, Tennessee, USA, reports it has completed the qualification of Niobium C103 powder for Additive Manufacturing in accordance with Addman Group and its subsidiary Castheon's technical specifications. The successful qualification triggers Addman's obligation to purchase no less than 2.25 tonnes of C103, with 0.25 tonnes expected to be shipped in 2024 and 2.0 tonnes expected to be shipped in 2025.

The agreement also establishes Amaero as the preferred and primary supplier of C103, refractory, and titanium alloy AM powders to Addman Group, including its Castheon and Keselowski Advanced Manufacturing (KAM) subsidiaries. The preferred supplier agreement is for a period of five years and does not establish a minimum order threshold.

"Since I assumed the role of chairman and CEO in October 2022, we have taken bold and decisive actions to position Amaero as a leading US domestic producer of C103, refractory and titanium alloy AM powder," stated Hank Holland. "In order for Additive Manufacturing to achieve its potential, it's imperative that we create a more resilient, more scalable, and more responsive US domestic supply chain for C103 and speciality alloy AM powder. And time is of the essence."

Castheon, under the leadership of Chief Scientist Dr Youping Gao, primarily serves the defence and space industries with additively manufactured Niobium C103 and refractory alloys. With over twenty years of experience in the traditional processing of C103 for space-borne products, including leading NASA-certified AM projects, Dr Gao has played a crucial role in refining the use of C103.

Addman's acquisition of Castheon and KAM creates one of the largest US domestic metal AM providers, with over fifty Additive Manufacturing machines across multiple locations. The companies actively collaborate with US Department of Defense-funded laboratories and major defence contractors on critical national security projects, including hypersonic and strategic missiles, space launch systems, and satellites.

"Amaero has acted with a sense of urgency to relocate its business to the United States to attract a leading technical and manufacturing team and to prioritise production of C103 and refractory alloy AM powders," stated Lieutenant General (retired) HR McMaster, Special Advisor to Chairman and CEO. "These were vital efforts to address critical vulnerabilities in US defence and national security supply chains and will help advance hypersonic and strategic missile programmes to serial production.

"Amaero's scalable production of C103 and refractory alloy powders and Castheon's leadership position in material science and Additive Manufacturing demonstrate that it is possible to use cutting-edge technologies to re-shore and scale critical industrial base capabilities that are atrophied to a dangerous level," McMaster concluded.

Amaero has stated it looks forward to collaborating with Addman to advance manufacturing readiness levels (MRL) and technical readiness levels (TRL) to enable broad insertion of metal AM to support the US Department of Defence, DoD-funded laboratories, and defence prime contractors to progress hypersonic and strategic missile platforms from development and demonstration phases to serial production.

www.amaero.com
www.addmangroup.com

FormAlloy Technologies opens new AM centre in San Diego

FormAlloy Technologies Inc, San Diego, California, USA, has celebrated the opening of its new Application Development Center. The state-of-the-art facility, designed to foster innovation and collaboration, officially opened its doors in July. The grand opening event featured a keynote address by Congresswoman Sara Jacobs, a dedicated advocate for technological advancement and economic development in the region.

The Application Development Center marked a significant expansion of FormAlloy's capabilities to provide solutions in Additive Manufacturing. The centre serves as a hub for research and development, offering customers and partners access to the latest in metal Additive Manufacturing technology, expert consultation, and a collaborative environment to develop and refine their applications.

"We were thrilled to open our new Application Development Center and welcome Congresswoman Sara Jacobs to join us in this celebration," said Melanie Lang, CEO and Co-Founder of FormAlloy. "This centre represents our commitment to driving innovation in Additive Manufacturing and supporting our customers in bringing their groundbreaking ideas to life."

Sara Jacobs delivered a keynote address at the event, highlighting the importance of supporting advanced manufacturing technologies and their potential to drive economic growth and job creation in the San Diego region. She also presented the FormAlloy team with a Certificate of Congressional Recognition to commemorate and recognise the centre's opening.

"I was excited to see companies like FormAlloy leading the way in technological innovation," said Congresswoman Jacobs. "The opening of this Application Development Center is a testament to the incredible talent and ingenuity in our community. I look forward to seeing the new advancements and opportunities that will emerge from this state-of-the-art facility."

The grand opening event included tours of the new facility, live demonstrations of FormAlloy's precision Directed Energy Deposition (DED) machines used to build, enhance, repair, and join components, and an impact statement from NAVAIR on the technology's importance to naval aviation. Attendees gained insights into the potential applications of metal Additive Manufacturing across various industries, including aerospace, automotive, energy, and general industry.

www.formalloy.com

Domin boosts hydraulic valve production with second Renishaw metal Additive Manufacturing machine

Renishaw, based in Wotton-Under-Edge, Gloucestershire, UK, has supplied Domin, a manufacturer of hydraulic valves and systems, headquartered in Bristol, UK, with a RenAM 500Q Ultra metal Additive Manufacturing machine. Domin intends to use the machine to increase production of its range of servo proportional hydraulic valves at its new Technology Centre near Bristol.

Domin purchased its first RenAM 500Q AM machine in 2023. After reaching its production capacity, the company needed the new machine to meet the growing market demand.

"The installation of a new Renishaw 500Q Ultra marks another exciting milestone in Domin's growth journey," said Marcus Pont, Chief Executive and co-founder of Domin. "This state-of-the-art technology will further enhance our manufacturing capabilities, allowing us to deliver even greater value to our customers. Our continued partnership with Renishaw is an example of our commitment to innovation and operational excellence."

Domin's valves are designed to meet the rigorous demands of industries such as automotive, aerospace and manufacturing. By using metal AM, Domin can create complex geometries with internal features that are not possible with traditional subtractive manufacturing methods. This results in parts with a good strength-to-weight ratio and reduced waste.

Domin's innovative approach, combining AM with high-speed motor control, modern electronics, big data, and connected technology, aims to save the hydraulics industry one gigatonne of CO_2e by 2023. The increased capacity provided by the RenAM 500Q Ultra will help Domin maintain low production turnaround times and deliver consistently high-quality products to its growing customer base.

The RenAM 500Q Ultra is the latest model in Renishaw's RenAM 500 series of Laser Beam Powder Bed Fusion (PBF-LB) machines. Using Renishaw's patented TEMPUS technology, the machine is said to reduce build times by up to 50% while maintaining high part quality. TEMPUS technology allows the lasers to fire while the powder recoater is moving, significantly boosting productivity. The machine also includes advanced process monitoring software, providing detailed insights into the build process and ensuring consistent high quality.

"We're very pleased to have installed this RenAM 500Q Ultra system to enable Domin to supercharge their production," said Josh Whitmore, Senior Technical Sales Engineer at Renishaw. "Our systems are designed and manufactured in the UK, and to sell to a UK volume producer of AM parts is a great result for UK plc and our wider manufacturing ecosystem."

www.domin.co | www.renishaw.com

Aconity3D opens new facility in Herzogenrath, Germany

Aconity3D has officially opened its new facility in Herzogenrath, Germany. During an inauguration ceremony, the company welcomed suppliers, project partners, financial institutions, and local dignitaries to the new site.

Dr Yves Hagedorn, Managing Director of Aconity3D, started the celebrations with an overview of the company's activities over the past ten years. Following this, tours were conducted, allowing guests to visit the new administration building and the production hall. Visitors were given a direct insight into the company's technologies and work processes.

The new facility will accommodate the production of the company's individually configurable Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing machines for use in the aerospace, automotive and medical sectors, among others.

Aconity3D, which was founded ten years ago and now has 70 employees, was previously based in Aachen and Kohlscheid. The new, sustainable and energy-efficient building offers 2,500 m^2 of floor space, with capacity for further growth.

www.aconity3d.com

Aconity3D has opened its new facility in Herzogenrath (Courtesy Aconity3D)

NIAR to leverage Velo3D's Sapphire Additive Manufacturing to produce next-gen airframe technologies

Velo3D, based in Fremont, California, USA, has announced that the National Institute for Aviation Research (NIAR) has purchased a Sapphire 1MZ Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing machine. The new machine will be used to develop performance-based qualification methods of metal AM parts for airframe applications.

The Sapphire 1MZ will be configured to produce parts in Inconel 718, a durable nickel-based alloy that provides high corrosion, oxidation and creep resistance at extreme temperatures. Inconel is used extensively in aerospace applications.

NIAR is a research organisation that was established at Wichita State University in 1985 to drive innovation in aeronautical applications. The organisation has a $350 million annual budget, a staff of 1,200, and seven locations across Wichita, Kansas, and Huntsville, Alabama. NIAR actively engages with many federal resources and programmes to drive innovation in aerospace and defence applications.

"Our team is focused on helping the US identify materials, designs, and techniques that can support the country's aerospace, defence, and manufacturing industries and we're glad to work with America's own metal Additive Manufacturing provider," said Lauren Tubesing, Business Development Lead, Advanced Manufacturing at National Institute for Aviation Research. "Our organisation is well-known for its work in aeronautical research and by leveraging Velo3D's solution to better understand the nuances within the Additive Manufacturing process, we can help build confidence in 3D-printed parts, thereby accelerating adoption of this advanced manufacturing technology."

The Sapphire 1MZ, with a 315 Ø x 1,000 mm build envelope, will be used to identify and validate best practices related to performance-based qualification of additively manufactured parts for airframe applications. NIAR also recently received $10 million from the Federal Aviation Administration (FAA) Center of Excellence for Composites and Advanced Materials (CECAM), which was established in partnership with the FAA and NIAR in 2004 at Wichita State University.

The FAA funding was granted to NIAR to research advanced materials, focusing on composites and Additive Manufacturing. NASA also awarded the organisation $10 million to support research related to the development and implementation of composites and advanced materials for hypersonic applications, which is another area where Additive Manufacturing is driving innovation.

"Qualifying 3D printed parts for production use is a massive challenge and something that has greatly impeded broad adoption of Additive Manufacturing for commercial aviation applications and it's great to see a brilliant organisation like NIAR work to solve this," said Brad Kreger, Velo3D CEO. "The work NIAR will conduct will not only be invaluable to their organisation, but the entire industry. We're proud to be a part of this effort."

www.velo3d.com

Sandvik launches Osprey HWTS 50 hot-work tool steel powder

Sweden's Sandvik AB has introduced Osprey HWTS 50, a hot-work tool steel powder designed for enhanced manufacturability. Primarily developed for Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing, it is also well-suited for Hot Isostatic Pressing (HIP) and Metal Injection Moulding (MIM).

The tempering and thermal fatigue resistance, as well as thermal conductivity of Osprey HWTS 50, are improved when compared with conventional H-class hot work tool steels. These advanced properties are intended to effectively address many common challenges in hot-work applications within general engineering, stated Sandvik.

Osprey HWTS 50 also improves the processability in PBF-LB, lowering the susceptibility of cold cracking compared with conventional H-class hot work tool steels. Typical applications include high-pressure die casting dies, injection moulds, and hot forming tools.

The chemical composition is tailored for improved hot hardness at temperatures exceeding 600°C. It is characterised by lower carbon content compared with those of medium carbon hot work tool steels and modifications to the carbide forming elements. This is to ensure a comparable or even enhanced tempering resistance despite lower carbon wt.%.

The thermal conductivity of Osprey HWTS 50 is higher compared to medium carbon tool steels over a wide temperature range. High thermal conductivity is beneficial for applications running at elevated temperatures, such as die casting and forging, explains Sandvik. It ensures rapid and efficient heat dissipation, resulting in faster cycles.

"Additive Manufacturing is increasingly being used to produce tools and dies with near-surface conformal cooling channels. Besides optimising processing parameters, it is important to develop chemistries specifically tailored for this technology to address fabrication challenges," stated Faraz Deirmina, Principal Metallurgist in metal powder at Sandvik. "Osprey HWTS 50 is designed to alleviate these challenges making it highly suitable for tooling applications at elevated temperatures. Examples are hot forming dies, extrusion and injection moulding dies, and high pressure die casting dies."

Osprey HWTS 50 metal powder is manufactured by either induction melting under Vacuum Inert Gas Atomisation (VIGA) or melting under argon prior to Inert Gas Atomisation (IGA). This produces a powder with a spherical morphology, which provides good flow characteristics and high packing density. In addition, the powder has a low oxygen content and low impurity levels, resulting in a metallurgically clean product with enhanced mechanical performance.

www.metalpowder.sandvik

Centorr Vacuum celebrates 70 years in vacuum furnace industry

In 2024, Centorr Vacuum Industries (CVI) is celebrating its 70th anniversary in the vacuum furnace industry. CVI was formed from the combination of Vacuum Industries, founded in 1954 in Somerville, Massachusetts, USA, and the Centorr Furnace company, founded in 1962 in Suncook, New Hampshire. The two were merged in 1989, with new facilities in Nashua, New Hampshire, where the company is still located.

In 1997, CVI became 100% management-owned and is now run as a private company under president and CEO William Nareski. "We have enjoyed long-term success over the past seventy years because our highest priority is customer satisfaction with our equipment and service" stated Nareski.

Vacuum Industries was started by the principles of the original National Research Corp. in Boston. It had a long history in the design and building of production size furnaces, primarily for the metals and hardmetals industry. Centorr Furnaces was a Laboratory and R&D furnace manufacturer, and was known for doing some of the first high temperature 3000°C furnaces for the growing ceramics market. In later years, Centorr was known as a world leader in fibre optics and high-temperature hydrogen sintering furnaces for the lighting industry.

Today, Centorr is best known for its line of metals and ceramics sintering furnaces, large equipment sold into the nuclear industry, and for its line of furnaces sold into the carbon, graphite, and composites industry for aerospace and hypersonics. The company is one of the leading custom and standardised vacuum furnace manufacturers, and has an installed base of over 7000 high temperature vacuum and controlled atmosphere furnaces worldwide. CVI operates a fully staffed Aftermarket Field Service group and an Applied Technology Center, offering R&D support and toll production service.

Centorr Vacuum Industries is celebrating its 70th year in the vacuum furnace industry (Courtesy Centorr Vacuum Industries)

www.centorr.com

3DEO names Scott Dennis as CEO

3DEO, Los Angeles, California, USA, has announced the appointment of Scott Dennis as the company's new Chief Executive Officer. In this role, he succeeds company co-founder Matt Petros.

Petros, who will remain a significant shareholder in 3DEO, stated, "3DEO has always been about pushing the boundaries of what's possible in manufacturing. Under Scott's leadership, I believe the company is well-positioned to accelerate its innovation trajectory and continue setting new industry standards. Scott's experience in engineering and product realisation, coupled with his proven ability to scale operations, makes him the perfect choice to lead 3DEO into the future."

Prior to this position, Dennis co-founded and served as CEO of D&K Engineering, a leading product realisation services company that successfully developed and manufactured a wide variety of products across the Additive Manufacturing,

Scott Dennis has succeeded Matt Petros as 3DEO CEO (Courtesy 3DEO)

industrial, and life science sectors. In this role, Dennis led the company's growth into a global organisation, known for its disciplined approach to engineering and manufacturing high-innovation content and hardware-based products.

With a strong background in mechanical and biomedical engineering, as well as a successful track record in product realisation, Dennis has demonstrated his ability to reduce the risks associated with bringing breakthrough products to market.

"I am thrilled to join 3DEO and lead this exceptional team," said Dennis. "We are committed to offering our customers innovative design and manufacturing solutions, centred around harnessing the power of Additive Manufacturing. Our goal is to unlock significant performance improvements not only in individual components but also in full assemblies and subsystems by leveraging additive-enabled technologies such as 3DEO's Intelligent Layering process. This approach, driven by 3DEO's deep expertise in Design for Additive Manufacturing (DfAM), allows us to revolutionise product development and create breakthrough value for our customers."

"Scott brings a unique combination of strategic vision, technical expertise, and operational excellence to 3DEO," Petros added. "His leadership will ensure that we continue to provide our customers with cutting-edge additive solutions that meet the highest standards of quality and reliability."

www.3deo.co

Farsoon announces Central European distribution partnership with MostTech

Farsoon Europe GmbH, the European subsidiary of Additive Manufacturing machine maker Farsoon Technology, headquartered in Changsha, China, has announced a distribution partnership with MostTech, based in Hürm, Austria. Under the agreement, MostTech will now offer Farsoon's metal and polymer Additive Manufacturing machines, materials, and part manufacturing services, to the Central European market.

"We are extremely honoured to embark on this meaningful journey with MostTech," stated Oliver Li, Managing Director of Farsoon Europe. "As a 3D printing machine supplier, we highly value MostTech's technical expertise and their strong connections within the local manufacturing markets. We look forward to exploring and serving the Austrian Additive Manufacturing market together, utilising Farsoon's latest laser powder fusion technologies."

MostTech eU was founded in 2013 by Michael Hofer. The company specialises in the distribution and professional consulting of advanced manufacturing technologies. Support spans from the initial use of prototype components from MostTech's service portfolio, through to the first small and series production parts, and finally to the implementation of new manufacturing technologies within the customer's company.

"We have been deeply connected to the topic of Advanced Manufacturing through decades of experience, from development to the finished part," added Hofer. "Our approach of 'Connecting People and Technologies' is the guarantee for sustainable technology implementations. The partnership with Farsoon enables us and our customers to reach the next level of advancement with industrial Additive Manufacturing. We are proud to elevate our service portfolio to the next level with Farsoon."

www.farsoon.com
www.mosttech.at

Left to right: Michael Hofer, owner of MostTech, and Oliver Li, Managing Director of Farsoon Europe (Courtesy Farsoon)

American Isostatic Presses expands Ohio manufacturing facility

American Isostatic Presses Inc (AIP), headquartered in Columbus, Ohio, USA, has announced that it recently expanded its manufacturing operations in central Ohio.

"With this new expansion, we look forward to continuing meeting the unique demands of our diverse customer base, ensuring high-quality and comprehensive isostatic pressing solutions," the company stated in a release.

AIP has expanded its Ohio headquarters (Courtesy American Isostatic Presses)

A provider of Hot Isostatic Pressing equipment, AIP also installs every system it sells. The company reports that it has never experienced failure on the part of any of its pressure systems or subsystems.

AIP holds ASME U1, U2 and U3 code stamps, US National Board approval, and European Union PED certification. Its systems have been tested by F2 Labs for UL and CE compliance and is reputedly the only company certified by South Korea for high-pressure vessels. AIP is also in application for Chinese certification.

Beyond its Ohio headquarters, the American Isostatic Presses family of companies consists of Isostatic Pressing Services (IPS) in Oregon City, Oregon; Isostatic Toll Services (ITS) in Olive Branch, Mississippi; and Isostatic Toll Services Bilbao SL, Bilbao, Spain. ITS Bilbao is a collaborative effort intended to break the company into the European market.

www.aiphip.com

AML3D revenues up over 1,000% in 2024 financial results

AML3D Limited, headquartered in Edinburgh, Australia, has posted its 2024 results, with revenue reported to be up 1,055%. During its financial year, revenue was recorded at AU $7.32 million, compared to AU $0.60 million in the prior year. The company highlighted that AU $4.44 million, more than half (61%) of AML3D's FY24 revenues, were derived from Arcemy machine sales in the US. A further 36%, or AU $2.66 million, of revenue was generated from component manufacturing and alloy characterisation and testing contracts with the remaining 3% of revenue from recurring licence and lease fees.

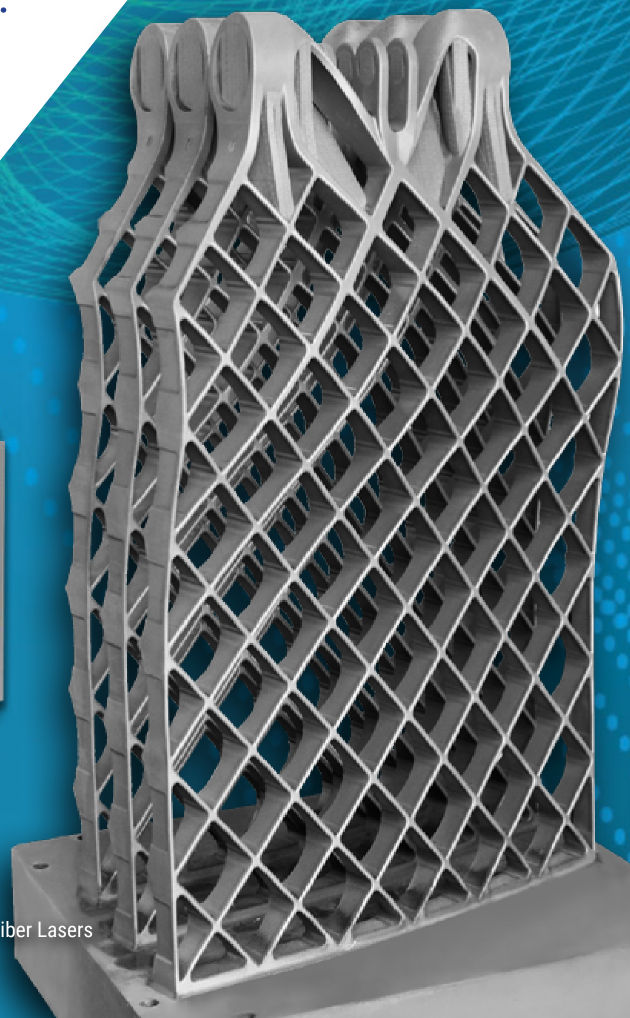
The company reported that EBITDA loss for FY24 of AU $3.31 million is 31% lower than in the prior comparable period. The net loss after tax for FY24 of AU $4.17 million, down 23% on the prior comparable period.

AML3D spent 2024 investing in the expansion of its software development team and capabilities. The company is also investing to establish a manufacturing hub in the US to maximise the growth opportunities in that market. Overhead expenses of AU $8.09 million were AU $2.81 million higher than in FY23, largely attributable to the investment in the 'US scale-up' strategy and software development team.

This scale-up strategy is focused on supplying the AML3D's proprietary Arcemy metal Additive Manufacturing machines and contract manufacturing services to industrial manufacturers in and supporting the US defence, marine and aerospace industries. The scale-up strategy underpinned a more than ten-fold increase in AML3D's revenues during the financial year, when compared to the prior year.

"AML3D believes our technology advantage will transform metal manufacturing and help to rebuild sovereign manufacturing capabilities in the markets we serve," the company stated. "AML3D's Arcemy systems can be deployed at the point of need to deliver large-scale, custom-built components with significantly shorter lead times. Our technology has met some of the most rigorous civil and military accreditation standards, including the award, in FY24, of the AS9100D:2016 Aerospace Quality Systems Accreditation. The ability to manufacture high quality metal components faster than traditional casting and forging processes, with lower waste, reduced emissions and lower electricity consumption means AML3D can also be price competitive and address customers' sustainability requirements."

www.aml3d.com



Titomic sells D523 cold spray Additive Manufacturing machine to Triton

Titomic Limited, based in Brisbane, Australia, has announced the sale of a low-pressure D523 cold spray Additive Manufacturing to Triton Systems Inc, headquartered in Chelmsford, Massachusetts, USA. This acquisition of the D523 System complements Triton Systems' recent purchase of a high-pressure TKF System.

The sale of the D523, valued at AU $72,000, is said to mark another step in the ongoing collaboration between Titomic and Triton Systems, adding to Triton's advanced manufacturing capabilities and allowing it to further develop novel solutions based on Titomic's cold spray Additive Manufacturing.

"We are pleased to see that our partnership with Triton Systems continues to strengthen with the sale of the D523 System. This demonstrates our ongoing commitment to working closely with Triton Systems to bring new capabilities to the US manufacturing market," stated Herbert Koeck, Managing Director of Titomic. "By providing both low and high-pressure cold spray systems, we are confident that Triton Systems will be well-equipped to develop and implement innovative solutions that meet the industry's evolving needs. We look forward to continuing our collaboration and driving forward the future of advanced manufacturing together."

Dr Bryer C Sousa, Focus Area Lead for Metals & AM at Triton Systems, commented, "We are pleased to enhance our capabilities with the acquisition of Titomic's low-pressure D523 System. Titomic is driving innovation in integrated and modular cold spray systems, providing custom solutions for specific needs and applications. This acquisition strengthens our ability to deliver advanced solutions and supports our commitment to advancing the US manufacturing sector.

"Titomic's technology aligns with our mission to develop high-performance materials and manufacturing processes. We look forward to furthering our collaboration with Titomic to push the boundaries of manufacturing," Sousa concluded.

www.titomic.com

Titomic's D523 low-pressure cold spray Additive Manufacturing machine (Courtesy Titomic Limited)

BLT launches high-strength aluminium and titanium alloys for Additive Manufacturing

Xi'an Bright Laser Technologies Co, Ltd (BLT), Xi'an, China, has introduced a new high-strength aluminium alloy for Laser Beam Powder Bed Fusion (PBF-LB) and a new titanium alloy for PBF-LB and Directed Energy Deposition (DED) Additive Manufacturing.

BLT-AlAM500 aluminium alloy

BLT's new high-strength aluminium alloy, BLT-AlAM500, is specifically designed for aerospace applications. High-strength aluminium alloys are renowned for their strength, thermal stability, and superior processing performance, making them ideal for aircraft structural components and engine parts. Beyond aerospace, high-strength aluminium alloys are also essential in high-speed trains, lightweight automotive parts, and premium sports equipment.

At TCT Asia 2024, BLT showcased parts made from BLT-AlAM500, these included the bent tube, ventilation duct, and connecting pipe seen below.

These components, characterised by thin-walled, irregularly shaped tubular structures with internal cavities, demand high precision. Traditional manufacturing methods are complex, challenging, and costly. BLT optimised the design for Additive Manufacturing, and used its high-strength aluminium alloy and the company's BLT-S400 metal PBF-LB machine, to produce the parts. Each component takes approximately thirty hours to form, and achieved an average weight reduction of around 20% compared to the original.

Post-heat treatment, the material achieves tensile strengths of 530-550 MPa, yield strengths of 480-500 MPa, and elongation rates of 11-17%. The material also boasts excellent fracture toughness and fatigue performance, with a room temperature fracture toughness of 30.8 MPa $\cdot m^{1/2}$ and a high-cycle fatigue strength of 245 MPa (smooth sample) at room temperature. Compared to similar imported powders, the BLT-AlAM500 material is reported to offer a cost reduction of about 40-50%, significantly lowering manufacturing costs.

BLT-Ti65 titanium alloy

BLT's new Ti65 is a multi-component, near-alpha high-temperature titanium alloy, said to maintain excellent strength, plasticity, creep resistance, and thermal stability at temperatures up to 650°C. This performance exceeds the limitations of traditional high-temperature titanium alloys, making Ti65 favoured in aerospace, chemical equipment, and marine engineering applications.

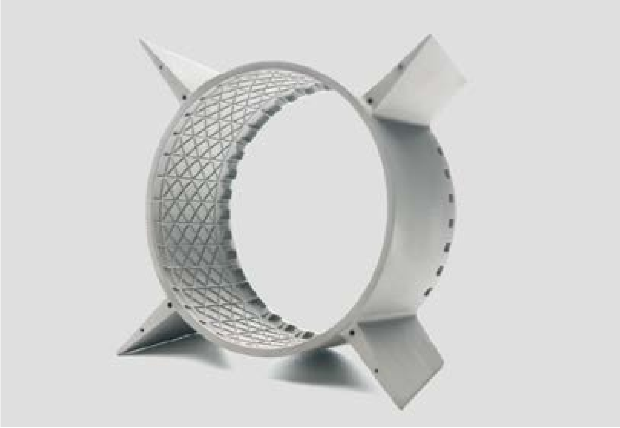
However, Additive Manufacturing Ti65 powder can result in defects such as unmelted or partially melted powder particles, inter-track and inter-layer porosity, and cracking, explains BLT. These can concentrate stress and increase the likelihood of material failure. These difficulties led BLT to develop and introduce its BLT-Ti65 powder.

The nominal chemical composition of BLT-Ti65 is Ti-5.9Al-4Sn-3.5Zr-0.3Mo-0.4Si-0.3Nb-2.0Ta-1.0W-0.05C, available in 15-53 µm (for PBF-LB) and 75-180 µm (for DED). Post-heat treatment, parts produced with 15-53 µm BLT-Ti65 powder can achieve yield strengths of 483-503 MPa, tensile strengths of 604-624 MPa, and elongation rates of 16.5%-26.5% at 650°C. Parts produced with 75-180 µm BLT-Ti65 powder can achieve yield strengths of 478-538 MPa, tensile strengths of 588-648 MPa, and elongation rates of 22%-32% at 650°C.

BLT's material portfolio now includes over eighty types, including titanium alloys, high-temperature alloys, aluminium alloys, titanium-aluminium alloys, copper alloys, stainless steel, tool steel, high-strength steel, tantalum-tungsten alloys, silver, and hard alloys.

www.xa-blt.com

The bent tube, ventilation duct, and connecting pipe are additively manufactured from BLT-AlAM500 aluminium alloy powder (Courtesy BLT)



BLT demonstrated the capabilities of its new BLT-Ti65 titanium alloy by producing this high density sample aerospace part (Courtesy BLT)

Seco/Warwick expands USA furnace manufacturing operations

Seco/Warwick Group, headquartered in Swiebodzin, Poland, has announced plans to expand its operations in the USA. The group, parent company of Seco/Vacuum and Seco/Warwick USA, has committed to expanding its manufacturing capacity in Pennsylvania by relocating a portion of its manufacturing, and a metallurgical lab for vacuum furnaces, from Poland to Crawford County.

In support of the expansion plans, the government of Pennsylvania has awarded the company a $2 million package of matching fund grants from the Department of Community and Economic Development through its Redevelopment Assistance Capital Program (RACP). The primary use and intent of the RACP fund is for reimbursement of eligible construction costs which Seco/Warwick Group companies will match on a 1:1 basis.

Seco/Vacuum manufactures heat-treating furnaces specialised for heat-treatment processes that must be conducted inside a vacuum chamber to prevent contamination from atmospheric gases. Seco/Warwick USA manufactures atmosphere heat-treatment furnaces, aluminium melting furnaces and controlled aluminium brazing (CAB) furnaces.

The expanded facility will benefit the community as well as the heat-treatment equipment manufacturer's customers. The company will begin upfitting their now-empty factory floor in the Crawford Business Park, which itself was recently redeveloped from the long-abandoned American Viscose Corporation's synthetic textile mill in Meadville, Pennsylvania, USA.

At its peak in the 1950s, the mill employed nearly half of Meadville. After many decades of operation, the mill closed in 1986. Beginning in 1989, the Crawford County Redevelopment Authority, the predecessor to today's Economic Progress Alliance of Crawford County, invested in cleaning, remodelling, and subdividing the million-square-foot plant into more than fifty smaller commercial and industrial spaces.

The added capabilities look to improve the company's response to its North American customers' needs, not only through manufacturing but also through the addition of parts, service, and training capacity. At the same time, the new facility will require an expanded staff, at both entry-level and skilled positions.

"We look forward to working with our local partners including the City of Meadville, the Economic Progress Alliance of Crawford County (EPACC), the Workforce and Economic Development Network (WEDnet), and the Pennsylvania Department of Community and Economic Development (DCED) to make this expansion happen," said Piotr Zawistowski, SECO/VACUUM President, Managing Director.

www.secovacusa.com

AM Craft and alphacam partner to target aerospace market

AM Craft, Riga, Latvia, has announced the addition of alphacam GmbH, Schorndorf, Germany, as an independent partner. It was stated that alphacam will open a new satellite office in Hamburg, Germany, focusing on support to the commercial aviation market, in partnership with AM Craft.

"We have proudly supported the aerospace industry for many years. We're qualified to print flight parts for several aviation OEMs and have delivered thousands of parts," stated alphacam founder and CEO, Michael Junghanss. "Yet Additive Manufacturing adoption in aviation is only at the beginning and we see tremendous opportunity to further accelerate our business growth in this market with the innovative approach brought by AM Craft. Airlines and MROs are looking for install-ready parts with a Form 1 airworthiness certificate and AM Craft brings that capability to alphacam."

AM Craft will lead design and certification activities and will rely on alphacam's manufacturing to fulfil customer orders in Germany and Western Europe. Along with local airworthiness authorities, AM Craft will work to extend its EASA Part 21G Production Organization Approval (POA) to alphacam facilities, beginning with Hamburg for customer proximity and Schondorf for massive capacity. This follows the successful extension of AM Craft's POA to network partner Paradigm 3D in Dubai earlier this year.

"It is our strategy to bring certified Additive Manufacturing to our customer's point of need. Hamburg, Germany, is a key hub for commercial aviation maintenance, and it's important for AM Craft to be in Hamburg to support our customers," shared Didzis Dejus, co-founder and CEO of AM Craft. "There is no better partner for us in Germany than alphacam. Our partnership will benefit from their long history in the German market and their deep experience with Additive Manufacturing in a production environment."

The AM Craft Production Network currently includes AM Craft in Riga, Additive Flight Solutions in Singapore, and Paradigm 3D in Dubai with alphacam Hamburg expected to open in Q4.

With the addition of alphacam, AM Craft reportedly leads the largest network of production Additive Manufacturing machines under an EASA Part 21G approval, with over twenty AM machines around the globe that can be deployed for the on-demand production of install-ready Form 1 parts for aviation.

www.alphacam.de
www.am-craft.com

Markforged's FX10 Metal Kit add-on enables both metal and composite Additive Manufacturing

Markforged, headquartered in Watertown, Massachusetts, USA, has introduced the FX10 Metal Kit, a bolt-on that brings metal capability to the company's FX10 Additive Manufacturing machine. With the new kit, the FX10 can now process both metal filaments and composites with continuous fibre reinforcement.

Markforged also announced a new 316L stainless steel metal filament to be used with the FX10 Metal Kit. The company added that users will also be able to use 17-4PH, with additional support for other Markforged metal filaments coming in the future.

"Customers no longer have to choose between a metal and a composite printer. Years of R&D investment and field experience have come together to provide an all-in-one solution for 3D printing to provide immediate return on investment once installed on a factory floor," stated Shai Terem, CEO of Markforged. "The FX10 supercharges other equipment on the factory floor to be better utilised and run more efficiently, increasing productivity and reducing potential line down events."

The FX10 Metal Kit consists of a swappable build engine that includes a metal-specific print head, material feed tubes, routing back, and dual pre-extruders. The FX10 can be swapped between metal and composite as many times as needed, with the process said to take around fifteen minutes.

"We designed the FX10 to be a modular platform, so that we are able to release new innovations and upgrades without customers having to purchase a new printer every year," continued Terem. "Along with new software capabilities we release regularly, the FX10 Metal Kit is poised to provide continuously growing value on factory floors for years to come."

Similar to the 5th Generation Continuous Fibre Reinforcement (CFR) build system in the FX10, that is nearly twice as fast as previous composite machines, the 2nd Generation Metal FFF engine, built on years of Markforged's experience in metal Additive Manufacturing, is said to be significantly faster than its previous metal systems. The FX10 also has a build volume twice as large as Markforged's earlier industrial metal AM machines.

The new FX10 Metal Kit is reported to make the FX10 the world's first industrial AM machine that can process both metal filaments and composites with continuous fibre reinforcement (Courtesy Markforged)


The FX10 can be swapped between metal or composite in around 15 minutes (Courtesy Markforged)

With the Markforged AM process, metal parts are built from the metal filament and a ceramic release filament. The ceramic release is extruded as an interface between the part and supports for ease of separation and removal. Once the green metal parts are produced, they must be solvent debound (or 'washed' in Markforged's terminology) and sintered in the company's Wash-1 and Sinter-2 systems. Eiger, Markforged's slicer and build management software automates the process, including scaling parts to account for shrinkage during the sintering stage.

The Digital Forge is the Additive Manufacturing platform that enables every aspect of the FX10 and is purpose-built to integrate into existing manufacturing ecosystems. With the Digital Forge, users can share parts across their organisation, and monitor fleet performance from a central location.

www.markforged.com

Knust-Godwin partners with Continuum Powders for advanced Ni718 recycling in the oil and gas industry

Continuum Powders, based in Los Gatos, California, USA, has announced that Knust-Godwin, a precision contract manufacturer headquartered in Katy, Texas, USA, has selected it as the exclusive metal powders provider for a project supporting a large oil and gas customer needing to recycle nickel alloy parts.

The oil and gas company had a large amount of Ni718-grade internal products hitting end-of-life and needed a cost-effective means to recycle the parts. The company approached Knust-Godwin to determine the best available solution. An existing Knust-Godwin customer recommended that the firm evaluate Continuum Powders.

Initially, Knust-Godwin was sceptical of recycled powder, but after multiple mechanical test coupons reportedly showed that Continuum Powders' products met or exceeded other leading non-sustainable powder suppliers, Continuum Powders was officially selected for the project.

"Continuum is doing things that no other metal powders company can currently do when it comes to complete lifecycle management of consumable metal parts," stated Rob Higby, Chief Executive Officer of Continuum Powders. "With the incredible advancements we've made in converting worn parts into new metal powders, it no longer makes sense to simply scrap those parts and purchase metal powders made from virgin metals."

Not only was Continuum Powders able to easily recycle end-of-life bulk parts with its proprietary, single-step Greyhound M2P platform, but it also supplied Knust-Godwin with new, high-quality Ni718 through its Continuum Powder as a Service (CPaaS).

Knust-Godwin was then able to manufacture new parts for its customer using a Renishaw RenAM500Q Additive Manufacturing machine. Following this project, Knust-Godwin realised the power of using Continuum's M2P process for recycling manufacturing by-products like oversized or sieved powder.

"Continuum Powders consecutively proved to have the highest quality powders on the market—equal to or above that of all other manufacturers," stated Michael Corliss of Knust-Godwin. "When you combine that level of quality with the level of sustainability they offer and their Powder as a Service offering – it makes them our de facto go-to provider."

www.continuumpowders.com
www.kgsbo.com

Alleima and KTH Royal Institute of Technology form strategic partnership for research and education

Alleima, headquartered in Sandviken, Sweden, has signed an agreement with KTH Royal Institute of Technology, Stockholm, Sweden, to deepen collaboration in research and education, enhance scientific excellence, strengthen societal benefits, and increase innovative capacity in addressing the major challenges faced by society today.

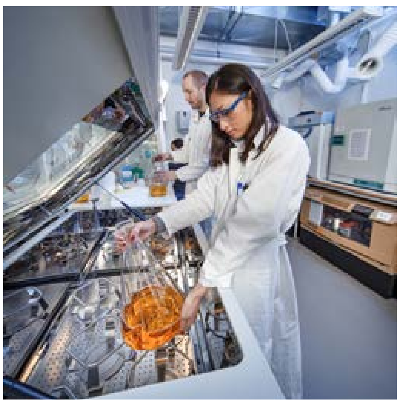
Alleima, formerly part of Sandvik, and KTH have a long-standing collaboration across various fields. This includes joint research and development activities, exchanges through industrial PhD students, study visits, and guest lectures. Alleima has also contributed an industrial perspective to the design of university programmes to better align with labour market needs.

The collaboration is now further strengthened through the strategic partnership, which is intended to support both existing and new forms of cooperation between Alleima and KTH. It seeks to deepen collaboration in the fields of materials science, chemistry, and chemical engineering – areas where both parties conduct research and development at an international level.

"In close collaboration with Alleima, we can develop innovative solutions for leading research and education. In this way, we jointly contribute to a more sustainable society and accelerate the transition. The partnership ensures a secure supply of talent, access to knowledge and cutting-edge research, and enhances competitiveness and innovative capacity," said Björn Glaser, Partnership Manager Director of Alleima at KTH.

"It feels fantastic that through this strategic partnership with KTH we have the opportunity to further deepen the collaboration in research and education. This means that with joint ambitious research, we can increase the power of innovation in areas where the world and society today face major challenges," Tom Eriksson, EVP & Head of Strategic Research, at Alleima, stated.

www.alleima.com
www.kth.se



Alleima and KTH Royal Institute of Technology partner for research and education (Courtesy KTH Royal Institute of Technology)

ORNL's datasets evaluate the quality of additively manufactured components

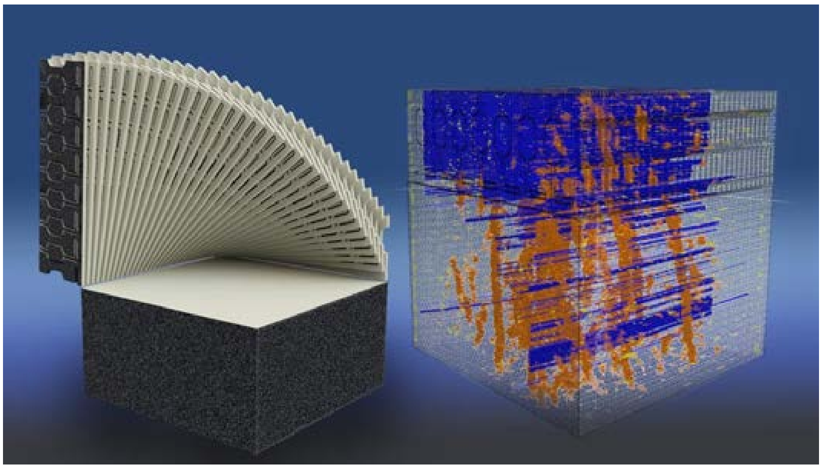
The US Department of Energy's (DOE) Oak Ridge National Laboratory (ORNL), based in Tennessee, USA, has released a new set of Additive Manufacturing data that industry and researchers can use to evaluate and improve the quality of additively manufactured components. The breadth of the datasets can significantly boost efforts to verify the quality of the parts using only information gathered during Additive Manufacturing, without requiring expensive and time-consuming post-production analysis.

Data has been routinely captured over a decade at DOE's Manufacturing Demonstration Facility (MDF) at ORNL, where early-stage research in advanced manufacturing, coupled with comprehensive analysis of the resulting components, is reported to have created a vast trove of information about how Additive Manufacturing machines perform.

The conventional manufacturing industry benefits from centuries of quality-control experience. However, Additive Manufacturing is a newer, non-traditional approach that typically relies on expensive evaluation techniques for monitoring the quality of parts. These techniques might include destructive mechanical testing or non-destructive X-ray computed tomography, which creates detailed cross-sectional images of objects without damaging them. Although informative, these techniques have limitations, for example, they are difficult to perform on large parts. ORNL's Additive Manufacturing datasets can be used to train machine learning models to improve quality assessment for any type of component.

"We are providing trustworthy datasets for industry to use toward certification of products," said Vincent Paquit, head of the ORNL Secure and Digital Manufacturing section. "This is a data management platform structured to tell a complete story around an additively manufactured component. The goal is to use in-process measurements to predict the performance of the printed part."

The 230 GB dataset covers the design, manufacturing and testing of five sets of parts with different geometric shapes, all made using a Laser Beam Powder Bed Fusion (PBF-LB) machine. Researchers can access machine health sensor data, laser scan paths, 30,000 powder bed images and 6,300 tests of the material's tensile strength.



The additively manufactured part (left) is sliced into small pieces, each of which is tested for tensile strength by pulling it until it breaks. A digital copy of the same additively manufactured part (right) has been analysed by an AI model to locate anomalies within its structure (Courtesy Andy Sproles/ORNL)

This is the fourth, and reportedly the most extensive, in a series of Additive Manufacturing datasets ORNL is making publicly available. Previous datasets have focused on the construction of parts made with Electron Beam Powder Bed Fusion (PBF-EB) and Binder Jetting (BJT) at the MDF. The datasets can be searched for specific information needed to understand rare failure mechanisms, develop online analysis software or model material properties.

The MDF, supported by DOE's Advanced Materials and Manufacturing Technologies Office, is a nationwide consortium of collaborators working with ORNL to catalyse the transformation of US manufacturing.

ORNL researchers demonstrated how to apply the datasets by training a machine learning algorithm using measurements taken during the Additive Manufacturing process. Paired with high-performance computing methods, the trained algorithm can reliably predict whether a mechanical test will be successful. It also made 61% fewer errors in predicting a part's ultimate tensile strength.

"Correlating in-process measurements with the final product is key to providing confidence about when an additional test of the part is needed – and when it's not. This is a key enabler to Additive Manufacturing at industry scale, because they can't afford to characterise every piece," Paquit shared. "Using this data can help them capture the link between intent, manufacturing and outcomes."

The data generated was part of the Advanced Materials and Manufacturing Technology Program, funded by DOE's Office of Nuclear Energy. These and other smart manufacturing approaches are being used to accelerate the development, qualification, demonstration and deployment of advanced manufacturing technologies to enable reliable and economical nuclear energy.

ORNL's dataset is available for free: www.osti.gov/biblio/2001425

www.ornl.gov

IperionX reports first successful HAMR titanium furnace production run

IperionX, based in Charlotte, North Carolina, USA, has announced the successful commissioning of its commercial-scale Hydrogen-Assist Metallothermic Reduction (HAMR) furnace. This marks the first titanium de-oxygenation production run at the Titanium Manufacturing Campus in Virginia, USA.

"The IperionX team delivered an important technological and commercial milestone for the global titanium industry," stated Anastasios (Taso) Arima, IperionX CEO.

"Over the last two years, we have successfully operated our pilot titanium production facility in Utah, producing high performance titanium products for customers and - importantly – delivering first revenues for our company. Today, we demonstrated that our HAMR technology works at commercial scale. We successfully increased the furnace production capacity by ~60x and produced high performance titanium that exceeds industry quality standards," continued Arima.

IperionX's proprietary HAMR technology offers a range of competitive advantages, including lower operating temperatures, reduced energy consumption, enhanced process efficiency, and accelerated production cycles – all achieved with lower capital investment intensity.

Produced entirely from 100% scrap titanium (Ti6Al4V alloy, Grade 5 titanium), quality assessments confirmed a large reduction in oxygen levels from 3.42% to below 0.07%, exceeding the ASTM standard requirement of 0.2% for Grade 5 titanium.

Over the coming months, IperionX will commission and optimise the supporting process equipment to achieve full system production capacity in Virginia, with end-to-end system operations expected in late 2024.

"IperionX plans to expand the capacity of its Titanium Manufacturing Campus by adding modular, low-risk and low-cost HAMR furnaces. IperionX aims to be a leading US titanium producer of +10,000 metric tons per annum by 2030. Our goal is to re-shore the full titanium supply chain to the United States, at lower costs for our customers, and deliver the most sustainable titanium products on the market," Arima concluded.

www.iperionx.com

IperionX team at the Titanium Manufacturing Campus for the first successful HAMR furnace production run (Courtesy IperionX)

Markforged agrees to $25M Continuous Composites patent lawsuit settlement

Markforged, headquartered in Watertown, Massachusetts, USA, has announced that it has entered into a Settlement and Patent License Agreement in connection with the patent infringement brought by Continuous Composites Inc. The settlement agreement is reported to resolve all claims and counterclaims in the litigation, which is currently pending before the United States District Court for the District of Delaware.

"We are pleased to announce this Settlement Agreement which, if approved by the District Court, will bring this litigation to a successful conclusion that will eliminate this distraction to Markforged and the uncertainty over the outcome of this litigation for all of our stakeholders," commented Shai Terem, president and Chief Executive Officer of Markforged.

As disclosed in Markforged's public filings, in July 2021, Continuous Composites filed a patent-infringement lawsuit against Markforged. Four patents originally asserted against Markforged, comprising a total of nineteen patent claims, were removed from the case in April 2023, leaving four claims from a patent that was added to the case in 2022.

Two of the four claims from the remaining patent were tried by a jury in April 2024. On April 11, 2024, the jury found one of the two remaining patent claims Continuous Composites asserted at trial against Markforged to be invalid and not infringed. However, the jury found that Markforged had infringed the other patent claim and awarded monetary damages to Continuous Composites in the amount of $17.34 million.

Markforged challenged this verdict through post-trial motions. Through its post-trial motions, Continuous Composites also asserted claims for additional royalty payments for sales of certain products manufactured and/or sold by Markforged in the United States after December 31, 2023.

Under the terms of the settlement agreement, Markforged will make an upfront payment of $18 million to Continuous Composites, which is expected to occur in the fourth quarter of fiscal year 2024, and three additional instalment payments thereafter of $1 million, $2 million and $4 million in the fourth quarters of fiscal years 2025, 2026 and 2027, respectively.

The Settlement Agreement reportedly acknowledges that neither party admitted to any liability or wrongdoing with respect to the claims alleged in the Continuous Composites Lawsuit.

www.continuouscomposites.com
www.markforged.com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ASTM and EOS Additive Minds expand PBF-LB Machine Operator Certification to include EOS M 400 Series

The ASTM International Additive Manufacturing Center of Excellence (AM CoE), along with Additive Minds, the applied engineering, and training group of EOS GmbH, Krailling, Germany, have jointly announced the expansion of the PBF-LB Machine Operator Certification programme to include the EOS M 400/EOS M 400-4 metal Additive Manufacturing platform.

The PBF-LB Machine Operator Certification programme was initially launched in April 2022 and tested with the EOS M 290 machine. It serves as a standard for evaluating the reliable and competent operation of metal PBF-LB machines, based on the joint ISO/ASTM standard (ISO/ASTM 52942:2020). This certification is now offered to both EOS M 290 and EOS M 400/EOS M 400-4 operators, providing a 'stamp of approval' along with theoretical and practical assessments to evaluate machine-specific competency.

The ASTM certification evaluates:

- Additive Manufacturing Procedure Specification (APS)
- Standard operating procedures
- Machine management and build process monitoring
- Post-processing optimisation
- Operator maintenance of systems
- Powder material family specialisations: up to two material groups based on the user's selection

"ASTM continues its effort to support the industrialisation of Additive Manufacturing by offering programmes such as certification. This certification allows operators of sophisticated AM machines to demonstrate expertise and stand out in the industry. The certification will emphasise your organisation's commitment to quality and consistency using PBF-LB processes, and open doors to new production opportunities in the world of Additive Manufacturing," stated Paul Bates, Senior Training & Certification Leader at ASTM International.

"We are pleased to see the Additive Manufacturing Operator Certification Program continuing to blossom. Coupled with the recent launch of our in-person Additive Minds Academy training centre, we are taking substantial steps towards closing the industrial 3D printing educational gap and building a stronger, more robust AM workforce for the future of our industry," Fabian Alefeld, senior manager of the Additive Minds Academy and Consulting at EOS, stated.

www.amcoe.org
www.eos.info

Voxel Innovations expansion to boost material research, metrology and production capabilities

Voxel Innovations, an advanced manufacturing company specialising in pulsed electrochemical machining (PECM), has relocated to a larger, newly constructed facility in Knightdale, North Carolina, USA. The move, quadrupling its original floor space, will enable the company to expand its material research, metrology, and production capabilities.

PECM is a unique non-thermal, non-contact material removal method utilising electrochemistry that is capable of creating small features and superfinished surfaces on metallic parts with high repeatability. The technology can be used as a post-processing method for metal additively manufactured parts.

Voxel Innovations was founded in 2015 in Raleigh, North Carolina, by its current CEO, Daniel Herrington. Voxel initially developed PECM as a response to engineers struggling to manufacture next-generation critical components for challenging environments that require tough-to-machine materials such as Inconel and refractory metal alloys.

Voxel has continuously improved the precision capabilities of its process, discovered proprietary methods to machine new materials, and developed fully automated PECM production lines. It reportedly machines millions of high-quality parts annually and is looking to continue this trend in its new facilities.

"Voxel's growth into our new facility is an important milestone in our growth, allowing us to expand our capacity for both existing and new customers," stated Herrington. "We are excited for this next chapter in Voxel's story while also helping to grow the advanced manufacturing industry in the research triangle region of North Carolina."

www.voxelinnovations.com

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

EOS integrates Oqton's AI-powered build quality suite for enhanced Additive Manufacturing

Oqton, a software provider based in Ghent, Belgium, has collaborated with EOS GmbH, Krailling, Germany, to integrate its Build Quality suite to EOSCONNECT Core. This tool has the potential to enable the production of high-quality parts, and process repeatability for accelerated time-to-market. Oqton Build Quality is an AI-powered solution for metal powder bed Additive Manufacturing machines that evaluates build performance across manufacturing workflows to prevent, detect, and can help with the correction of anomalies and defects.

The integration of this solution with EOS software looks to enable full end-to-end traceability of additively manufactured parts to help EOS' customers meet demanding quality assurance standards. Additionally, it can help lower production costs by reducing material use, minimising scrap, and enhancing the effectiveness of engineering teams.

Oqton Build Quality encompasses 3DXpert Build Inspection to monitor the entire manufacturing process and mitigate anomalies resulting from errors during the build setup, manufacturing, or with materials. The solution works with image and sensor technology that is already integrated into a variety of metal AM machines augmented with AI algorithms, thus avoiding the need to invest in additional hardware.

Detecting and correcting anomalies early in the process helps to ensure the success of each build – from first article inspection through final part – enabling manufacturers to develop repeatable processes for prototyping and production that efficiently yield high-quality parts while reducing costs. The software suite addresses the needs of a variety of manufacturers that rely on Additive Manufacturing technologies including product and equipment manufacturers (i.e., OEMs), service bureaus and engineering services teams, and those responsible for quality assurance. The solution is designed to focus on key areas before, during and after the build to maximise processes and outcomes.

Oqton has collaborated with EOS to integrate its Build Quality suite to EOSCONNECT Core (Courtesy EOS/Oqton)

"The new Oqton Build Quality suite has the potential to lead to a significant leap in terms of quality assessment of additively manufactured metal components," stated Rüdiger Herfrid , product manager, software, EOS GmbH. "The ease of use and automatic reporting capabilities are a key step towards the end-to-end traceability and assessment of AM parts. EOS customers can now access AI capabilities within the Oqton Build Quality suite, thanks to seamless integration with EOS software and the close collaboration between Oqton as a partner of the EOS Developer Network."

"Metal 3D printing has unlocked reliable production of final parts, but ensuring consistent quality was a challenge," said Kirill Volchek, chief technology officer, Oqton. "Oqton's Build Quality cuts through this complexity, offering a unified, reliable solution."

www.oqton.com
www.eos.info

US Air Force RSO expands A6061-RAM2 testing agreement with Elementum 3D

The United States Air Force Rapid Sustainment Office (RSO) recently expanded its material characterisation agreement with Elementum 3D, based in Thornton, Colorado. The agreement is focused on specification, dataset generation, and application testing of A6061-RAM2 for Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing.

As part of the project, Elementum 3D is developing a full dataset for A6061-RAM2 T6 — based in MMPDS S-basis guidelines — as well as performing additional testing to consider the impact of wall thickness, as-built surfaces, and Hot Isostatic Pressing (HIP) on material properties and applications.

The combination of material property characterisation and application studies, including non-destructive testing evaluation and a prototype part study, will provide the RSO with the information they need to start qualifying parts out of A6061-RAM2 on EOS M290 Additive Manufacturing machines used for this effort.

This robust material dataset, material and process specification, and application testing is intended to enable the use of aerospace-grade aluminium and Additive Manufacturing to support the US Air Force's life cycle management and sustainment.

www.elementum3d.com
www.aflcmc.af.mil

WEAREAM adds Freemelt e-MELT-iD for titanium, tungsten and molybdenum Additive Manufacturing

Emil Freed, Service Technician for Freemelt with the new e-MELT-iD (Courtesy Freemelt)

Freemelt AB, based in Mölndal, Sweden, has announced the successful installation of its first industrial metal Additive Manufacturing machine, the e-MELT-iD, at WEAREAM, headquartered in Lombardy, Italy. The e-MELT-iD is a single-module Additive Manufacturing machine for product development and production of high-quality components using hard-to-weld metals, refractories, and high-purity copper.

WEAREAM has experience with Electron Beam Powder Bed Fusion (PBF-EB) technology and intends to be a key enabler for the development of new applications and products in Europe. WEAREAM will focus on bridging the gap between research and industry, enabling an efficient transition to mass production.

"The past few weeks have been incredibly productive as we have welcomed Freemelt and the e-MELT®-iD into our facility," stated Maurizio Romeo, WEAREAM's CTO. "From pre-installation and configuration to hands-on operator training, the expertise of the Freemelt team has been appreciated and valuable."

"We've completed all the required steps to start operating the machine in a way that meets our expectations. With my extensive experience of E-PBF technology and from implementing new machine models, I am very impressed with the efficient site acceptance test process and the machine reliability. Our team is excited to start operating the e-MELT-iD machine, and we look forward to the upcoming advanced user training to unlock its full potential, so we can progress in our ongoing discussions with industrial partners. Our initial focus will be in Ti64, Tungsten and Molybdenum applications," added Romeo.

www.freemelt.com

Amnovis marks delivery of 50,000 implants made with heat-treatment-free Additive Manufacturing

Amnovis, based in Aarschot, Belgium, reports it has now successfully delivered 50,000 additively manufactured titanium implants since it began production in 2021. The company uses a propriety heat-treatment-free Additive Manufacturing process to produce spinal, orthopaedic, and cranio-maxillofacial (CMF) implants.

By eliminating the need for heat treatment in titanium AM, the production workflow is simplified, explained Amnovis, thus accelerating time-to-market and lowering costs for OEMs. "We developed and validated a proprietary process for pure titanium that requires no heat treatment," stated Ruben Wauthle, CEO and co-founder of Amnovis. "This unique process allows us to deliver faster, more cost-effective solutions for our customers while maintaining the highest quality standards."

Amnovis has developed a proprietary process for commercially pure titanium (CP Ti) that combines the chemical purity and ductility of CP Ti Grade 1 with high tensile strength. It is already used by several of Amnovis' customers around the world for orthopaedic and spinal implants.

One of Amnovis' partners to have benefitted from the technology is privelop-spine AG. "Since partnering with Amnovis, we've been impressed by their production quality and specialist expertise," stated Henning Kloss, privelop-spine's CEO. "Surgeons consistently praise the detailed resolution, look, and feel of our implant structures, while distributors and users appreciate the reliability and punctual delivery."

"Amnovis' heat-treatment-free titanium process has significantly streamlined our production, reducing

Amnovis has produced over 50,000 spinal implants (Courtesy privelop-spine AG)

time and costs," continued Kloss. "Their production capacity and reliability have made a substantial contribution to our collaboration with large customers, helping us bring products to market faster."

In addition to its proprietary AM process, Amnovis offers a full range of traditional AM services, including Ti-6Al-4V grade 23 with classical post-processing treatments such as Hot Isostatic Pressing. This option is intended to allow OEMs the flexibility to choose the most suitable manufacturing method for their needs.

www.amnovis.com

Mott Corporation acquires open architecture Renishaw RenAM 500S Flex machine

Mott Corporation, headquartered in Farmington, Connecticut, USA, has acquired a further metal Additive Manufacturing machine from Renishaw, based in Wotton-Under-Edge, Gloucestershire, UK. The new RenAM 500S Flex machine has reportedly enabled Mott Corporation to reduce machine turnaround and setup times, compared to previous AM technologies, while giving more confidence in the performance of additively manufactured parts.

Mott Corporation specialises in solving filtration and flow control engineering challenges in integrated components, point-of-use sub-assemblies, and integrated subsystems. It offers an extensive material selection for the most critical operating conditions, such as highly controlled bioreactor environments, semiconductors, chemical processing and refinement, and aerospace applications.

Historically, Mott Corporation produced components using three compaction methods: axial, isostatic, and rolling. However, these techniques are unable to produce some geometries. To expand its capabilities, Mott decided to investigate AM, identifying Laser Beam Powder Bed Fusion (PBF-LB) as the best technique for its needs.

Mott Corporation's most important consideration when choosing a machine was said to be its open architecture, which enabled the parameter editing essential to research and development work. The organisation, therefore, originally approached Renishaw to purchase a RenAM 400 system.

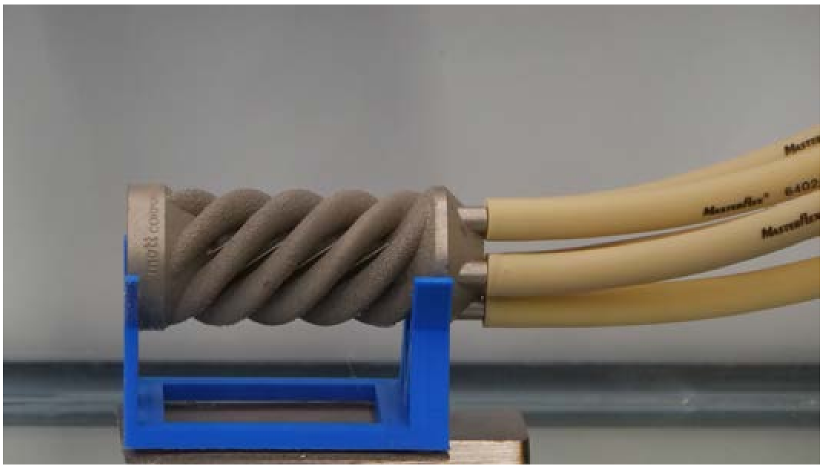
For added control, the company then upgraded its system to the new RenAM 500S Flex machine. This machine uses the same gas flow system, safety, and precision digital optics as the rest of Renishaw's RenAM 500 series of Additive Manufacturing machines, but offers additional flexibility with the ability to swap the metal powder feedstock in a short amount of time. It is available with either single (S) or quad (Q) laser configuration, and the laser(s) can be used in either modulated or continuous wave regimes, adding an additional level of customisation. Incorporating the RenAM 500S Flex reduced machine turnaround and setup times for Mott by over 50% compared to the older machine. It has also improved the standard deviation of performance metrics by approximately 30% in certain cases, giving Mott more confidence in the performance of parts manufactured on the system.

"Renishaw's philosophy is that process parameters should be as customisable as possible," said John Laureto, AM Business Manager at Renishaw Inc. "Using the RenAM 500S Flex, Mott Corporation was able to optimise its processes for specific applications and can tweak the parameters as needed for novel projects."

"Our ethos is to combine our design, filtration, and flow control expertise with cutting-edge technology to create highly engineered products," explained Vincent Palumbo, Technical Program Manager at Mott Corporation. "That's exactly what we're doing here. The new machine gives us greater confidence in the reliability and performance of our parts, while speeding up development cycles, and better enabling us to bring our designs to life."

Palumbo concluded, "The Flex has been the most popular stop on our facility tours. It's great to see customers' reactions to the parts we have been able to create. It has also generated useful dialogue between us and our customers to come up with development projects and think of other components we can design with them in the future."

www.renishaw.com
www.mottcorp.com



Mott Corporation has used a RenAM 500S Flex machine from Renishaw to produce AM filtration components (Courtesy Renishaw)

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Dowlais considers sale of GKN Powder Metallurgy business

Liam Butterworth, Dowlais CEO, has announced a strategic review of GKN Powder Metallurgy (Courtesy Dowlais Group)

Dowlais Group plc, the UK-based parent company of GKN Automotive and GKN Powder Metallurgy, has published its half year 2024 results. In the report, the company confirmed it has commenced a strategic review of the Powder Metallurgy business, as it eyes a potential sale of the division.

GKN Powder Metallurgy noted a good start to the year, with adjusted revenues growing by 0.2%, ahead of the market, while adjusted operating profit increased by 6.0%, resulting in an adjusted operating margin expansion of 50 bps, to 9.5%.

The company stated that proactive management of the cost base had enabled GKN Powder Metallurgy to offset inflationary increases through operational efficiencies. This led to restructuring activities continuing in the first half of the year, with one site closed in the US and another set to close by the end of the year. The location of the second site closure was not stated, but this was expected to further optimise the manufacturing footprint, Dowlais stated.

It was added that GKN Powder Metallurgy continued to advance its EV transition, winning new EV-specific contracts and identifying additional growth areas for propulsion-agnostic products.

For the group as a whole, Dowlais reported adjusted revenue of £2,571 million for the six months ending June 30, 2024, a reduction of 5.1% on the prior year, said to be driven by weakness in the ePowertrain product line of the Automotive business. Driveline, China and Powder Metallurgy, totalling more than 75% of the group's revenues, were reported to be performing above their markets.

The group posted adjusted operating profit of £151 million, including £7 million of operating losses from Hydrogen operations, a decline of 9.0% compared to the prior year, said to be driven by lower volumes.

www.gknpm.com

Tucker Induction uses Nikon SLM Solutions for copper Additive Manufacturing

Tucker Induction Systems, based in Shelby Township, Michigan, USA, and Nikon SLM Solutions have announced a strategic partnership to advance copper Additive Manufacturing in the United States. This collaboration will see Tucker Induction Systems offer copper Additive Manufacturing capabilities using an SLM 280 PS Additive Manufacturing machine from Nikon SLM Solutions.

Copper Additive Manufacturing in the US is reportedly rare, but Tucker Induction Systems is now capable of manufacturing induction coils and copper parts.

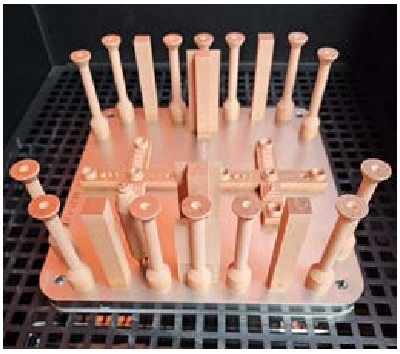
Joshua Tucker, Manager of Tucker Induction Systems, stated, "We are excited to be one of the few companies in the US printing induction coils with copper. Our collaboration with Nikon SLM Solutions allows us to push the boundaries of what's possible in the induction industry."

The partnership addresses a significant gap in the market. This capability not only enhances Tucker Induction Systems' production efficiency but also opens new possibilities for complex and high-performance designs.

Rocky Tucker, owner of Tucker Induction Systems, added, "Partnering with Nikon SLM Solutions has enabled us to innovate and develop functional copper inductors. Their technology and eagerness to collaborate have been key to our success."

Charlie Grace, CCO at Nikon SLM Solutions, commented, "We are thrilled to support Tucker Induction Systems in pioneering copper printing for the induction industry. This partnership exemplifies our commitment to driving innovation and delivering cutting-edge solutions that address the evolving needs of our customers."

www.tuckerinductionsystems.com
www.nikon-slm-solutions.com



Tucker Induction Systems is now capable of manufacturing induction coils and copper parts (Courtesy Nikon SLM Solutions)

Quickparts launches QuickQuote for efficient volume manufacturing requests

Quickparts, based in Seattle, Washington, USA, has announced the launch of a new online tool designed to streamline the request process for volume manufacturing solutions. QuickQuote, available through the Quickparts portal, is aimed primarily atcustomers with large-scale or complex projects primarily in CNC machining, injection moulding and Additive Manufacturing.

QuickQuote is designed to streamline the request process for volume manufacturing (Courtesy Quickparts)

Through the new online tool, customers can easily submit requests for volume manufacturing projects. The interface allows users to upload their files and then enter details such as proposed production scheduling, lead times, quality requirements, design specifications, materials, accreditation needs and preferred processes.

This streamlined approach triggers a rapid response from a dedicated project team, paving the way for further discussions around customer project needs. It also enables customised quotes and solutions that align with their requirements.

"We are thrilled to unveil this new online tool," said Ziad Abou, Chief Success Officer for Quickparts. "This innovative solution simplifies the request process for volume manufacturing projects, enabling our customers to receive customised solutions that perfectly align with their specific needs. At Quickparts, we are dedicated to delivering the competitive edge our customers need by providing exceptional service, unmatched quality, and innovative manufacturing solutions."

www.quickparts.com

Tekna Holding reports 30% increase in revenue

Tekna Holding ASA, Sherbrooke, Quebec, Canada, has announced the company's results for the second quarter and first half of 2024. In the second quarter, Tekna generated CA $11.2 million in revenue, a 1.9% increase year-over-year. The slower than expected revenue development has led management to consider additional strategic adjustments to better align with annual targets.

Despite the challenges, a 30% increase in revenue from the first to second quarter suggests that full-year 2024 revenue is likely to surpass that of previous years.

"While we have recorded good performance in some areas, our overall results are not where we expected them to be. To mitigate the impact on profitability, we are taking corrective actions with resilience and strategic foresight," said Luc Dionne, CEO of Tekna Holding ASA.

Systems revenue decreased by 1.9% compared to Q2 2023, due to the strong performance and revenue recognition of the PlasmaSonic system last year. As systems revenue is recognised based on project completion, fluctuations are expected.

Advanced Materials revenue increased by 4.2% year-over-year in Q2, below management expectations. This is primarily due to a softer than expected order intake in Q1 from the Additive Manufacturing machine manufacturers, aerospace, and medical sectors, reflecting a broader industry slowdown.

Adjusted EBITDA for Q2 2024 was CA $-1.5 million, down from CA $-0.6 million in Q2 2023. The profitability was reportedly affected by one-off costs of CA $0.5 million in the margin for materials, in part driven by efforts to reduce working capital, and indirect costs that were marked by CA $0.6 million higher costs due to the absence of services historically invoiced to the joint venture.

"We have accelerated the implementation of a comprehensive profitability improvement programme. This programme is focusing on improving product cost, reducing overhead costs and enhancing organisational efficiency. We anticipate that the cost saving programme can contribute CA $2 million in adjusted EBITDA over the next six months, with some of the cost savings recurring in 2025," said Luc Dionne.

Tekna's total order backlog was CA $18.2 million going out of the second quarter, down from CA $22.0 million in Q2 2023, largely due to lower order intake in systems. The pipeline remains strong for the rest of the year, with CA $2.0 million in system orders already secured in Q3 2024. Conversely, Advanced Materials showed strong demand with an order intake of CA $5.9 million (+18%) and a backlog of CA $14.0 million (+28%).

In the second quarter, Tekna reported that it won an intellectual property case concerning competing patent rights to produce titanium powder in Canada. The losing party has a limited time to appeal the judgement. Per the Federal Court process, Tekna is reportedly working to recoup a potentially significant part of its related legal costs.

Looking ahead, Tekna is experiencing the usual seasonal decline in activity due to the summer holiday period in North America and Europe in Q3. However, the company said it expects a recovery in Q4 2024.

www.tekna.com

voestalpine reports solid results despite extremely difficult environment

The voestalpine Group has reported a solid result in the first quarter of the 2024/25 business year. The group's stability was said to be attributed to its global positioning and sector diversification, despite a poor European economic environment.

"In an extremely difficult environment, especially for European steel companies, we were able to perform very well both in steel production and in the area of downstream processing. Our high-quality steel products are highly sought after in the most technologically demanding segments, such as the rail and aerospace industries. Our strategic goal remains continued growth in high-yield markets," stated Herbert Eibensteiner, CEO of voestalpine AG.

The rail infrastructure and aerospace sectors performed particularly strongly in the first quarter. The energy sector recorded positive demand, especially in the renewable energy segment. By contrast, the construction and mechanical engineering industries remained at a persistently low level. The ongoing weak development, particularly in the German automotive industry, led to low demand for tool steel and in the Automotive Components business segment. In contrast, demand from the automotive industry for products from voestalpine's Steel Division was satisfactory. Demand for voestalpine's high bay warehousing systems made from the most robust steel profiles remains strong.

At €4.1 billion, revenue in the first quarter of the business year 2024/25 was slightly below the same period in the first quarter of the business year 2023/24 (€4.4 billion). The EBITDA operating result decreased by 16.5% year-on-year to €417 million (Q1 2023/24: €499 million). The EBITDA is influenced by negative one-off effects of €28 million from the ongoing sales process for Buderus Edelstahl.

Profit from operations (EBIT) fell by 26.7% year-on-year to €228 million (Q1 2023/24: €311 million). Earnings before taxes amounted to €189 million (Q1 2023/24: €273 million). Profit after tax fell to €150 million (Q1 2023/24: €213 million). Cash flow from operating activities increased significantly from €10 million in the previous year to €215 million.

Equity increased by 0.8% compared to the reporting date (March 31, 2024) and amounted to €7.6 billion as of June 30, 2024. Net financial debt increased by 6.3% compared to the reporting date to reach €1.8 billion as of June 30, 2024. At 23.2%, the gearing ratio (net financial debt in relation to equity) increased slightly compared to the balance sheet date (22.0%).

As of June 30, 2024, the number of employees in the voestalpine Group worldwide amounted to 51,400 (full-time equivalent), which is 0.4% more than in the previous year (51,200).

www.voestalpine.com

Kennametal reports a strong finish in fiscal year 2024 results

Kennametal Inc, based in Pittsburgh, Pennsylvania, USA, has announced its fourth quarter and fiscal 2024 results. For 2024, sales of $2,047 million decreased 2% from $2,078 million in the prior year, said to reflect an organic sales decline of 1% and an unfavourable currency exchange effect of 1%.

"Thanks to the hard work and diligence of our global team, we delivered a strong finish in fiscal year 2024 despite persistent market softness, foreign exchange headwinds and a natural disaster affecting our facility in Arkansas. We successfully met our revenue and EPS outlook and generated $277 million in cash from operations, the highest as a percent of sales in over twenty-five years," said Sanjay Chowbey, president and CEO.

Operating income for the year was $170 million, or 8.3% margin, compared with $192 million, or 9.3% margin, in the prior year. The decrease in operating income was primarily due to lower sales and production volumes, higher wages and general inflation, higher restructuring and related charges of approximately $6 million, charges of approximately $4 million, consisting of repairs and impairments of fixed assets and inventory due to the tornado that affected the company's Rogers, Arkansas facility during the fourth quarter, and unfavourable foreign currency exchange of approximately $2 million.

These factors were partially offset by pricing, restructuring benefits of approximately $21 million and lower raw material costs. Adjusted operating income was $183 million, or 8.9% margin, compared with $199 million, or 9.6% margin, in the prior year.

Net cash flow provided by operating activities in fiscal 2024 was $277 million compared to $258 million in the prior year. The change in net cash flow from operating activities was driven primarily by working capital changes including improved inventory levels, partially offset by lower net income compared to the prior year.

Free operating cash flow (FOCF) was $175 million compared to $169 million in the prior year. The increase in FOCF was driven primarily by working capital changes, including improved inventory levels, partially offset by higher capital expenditures and lower net income compared to the prior year. FOCF was 146% of adjusted net income in fiscal 2024.

In fiscal 2024, Kennametal returned $129 million to the shareholders through $65.4 million in share repurchases and $63.4 million in dividends, while investing $108 million in capital expenditures.

www.kennametal.com

SWISSto12 gains $10 million contract to enhance safety at sea with RF antenna technology

SWISSto12 has been awarded a $10 million contract to provide a European aeronautical OEM with equipment for improved safety at sea (Courtesy SWISSto12)

SWISSto12, based in Renens, Switzerland, has been awarded a $10 million contract to provide a European aeronautical OEM with equipment for improved safety at sea. This follows the recent supply of RF antennas by SWISSto12 to Northrop Grumman.

SWISSto12 offers a portfolio of antenna systems which leverages the company's designs and proprietary Additive Manufacturing technology to deliver RF communication and sensing products qualified for maritime, airborne and ground applications. The company's RF products are lightweight, compact, and robust and offer high-quality performance well-suited for demanding applications in marine environments.

Frank Schreckenbach, Chief Product Officer, said, "Legacy antennas were restricted by traditional manufacturing and assembly constraints. SWISSto12's proprietary 3D printing technologies allow for the Additive Manufacture of highly complex, lightweight antenna designs that optimise performance and throughput while enhancing coverage flexibility. This introduces a new category of antenna performance which has broad benefits for safety applications in maritime, airborne and ground environments."

www.swissto12.com

Xometry marketplace announces record Q2 revenue of $133 million

Xometry, Inc, headquartered in North Bethesda, Maryland, USA, has posted its financial results for the second quarter ended June 30, 2024. The company reported a revenue increase of 19% year-over-year, with record revenue of $133 million driven by marketplace growth of 25% year-over-year.

"We delivered record revenue, record gross profit and record gross margins as our AI-powered marketplace continues to gain market share," said Randy Altschuler, Xometry's CEO. "In Q2 2024, we grew our marketplace revenue 25%, with accelerated growth in the US and a record 33.5% marketplace gross margin as more customers turn to Xometry for their supply chain solutions. The combination of data-driven AI and supplier network expansion will fuel robust growth and continued margin improvement."

"We delivered another strong quarter with better-than-expected results driven by improving marketplace gross margin and significant operating leverage," stated James Miln, Xometry's CFO. "This resulted in a 70% improvement in our Adjusted EBITDA loss to $2.6 million, or 2.0% of revenue. We remain focused on our path to Adjusted EBITDA profitability."

Total gross profit for the second quarter 2024 was $52.9 million, an increase of 21% year-over-year. Q2 marketplace gross margin increased 180 basis points year-over-year to a record 33.5%.

Net loss attributable to common stockholders was $13.7 million for the quarter, a decrease of $12.9 million year-over-year. Net loss for Q2 2024 included $8.1 million of stock-based compensation, $0.8 million of payroll tax expense related to stock-based compensation and $3.3 million of depreciation and amortisation expense.

Q2 Adjusted EBITDA improved 70% year-over-year to a loss of $2.6 million for the quarter, reflecting an improvement of $6.0 million year-over-year. Q2 Adjusted EBITDA loss represented 2.0% of revenue.

During Q2 Xometry developed new auto-quote categories and is now beta-testing new auto-quote tube-bending and tube-cutting processes within Xometry's AI-powered marketplace which the company expects to release later in Q3. Xometry is leveraging Google Cloud Vertex AI to accelerate the development of new instant-quoting capabilities.

There were expanded offerings in the Asia Pacific region, including new English-speaking countries Australia, Singapore and New Zealand through an upgraded xometry.asia site.
In China, Xometry also launched enhanced customer service capabilities on its WeChat mini app for buyers to quote, order and track deliveries.

Expanded European marketplace menu with new finishes and materials. For CNC, Xometry Europe added eleven new materials including new steel and aluminium grades. Additionally, the EU site expanded its finishing options for Additive Manufacturing. Xometry Europe now offers localised marketplaces in fifteen different languages.

Xometry is expecting revenue growth of 14-16% year-over-year to $136-$138 million in Q3 2024 as well as an Adjusted EBITDA loss of $1.5-$3.5 million. It also looks to reaffirm fiscal 2024 marketplace revenue growth of at least 20% year-over-year and expects supplier services revenue to be down approximately 10% year-over-year.

www.xometry.com

Concurrent Technologies expands Additive Manufacturing in defence with AFRL contract

Concurrent Technologies Corporation (CTC), Johnstown, Pennsylvania, USA, has been selected by the US Air Force Research Laboratory (AFRL) to develop an Additive Manufacturing machine especially suited for US Department of Defense (DoD) advanced weapon system part manufacturing. The $4.4 million contract, phase two of the project, aims to overcome the limitations of current AM equipment and enhance the production of longer parts for critical defence applications.

The current process of manufacturing large, advanced weapon system components involves joining multiple smaller AM parts, which introduces challenges such as strength issues, inconsistent mechanical properties, and limited design flexibility. By increasing the capabilities of AM for DoD applications, CTC seeks to eliminate these drawbacks and streamline the manufacturing process.

"CTC is committed to advancing manufacturing capabilities and supporting the defence industry's critical needs," said Edward J Sheehan, Jr, CTC President and CEO. "The technical work we are performing for this project includes elements of CTC's full-service portfolio of AM capabilities including design, testing, post processing, machining, and qualification."

Under the contract, CTC will finalise the machine design, install the equipment, conduct qualification tests, and additively manufactured near- or full-height representative geometry in an effort to ensure optimal performance.

CTC has been selected by the US Air Force Research Laboratory (AFRL) to develop an Additive Manufacturing machine especially suited for advanced weapon system part manufacturing (Courtesy Concurrent Technologies Corporation)

"We are proud of AFRL's continued trust in our ability to provide value on this important effort," said Ken Sabo, Senior Director, Manufacturing.

www.ctc.com

AML3D's ARCEMY X operational at US Navy supplier Cogitic

AML3D Limited, headquartered in Edinburgh, Australia, has announced that the industrial-scale ARCEMY X-Edition 6700 Wire Arc Directed Energy Deposition (DED) Additive Manufacturing machine ordered by Cogitic, Colorado Springs, Colorado, USA, is now fully operational. The testing and installation of the AU $2.5 million (US $1.6 million) ARCEMY X was completed in June 2024, with final commissioning late July 2024.

Cogitic is a supplier of components to the US Navy's Submarine Industrial base and specialises in complex parts and assemblies that are integral to 'cannot-fail' applications for critical marine defence and defence-related industries.

AML3D Managing Director Sean Ebert said, "The successful commissioning of this Cogitic ARCEMY X system advances a key objective of AML3D's US scale-up strategy, embedding our WAM technology in the supply chains for the US defence industry and, in particular, US Navy's submarine industrial base. AML3D recently established a US Headquarters and manufacturing hub, in Ohio, to maximise opportunities for ARCEMY system and component manufacturing and testing sales to the US defence sector.

"AML3D's US scale-up strategy includes expanding beyond the US defence sector to supply advanced manufacturing and metal 3D printing solutions to US based, global Tier 1 Oil and gas, marine and aerospace companies.

"Alongside supporting the US defence sector, Cogitic is also a key supplier to other industries," Ebert continued. "AML3D is keen to build on its existing commercial relationship with Cogitic to explore the provision of AML3D's advanced manufacturing solutions to the benefit of Cogitic's broader client base, as we advanced our strategy to support Tier 1 US corporates."

www.aml3d.com
www.cogitic.net

An ARCEMY X 6700 machine is now installed and operational at Cogitic (Courtesy AML3D Limited)

Ursa Major to establish $14.5 million R&D centre for Additive Manufacturing

Ursa Major Technologies Inc, located in Berthoud, Colorado, USA, is establishing a new $14.5 million research and development centre in Youngstown, Ohio. The R&D centre will focus on advancing Additive Manufacturing and materials development technology for liquid rocket engines and solid rocket motors.

Ursa Major is establishing a new R&D centre for Additive Manufacturing and materials development in Youngstown, Ohio (Courtesy Ursa Major)

Liquid rocket engines and solid rocket motors power platforms used for high-performance munitions, hypersonic weapons, in-space propulsion systems, and space launches, are seen as essential for America's security. Ursa Major said it is expanding its R&D efforts to meet a rapidly growing portfolio of US Department of Defense development contracts.

The new R&D centre, located in Boardman, will accelerate new material development and qualification processes for Additive Manufacturing in aerospace applications. This includes developing metallic alloys for solid rocket motors and copper and nickel alloys for liquid rocket engines. The centre will be home to multiple Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing machines.

"The new R&D centre in Youngstown takes advantage of Ohio's manufacturing heritage and uniquely skilled workforce to advance manufacturing in service to our national security," said Ursa Major CEO Joe Laurienti. "Raw material access, supply chain, and a vibrant Additive Manufacturing ecosystem as a result of the America Makes programme make Youngstown an ideal home for this centre."

The capital investment includes $4 million in assistance in the form of a JobsOhio R&D Grant. Ursa Major worked closely with JobsOhio Network partner Team NEO to secure funding for the expansion, which will be in the new Lake to River region.

JobsOhio President and CEO J P Nauseef added, "Ursa Major's R&D centre plans in the Mahoning Valley represent Ohio's strong aerospace and manufacturing legacy and how this state is driving the future of how things are made in America and worldwide. Innovation from Mahoning County is rapidly advancing Additive Manufacturing technology, and Ursa Major's investment is an example of how that attracts extraordinary companies."

www.ursamajor.com

Manuevo acquires assets of Shapeways BV

Manuevo BV, based in Eindhoven, has acquired the assets of Shapeways BV, a subsidiary of US-based Shapeways Holdings Inc, which ceased operations and filed for bankruptcy in July 2024.

Manuevo was founded by the local management team in collaboration with two former Shapeways co-founders and has raised financing for a restart. The company intends to mainly focus on B2B customers who need small and medium series of additively manufactured and finished products.

Jules Witte, former Plant Manager at Shapeways BV and currently COO of Manuevo, said, "The Eindhoven team has been delivering high-quality parts with personal service for many years, and our customers have missed this service over the past month. Supported by the intention of many of our customers to return, we are pleased that we can make a restart; the unanimously positive responses from our regular customers are heartwarming. The team is particularly motivated to show that we can be independently successful."

Manuevo BV aims to provide flexible on-demand Additive Manufacturing service and end-to-end production solution, from prototypes to finished parts. With local production, design advice, and quality control based in Eindhoven, and forty strategic partners in the supply chain, Manuevo states that it can efficiently scale with customer demand. The company operates according to ISO:9001, IATF 16949, and ISO 14001 standards.

www.manuevo.com

MX3D expands facility for large-scale DED parts and high-value production

MX3D, based in Amsterdam, the Netherlands, reports that it has significantly expanded its in-house part production capacity.

By doubling its facility and adding several large-scale metal Additive Manufacturing machines, MX3D intends to be the 'go-to partner' for large-scale Directed Energy Deposition (DED) parts and high-value series production.

The company supplies its M1 and MX metal Additive Manufacturing machines and MetalXL workflow software to industry.

www.mx3d.com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Molymet invests in plasma atomisation technology for rhenium and molybdenum powders

Molymet, headquartered in San Bernardo, Chile, reports it has acquired plasma atomisation equipment to enable the production of highly spherical powders of rhenium, molybdenum, and their alloys, all specifically designed for industrial applications.

The spherical powders produced through this process are intended for various advanced manufacturing technologies, including Additive Manufacturing, Metal Injection Moulding, Thermal Spray, and Hot Isostatic Pressing. These methods, state Molymet, allow users to benefit from enhanced flowability, purity, and density and support the creation of complex parts with lower production costs and processing time.

"We are excited to launch Molymet 3D metal powders. These powders, created through a spheroidisation process, will meet the growing demand of industries that require high-performance materials," stated Mario Lama, Market Development Executive Manager at Molymet.

"As the world's largest Rhenium producer, Molymet is committed to responsibly responding to market trends. The targeted markets are expanding, and we are particularly enthusiastic about the applications in the medical, aerospace, and high-end jewellery industries," Lama added.

The plasma spheroidisation system, which has completed its trial phase at MolymetNos' facilities, is now operational. The system is reported to be transforming the company's capabilities, reinforcing its position as the world's leader in rhenium and molybdenum processing.

Molymet has acquired plasma atomisation equipment to enable the production of highly spherical rhenium, molybdenum and related alloy powders (Courtesy Molymet)

Edgardo Cisternas, Research and Development Manager at Molymet, added, "Our new plasma atomisation equipment positions us at the forefront of technological innovation in Additive Manufacturing, meeting the high-performance material demands of our growing markets."

www.molymet.com

IRPD launches its ‘Swiss-made’ PBF-LB machine, IMPACT 4530

IRPD, a member of the United Grinding Group based in St Gallen, Switzerland, has debuted its IMPACT 4530 Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing machine.

The IMPACT 4530 features a 450 x 300 mm build chamber, enabling the production of components up to 400 mm high. The machine functions with either two or four 1,000 W lasers. The IMPACT 4530, states the company, is the first metal AM machine developed under the 'Made in Switzerland' banner.

"The fact that this success has been achieved in little St Gallen of all places may surprise some, but it is no coincidence," said Stefan Lang, CEO of IRPD. The release of the IMPACT 4530 is built on thirty years of experience in Additive Manufacturing; close links with universities such as ETH Zurich; and the United Grinding Group's over 100 years of experience in the manufacture of grinding, eroding, laser, and measuring machines with the long-established brands Mägerle Blohm, Jung, Studer, Schaudt, Mikrosa, Walter and Ewag.

"Industrial production places particularly high demands on an additive machine tool for metal components, and the IMPACT 4530 meets these demands," explained Dr Kai Gutknecht, Head of Process and Software Engineering at IRPD. "The decisive factor is that we can control the entire Additive Manufacturing process in the IMPACT 4530 in a reproducible and documentable manner and achieve a reliably high production quality as a result."

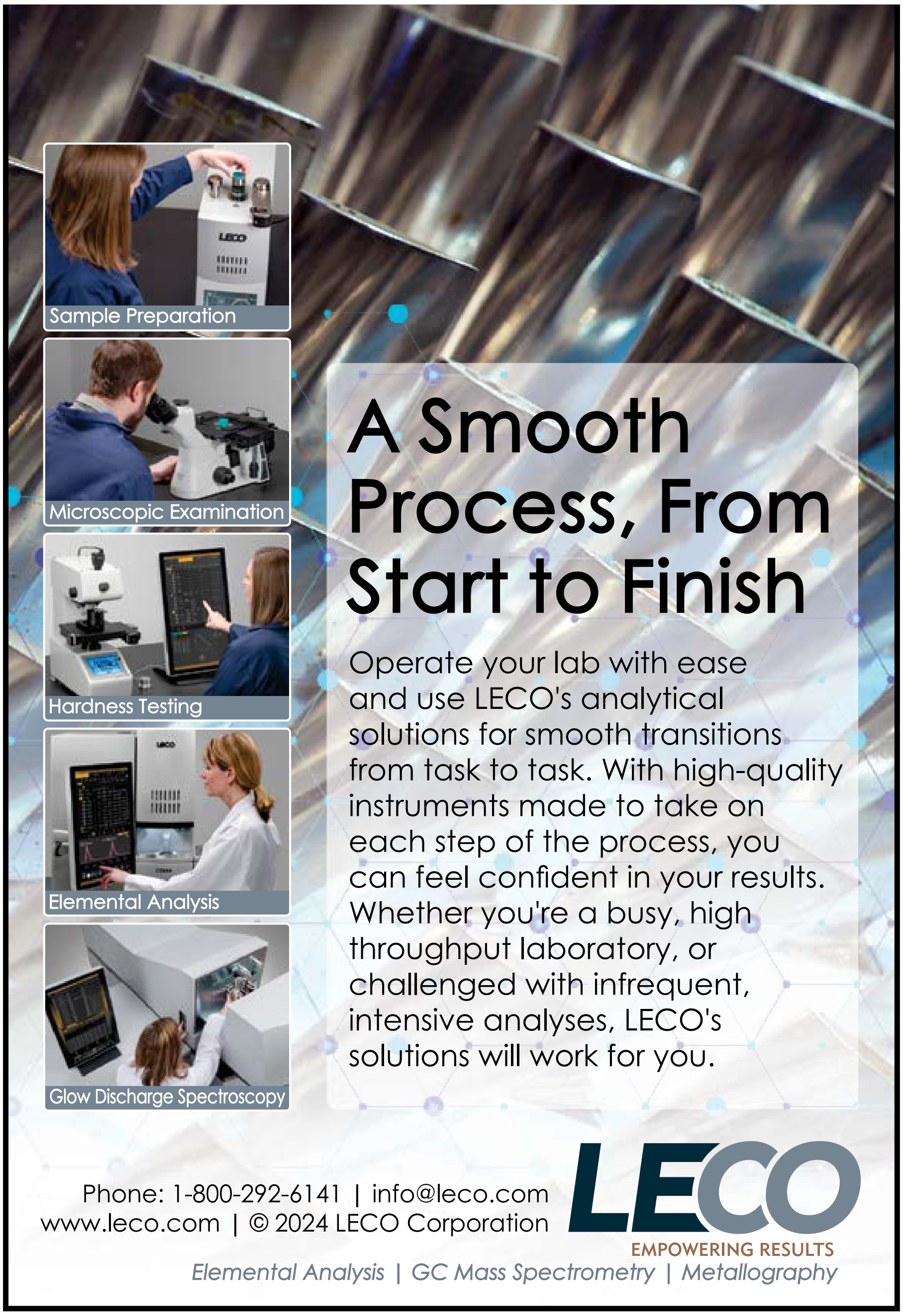
IRPD stated that short changeover times when switching between materials, very low maintenance requirements, and long service life meet the requirements of industrial customers looking for an Additive Manufacturing machine.

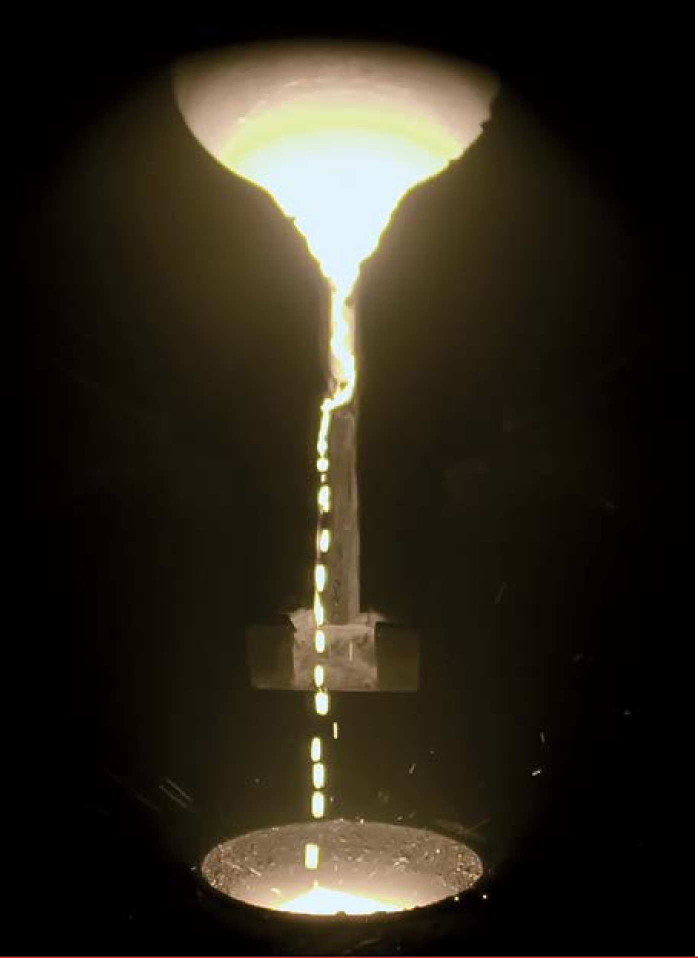
This is made possible by the system design, which features a thermo-stabilised machine core and vacuum-capable process chamber. The latter is a robust cast component with very high rigidity and hermetic sealing. Modern sensors and cameras record the process in real-time.

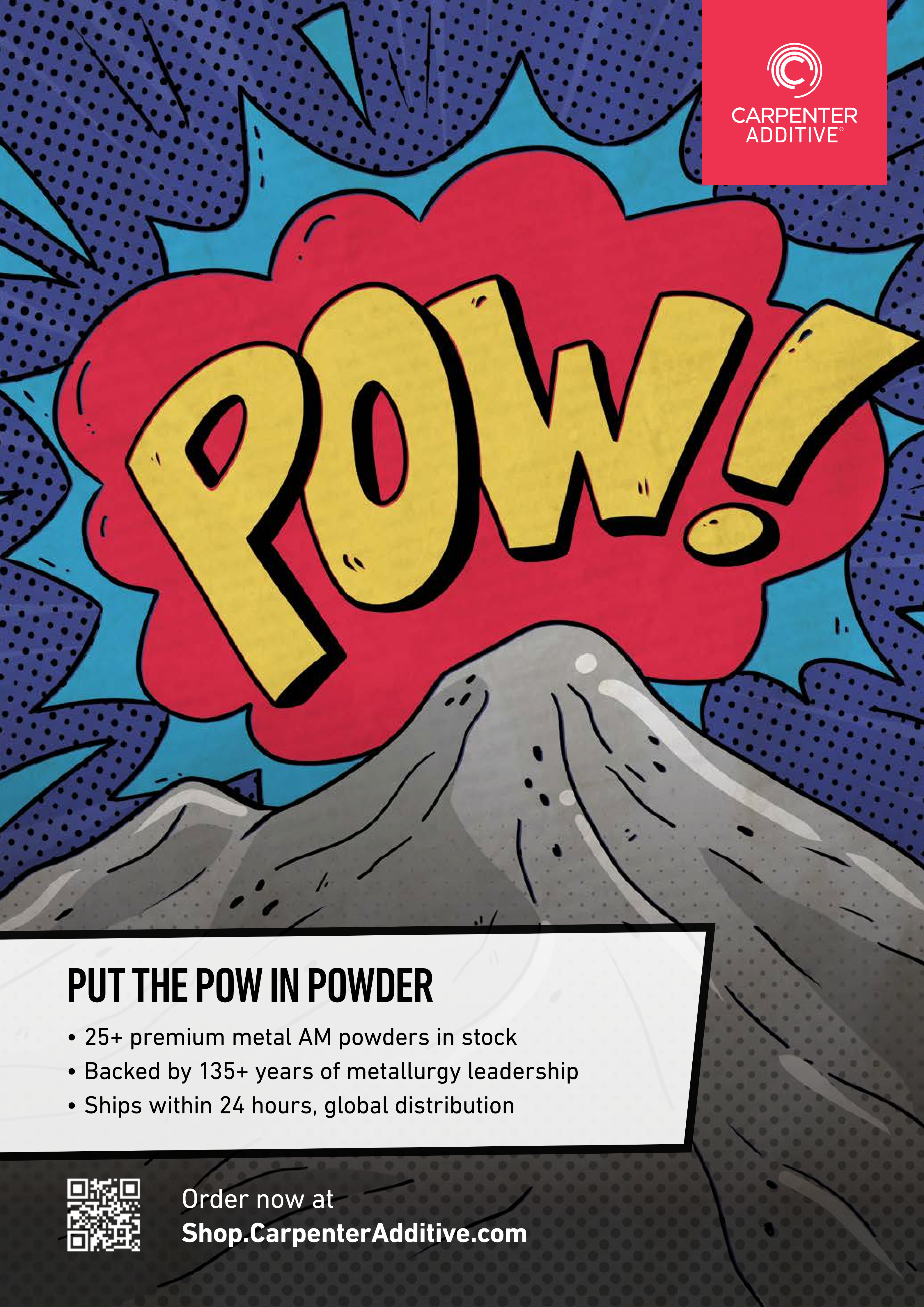
The 137 cm display on the machine gives the user a virtual view of the work process inside the chamber with all relevant data. The IMPACT 4530 is also equipped with CORE, the hardware and software architecture for machine tools from the United Grinding Group. The 61 cm control panel allows the operator to operate the machine without programming knowledge.

"The machine has already proven itself in the contract manufacturing of high-quality individual parts and for component production within the United Grinding and I am very pleased that we are now starting the sales phase with selected industrial customers," concluded Stefan Lang.

www.irpd.ch



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Eplus3D names Hi-Tec Group as Mexican sales partner

Eplus3D, based in Hangzhou, China, has announced a new partnership with Hi-Tec Group, an industrial equipment supplier in Mexico. Under the agreement, Hi-Tec will offer Eplus3D's metal Additive Manufacturing machines to customers in the region.

In addition to leveraging Hi-Tec Group's three-decades of experience in advancing sectors such as aerospace, aviation, energy, oil and gas, automotive, tools, healthcare, consumer goods, and precision manufacturing, this partnership with Eplus3D looks to spearhead the use of Laser Beam Powder Bed Fusion (PBF-LB) AM in the Mexican market.

"The 3D printing of metal powders represents a transformative manufacturing technique," stated Luciano Diorio, CEO of Hi-Tec Group. "It offers a more straightforward and expedient method for the production of enhanced products and the fabrication of components in closer proximity to their intended use. It is the gateway to innovation in design, releasing the imagination and functionality of new parts and spare parts."

www.grupohitec.com
www.eplus3d.com

Desktop Metal qualifies 100% recycled Ni superalloy from Continuum

Desktop Metal has announced that it has qualified Mar-M247 powder, a 100% recycled nickel-based superalloy from Continuum Powders, for use in its X25Pro Binder Jetting (BJT) Additive Manufacturing machine. The nickel-based superalloy is used for applications requiring high strength at elevated temperatures of up to around 1,000°C.

"We see a bright future for high-quality, sustainable powder options for our Additive manufacturing technologies," said Ric Fulop, CEO of Desktop Metal. "Having a qualified 100% reclaimed metal powder from Continuum Powders is just a first step in what we hope is a long line of recycled, eco-conscious materials that offer a significant return on investment."

Continuum's recycled Mar-M247 received thorough evaluation and rigorous testing to determine that it met all of the material property requirements of the same alloy from conventional metal powder production.

"The fact that we're seeing reclaimed metal powders validated by Desktop Metal, along with other leading AM OEMs, signals that these materials are now a proven resource for manufacturers," added Continuum Powders' CEO Rob Higby.

www.desktopmetal.com
www.continuumpowders.com

3D Lab secures US patent for ultrasonic metal atomisation technology

3D Lab sp zoo, based in Warsaw, Poland, has been granted a US patent for its "Method and Device for Producing Heavy Metal Powders by Ultrasonic Atomization." This new patent further strengthens 3D Lab's growing IP portfolio and highlights its ultrasonic metal atomisation capabilities. This US patent is the latest success in a series of submitted patent applications, and follows the recent Chinese Patent granted for metal powder production technology.

The patented technology is at the core of the company's ATO series of ultrasonic metal atomisers. This technology produces high-quality spherical metal powders with precise control over particle size, excellent flowability, and low oxygen content. These characteristics are critical for Additive Manufacturing and various industrial applications.

"We are proud to add this USA patent to our rapidly growing portfolio of global intellectual property. Our patented technologies drive our mission to provide advanced and versatile solutions for metal powder production, ensuring superior material quality and accelerating material innovations. This patent is a significant milestone in our journey, reflecting the dedication and innovative spirit of our team," shared Jakub Rozpendowski CEO of 3D Lab.

The company produces both the ATO Lab Plus and ATO Noble ultrasonic metal atomisers, designed for lab-scale production of metal powders. The ATO Lab Plus is designed for reactive and non-reactive metals, whereas the ATO Noble is geared towards the precious metals market. Both are reported to be ideal for research and production environments, enabling the efficient and cost-effective production of metal powders.

www.metalatomizer.com

The patented technology is at the core of ATO's ultrasonic metal atomisers (Courtesy 3D Lab)


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China sees surge in metal AM machine shipments, while polymer machine sales decline

Market intelligence and analytics company Context, headquartered in London, UK, has reported that global Additive Manufacturing machine shipments started the year at similar numbers to what was seen in the end of 2023. In Q1 24, industrial metal Additive Manufacturing machine shipments increased in China, while industrial polymer shipments faced challenges in all regions.

"Regional moods were divided amongst Chinese vendors – particularly those engaged in the industrial metal Powder Bed Fusion side of the industry – who were elated by their strong domestic demand, while Western vendors noted continued end-market challenges associated with low CapEx spending due to high interest rates and sticky inflation," said Chris Connery, global VP of analysis at Context.

"In the US and across Europe, the news was not all negative however, with many vendors reporting strong demand from domestic defence markets in the period."

Industrial machines

In the first quarter of 2024, global shipments of all industrial-grade AM machines decreased by 15%; on a trailing twelve-month basis, they were down by 8%, according to the latest market insights from Context.

Polymer and metal machines together made up 96% of all industrial AM machine shipments during this period, with polymers accounting for 50% of the total shipments and metals accounting for 46%. Weak industrial polymer shipments were the main factor contributing to the overall decline in performance, with a 29% decrease in shipments compared to the previous year. In contrast, global industrial metal machine shipments increased by 10%. Looking at the trailing-twelve-month basis, worldwide industrial polymer machine shipments have decreased by 16%, while industrial metal shipments have increased by 4%.

Industrial metal machines

Shipments for industrial metal Additive Manufacturing machines across the globe in all modalities were up 10% year-over-year in the first quarter of 2024, with shipments for metal Powder Bed Fusion (PBF) machines — which accounted for the largest percentage of AM machines at 74% — up 7% from a year ago. Shipments of all metal modalities were up in the period with the exception of Material Jetting, with Directed Energy Deposition (DED) shipment up 21%, Material Extrusion (MEX) up 32%, and Binder Jetting up 15%.

Demand for industrial metal Powder Bed Fusion was particularly strong in China, with shipments from Chinese vendors up 45% in the period, while shipments of metal PBF machines from Western vendors were down 4% from a year ago. Chinese vendors have seen year-over-year quarterly shipments grow the last four consecutive quarters, while Western vendors have seen four consecutive quarters of declining shipments.

Four of the top five global vendors for industrial metal Powder Bed Fusion AM machine shipments in the period (Eplus3D, BLT, ZRapid Tech and Farsoon) were headquartered in China, with Eplus3D leading the industry in the period. Vendors focused on the West continue to lead in System Revenue contribution, with Nikon SLM Solutions and EOS enjoying the top market share positions in metal PBF machine revenues in the period. Nikon SLM Solutions was particularly notable as the leader in large form-factor, multi-laser machines.

Outlook

"Talks of industry consolidation dominated the recent conversations in the West, highlighted by Nano Dimension's planned acquisition of Desktop Metal," said Connery. "Ongoing merger and acquisition rumours persist in the US and Europe, with several publicly traded companies under strategic review. In contrast, Chinese companies continue to thrive domestically and focus on expanding their overseas business."

Western forecasts remain conservative, but strong Chinese demand — especially for metal Powder Bed Fusion solutions — has led to a revised global industrial AM machine shipment forecast, now projected to rise by 7% in 2024. Western defence sector demand from companies like Nexa3D and Velo3D also supports this increase.

"Accelerated growth in the industrial price class is anticipated in 2025 and beyond as the US and Europe stabilise post-election cycles and interest rates drop," Connery continued.

"While system vendors remain focused on further advancing Additive Manufacturing into mainstream manufacturing, many strategic growth initiatives are now starting to also incorporate other digital production technologies beyond just additive into their portfolios, as a way to accelerate growth."

www.contextworld.com

GE Aerospace announces $1B+ investment in global MRO and component repair facilities

GE Aerospace has announced plans to invest more than $1 billion over five years in its Maintenance, Repair and Overhaul (MRO) and component repair facilities worldwide. Thee investments are intended to help GE Aerospace create capacity to meet growth in both the widebody and narrowbody installed base by adding additional engine test cells and equipment. The funding will also add technology, including enhanced inspection techniques, to reduce turnaround times for customers as well as expand component repair capability within its overhaul shops.

"Our customers are experiencing strong air travel demand, and we are investing to increase our capacity and efficiency so we can meet their growing needs and keep their planes flying safely and reliably," stated Russell Stokes, GE Aerospace President and CEO, Commercial Engines and Services.

"With this major investment, we are reinforcing our longstanding focus on safety, quality, and delivery for our customers and the flying public."

The largest portion of the investment will support growing demand for CFM LEAP engines — which power Airbus A320neos, the Boeing 737 MAXs, and the COMAC C919s — as the fleet continues to mature and expand. Currently, there are more than 3,300 LEAP-powered aircraft in service and over 10,000 additional engines currently in backlog, increasing the global commercial airline fleet by thousands of planes in the coming years.

Many of these investments are being made as the result of employees working to improve safety, quality, delivery and cost through Flight Deck, GE Aerospace's proprietary lean operating model.

Global MRO investments to support customers across engine portfolio

A major part of the MRO funding this year will support the construction of a new Service Technology Acceleration Center (STAC) near Cincinnati, Ohio, USA. Scheduled to open in September 2024, STAC is intended to help accelerate the deployment of advanced service approaches, including inspection technologies that detect emerging issues sooner and reduce downtime for customers.

In total, GE Aerospace regional repair and overhaul facilities across the globe will receive $250 million in 2024 of the $1 billion planned five-year investment to help fund facility expansion, new machines, tooling, and safety enhancements, including:

- United States: ~$65 million Cincinnati, Ohio; McAllen and Dallas, Texas; Lafayette, Indiana; Winfield, Kansas

GE Aerospace plans to invest more than $1 billion in its Maintenance, Repair and Overhaul (MRO) and component repair facilities worldwide, with one focus being on the CFM LEAP engine, widely known for its use of fuel nozzles produced by Additive Manufacturing (Courtesy CFM)

- South America: ~$55 million Petropolis, Brazil
- Europe and Middle East: ~$60 milliion Budapest, Hungary; Prestwick, Scotland; London, England; Cardiff, Wales; Wroclaw, Poland; Doha, Qatar; Dubai, United Arab Emirates
- Asia Pacific: ~$45 million Singapore; Taipei, Taiwan; Kuala Lumpur, Malaysia; Seoul, South Korea

www.geaerospace.com

NY Ventures invests $1M in PostProcess Technologies' Series C funding

NY Ventures, a programme of Empire State Development, has placed its fourth investment in PostProcess Technologies Inc, Buffalo, New York. NY Ventures' decision to make an additional investment in PostProcess Technologies is said to reflect its commitment to fostering technological innovation and driving economic growth within the state of New York.

By supporting companies like PostProcess Technologies, NY Ventures hopes to cultivate a thriving ecosystem of entrepreneurship and industry leadership in advanced manufacturing.

PostProcess Technologies plans to use the Series C funding to enhance its product offerings, expand its market reach, and continue to build the infrastructure to rapidly scale the company. The additional investment from NY Ventures will play a pivotal role in propelling the company towards its strategic objectives.

NY Ventures has placed its fourth investment in PostProcess Technologies (Courtesy PostProcess Technologies)

Empire State Development Commissioner Hope Knight said, "We are excited to support the continued growth of Post Process in Buffalo, a company that is helping to advance Additive Manufacturing into mainstream production. It is companies like Post Process that are helping to reshape the future of Western NY as a hub of innovation. NY Ventures is among one of many programmes that ESD has to offer to provide support to innovative companies across the state."

"We are thrilled with the continued support of NY Ventures as we enter this exciting phase of growth," added Jeff Mize, CEO of PostProcess Technologies. "This investment underscores the significance of our technology in revolutionising the Additive Manufacturing landscape. It will allow us to continue to attract the best & brightest talent and capitalise on new opportunities to drive innovation at an accelerated pace."

www.postprocess.com

Ermaksan introduces Enavision 150 Dual metal Additive Manufacturing machine

Ermaksan Additive, based in Nilüfer, Bursa, Türkiye, has announced the launch of its Enavision 150 Dual, a metal Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing machine designed to meet the precision and productivity demands of the dental industry.

Equipped with dual 300W fibre lasers, the Enavision 150 Dual delivers up to 50% faster output when compared to traditional single-laser systems. The 150 mm diameter build platform offers expanded production capacity, allowing for the creation of up to 250 dental crowns per cycle. This will enable dental laboratories to scale their operations efficiently while maintaining the highest standards of quality and precision, explains Ermaksan.

The Enavision 150 Dual is compatible with a wide range of materials, including Ti64, CoCr, S316, 17-4PH, and more, providing versatility for various dental applications. This flexibility allows users to craft intricate, customised designs for everything from crowns and bridges to implant structures, the company stated.

To celebrate the launch, the Enavision 150 Dual is currently available at a special introductory price, offering dental professionals the opportunity to upgrade their technology at a competitive cost.

Ermaksan Additive's new Enavision 150 Dual Additive Manufacturing machine features two 300W fibre lasers (Courtesy Ermaksan Additive)

www.ermaksanadditive.com

Rosotics launches large-scale induction metal AM machine; partners with Siemens

Rosotics, Mesa, Arizona, USA, has launched its large-scale induction heating Additive Manufacturing machine, called Halo. The company has also partnered with Siemens in order to develop – and bring to production – a super heavyweight Additive Manufacturing machine geared toward naval applications. The machine will be supported by Siemens' Sinumerik One CNCs system.

Rosotics' Halo is a large-format metal Additive Manufacturing machine targeting aerospace, naval, and defence applications. The Halo employs a multi-phase electromagnetic process in place of conventional AM energy sources such as lasers. The company's HalOs software controls three electromagnetic induction-based 'Mjolnir' Additive Manufacturing heads to produce near-net shape parts.

It is stated that the Mjolnir head assemblies have the ability to pre-heat, fuse materials at high feed rates, and conduct prolonged thermal cycles, producing net-shape parts with smooth surfaces. Each Halo machine features three Mjolnir heads mounted on freestanding towers with multi-axis gimbals, all developed in-house by Rosotics.

Christian LaRosa, CEO of Rosotics, with one of the company's metal Additive Manufacturing machines (Courtesy Rosotics)

Rosotics notes several benefits of this new technology, such as reduced power and infrastructure requirements. The Halo also features integrated post-processing and claims improved operational safety.

The machine is designed for heavy industrial production applications and for repairing and maintaining existing structures. Halo's 'Reach' configuration offers a 9 m build envelope. It is also advertised as supporting complex geometries and post-build inspection and servicing tasks.

As of launch, the Halo offers compatibility with a range of metals and alloys, including those frequently used in aerospace and naval applications. Additionally, Rosotics has qualified material performance in aluminium, meeting tensile and yield strength standards. A controlled atmosphere System Enclosure that offers an inert environment for more sensitive materials, like titanium, can also be added to the Halo system. The machines are assembled at Falcon Field Airport in Mesa, Arizona.

Working with Siemens, Rosotics intends to directly produce a new private-sector vessel and an autonomous underwater vehicle (AUV) for naval use. A 25 m super-heavyweight platform will carry the Mjolnir build architecture, which is currently used on Rosotics' Halo commercial Additive Manufacturing machines, and will be located near San Diego, California.

"Siemens is excited to join forces with Rosotics in this groundbreaking endeavour," the company stated. "The integration of Sinumerik One with Rosotics' advanced manufacturing system for this effort will create a platform of immense significance, capable of addressing the most complex production challenges in the naval industry."

"We are thrilled to work with Siemens on creating this remarkable architecture; their shared commitments to sustainable manufacturing and deep capabilities in complex kinematics will be paramount drivers of this endeavour," added Rosotics' founder Christian LaRosa. "Their demonstrated heritage in renewable energy speaks volumes to us and we do value it. We each carry optimism."

www.rosotics.com
www.siemens.com

AIM3D receives US and EU patents for its Composite Extrusion Modelling

AIM3D, based in Rostock, Germany, has announced that it has been granted fundamental European and US patents for its compact, decentralised pellet extruder and Material Extrusion (MEX) Additive Manufacturing with high-temperature materials. The US patents also include Fused Deposition Modelling (FDM) AM for high-temperature applications and high-flow hot ends.

"We now believe more than ever in our CEM [Composite Extrusion Modelling] technology," stated Dr-Ing Vincent Morrison, CEO. "The granted patents reflect our impressive achievements in research and development as pioneers in 3D pellet printing. These patents secure our know-how for 3D pellet printers. At the same time, we are open to establishing licencing partnerships."

Since 2017, AIM3D, a spin-off from the University of Rostock, has been consistently focused on pellet-based Additive Manufacturing rather than those that process filaments. Significantly lower material acquisition costs for pellets and the inline recycling of reclaimed material form the basis for the high cost-effectiveness of this AM production strategy. The development work on pellet Additive Manufacturing technology was reflected in four patent applications between 2016 and 2018, which have now been granted in 2023. The patents protect both the topology of the AM extruder as a whole and the detailed technical solutions in the area of pellet processing

Published patents

The patents granted are published as:

- EP3463799B1 (application: May 27, 2016) – 'System for the additive manufacture of metal parts'
- EP3648946B1 (application: June 26, 2018) – 'Compact extruder and extrusion of thermomechanically deformable pellets'
- Patent US11541593B2 (application May 27, 2016) – 'Extruder for a system for the additive manufacture of metal parts using the composite extrusion modelling (CEM) method'
- The US patent US11597118B2 (application: June 26, 2018) – 'Device and method for the extrusion of thermo-mechanically deformable materials in bulk form, and compact screw extruder'

CEM technology's growth potential

The still relatively young CEM Additive Manufacturing machines have found a market alongside the more widespread FDM machines. AIM3D's ExAM 255 and ExAM 510 machines enable the use of standard pellets with or without fillers to produce robust components. This reportedly enables significantly greater cost-effectiveness for the users.

The CEM process enables the use of various materials: hybrid multi-material solutions with different Voxelfill materials and different materials for the contour or the structure of the inner walls are possible. This way, the material properties — component weight, damping properties, elasticity or changes to the centre of gravity — can be customised.

By selectively filling only certain volume chambers (selective densities), the component properties can be influenced in a targeted manner based on FE simulations. With Voxelfill, it is possible to only fill the areas of a component that are absolutely necessary for the flow of forces. As a result, from the outside, these components look like conventional parts, and can further benefit from applying conventional finishing processes, whilst benefitting from lightweighting.

AIM3D has placed around forty industrial Additive Manufacturing machines on the market (Courtesy AIM3D)

The reproducibility of CEM

AIM3D's ExAM 510 machine is aimed at industrial applications, where reproducibility is crucial for the construction of a 3D component. Reproducibility is achieved primarily through the patented pellet extruder technology, which ensures gentle processing of the material and minimises degradation of the polymers in the extruder.

www.aim3d.de

The ExAM 510 is suitable for metals, ceramics and polymers (Courtesy AIM3D GmbH)

Gränges invests in post-processing line for aluminium Additive Manufacturing powders

Gränges Powder Metallurgy SAS, based in Saint-Avold, France, has invested in a new post-processing line used in the production of aluminium powders for Additive Manufacturing. The post-processing line includes ATEX-classified sieving, homogenising and packing equipment in a closed workspace to ensure the highest safety and cleanliness. The line is planned to be fully operational in the first quarter of 2025.

Gränges Powder Metallurgy has been producing high-performance Powder Metallurgy aluminium alloys by inert gas atomisation for over thirty years. The company is mainly known for the Dispal range of low-thermal expansion AlSi alloys, commonly used in the semi-conductor and precision optics industries. As well as Dispal, standard AlSi10Mg powder and customer-specific aluminium alloys are also produced.

"The investment is a step in our ambition to become a leading producer of aluminium AM powders. With the investment, Gränges can supply large quantities of homogeneous, spherical aluminium powders with sharp powder size cuts and processed under inert gas," said Peter Vikner, Managing Director, Gränges Powder Metallurgy. "The dedication to aluminium alloys guarantees cleanliness from cross-contamination with other alloys. It also enables synergies in raw material purchase, in processing and in R&D, ensuring that we have the right capacity, price and quality for the market."

Gränges Powder Metallurgy has invested in a new post-processing line for the production of aluminium powders for AM (Courtesy Gränges Powder Metallurgy)

Gränges Powder Metallurgy is part of the Gränges Group, an organisation dedicated to aluminium with a total net sales in 2023 of MSEK 22,518 and an operating profit of MSEK 1,576 (€1.92 billion and €135 million, respectively). The plant in Saint-Avold, France, is dedicated to aluminium powder production and spray forming with a total capacity of 3,500 metric tonnes per year.

www.granges.com

Interspectral secures investment to advance AI-driven quality assurance

Interspectral, a SaaS provider specialising in AI-driven quality assurance and process monitoring, based in Norrköping, Sweden, has announced a successful investment round led by Navigare Ventures, a prominent Swedish investor in industrial innovation and deep tech, and a wholly-owned subsidiary of Wallenberg Investments. The round also included strong support from existing shareholders, including Skagerack Ventures.

This strategic investment is expected to accelerate the growth and development of Interspectral's digital twin solutions, which aim to transform the landscape of smart manufacturing in Industry 4.0, with a special focus on enhancing metal Additive Manufacturing.

"We are delighted to partner with Interspectral as they continue to lead the way in AI-driven quality assurance and process monitoring for Additive Manufacturing," stated Salla Franzén, Investment Manager at Navigare Ventures. Franzén, who will also join Interspectral's board of directors, brings deep expertise in Artificial Intelligence to the team. "Interspectral's proficiency in developing advanced visualisation tools, AI-based algorithms for automatic error detection and efficient big data management is unparalleled. Together, we can accelerate the adoption of digital twins and revolutionise manufacturing on a global scale."

As the manufacturing industry continues its digital transformation, digital twins are becoming essential tools for optimising production processes. Interspectral utilises advanced visualisation and AI to efficiently review and automatically detect errors in manufactured parts. These innovations are said to be crucial in enabling manufacturers to achieve higher levels of precision, quality, and efficiency in their Additive Manufacturing operations.

The investment will enable Interspectral to scale its operations, expand R&D, and bring its AI-based technologies to the global market. It will also boost the adoption of digital twin solutions, driving Industry 4.0 growth and advancing AM capabilities.

"This investment is a major endorsement of our vision and technology. It will allow us to make significant strides in enhancing the accuracy, efficiency, and scalability of digital manufacturing," added Interspectral's CEO, Isabelle Hachette. "The infusion of capital will allow us to push the boundaries of what's possible with AI and digital twin technology, with the enormous potential for our solutions to redefine manufacturing excellence in metal AM."

www.interspectral.com

RusselSmith partners with SPEE3D to bring Cold Spray Additive Manufacturing to West Africa

SPEE3D, headquartered in Melbourne, Australia, has entered into a strategic partnership with energy solutions provider RusselSmith, based in Lagos, Nigeria. Under the agreement, RusselSmith will become a regional partner and value-added reseller, primarily targeting the West African oil & gas, defence and commercial industries. The company has also purchased a WarpSPEE3D machine in order to act as a Cold Spray AM parts provider.

RusselSmith has also purchased a WarpSPEE3D machine in order to act as a Cold Spray AM parts provider (Courtesy SPEE3D)

"SPEE3D is committed to the growth and development of Additive Manufacturing globally, and we're thrilled to bring our Cold Spray Additive Manufacturing solution to West Africa," said Byron Kennedy, CEO of SPEE3D. "Partnering with RusselSmith is a huge win for us – they are a respected leader bringing the latest Additive Manufacturing technologies to the region and helping solve major supply chain issues for the oil and gas and defence and other commercial industries. Together, we will not only bring the WarpSPEE3D printer to the region, but their support as a value-added reseller will ensure customers will have the sales, support, and training they need for all of our technology."

Nigeria has one of West Africa's most vibrant energy sectors, including oil & gas. However, the industry is challenged with sustaining and maintaining equipment on ageing assets due to supply chain issues and difficulty procuring legacy parts, causing significant operational delays. SPEE3D and RusselSmith intend to fill the gap between needed and available parts by additively manufacturing them locally, helping companies improve their operations and reduce costs.

RusselSmith is currently the only organisation qualified by the Nigerian Upstream Petroleum Regulatory Commission (NUPRC) to deploy industrial non-metallic Additive Manufacturing solutions in the oil & gas industry. RusselSmith was also recently inducted into the Additive Manufacturing Green Trade Association (AMTGA) and is currently the only African member company.

"This partnership enables us to rapidly manufacture high-quality parts on demand, locally and sustainably, leveraging the innovative Cold Spray technology to improve our customers' operational uptime," added Kayode Adeleke, CEO of RusselSmith. "Our focus at RusselSmith is to be Africa's leading provider of advanced digital and deployable Additive Manufacturing solutions for enhancing operational efficiency on the continent, and we aim to achieve that one part at a time."

www.russelsmithgroup.com
www.spee3d.com

Wall Colmonoy acquires thermal spray powder supplier Indurate Alloys Ltd

Wall Colmonoy, headquartered in Madison Heights, Michigan, USA, has announced the acquisition of Indurate Alloys Ltd, a supplier of hardfacing products, located in Edmonton, Alberta, Canada. The acquisition is intended to strengthen Wall Colmonoy's position in the Canadian market and provide customers with a wider range of products and expertise to meet their wear resistance and corrosion protection needs.

Indurate Alloys supplies metallic and carbide powders in HVOF, plasma spray, thermal spray, laser and plasma transferred arc (PTA) forms, as well as wires and electrodes. Indurate also provides Additive Manufacturing powders and collaborates with companies that use the latest AM technologies, including Powder Bed Fusion and Direct Energy Deposition.

Wall Colmonoy stated that it recognises the value of Indurate's established and growing customer base, high-quality thermal spray products, and excellent vendor relationships, which will add new products to complement Wall Colmonoy's portfolio.

"We are excited to welcome the talented Indurate Alloys team to Wall Colmonoy," stated Nicholas Clark, President, Wall Colmonoy. "This strategic acquisition extends our reach into the Canadian marketplace and allows us to better serve our customers across the country."

"Wall Colmonoy stood out as the right partner for us, thanks to its extensive history in the hardfacing industry and its shared commitment to strong customer relationships," said Lorne Chrystal, Founder & CEO of Indurate Alloys Ltd. "We are excited to merge the expertise and experience of both companies and eagerly anticipate expanding opportunities together."

www.induratealloys.com
www.wallcolmonoy.com

Desktop Metal announces first sale of PureSinter Furnace to AmPd Labs

Desktop Metal, Inc, headquartered in Burlington, Massachusetts, USA, has announced that AmPd Labs, based in Houston, Texas, USA, is the first company to place an order for its new PureSinter Furnace, a vacuum furnace developed for debinding and sintering in Binder Jetting (BJT) and Metal Injection Moulding (MIM) processes.

AmPd Labs offers a range of AM services, from design and prototyping to full-scale production. In addition to Desktop Metal's Binder Jetting technology, AmPd Labs offers other AM and traditional manufacturing technologies for metal and polymer part production.

"We are thrilled to add the Pure Sinter Furnace to our fleet of Desktop Metal equipment," stated Sean Harkins, COO & co-founder of AmPd Labs. "Pure Sinter is a technological game changer that will enable us to rapidly meet high-volume customer production demands."

Ric Fulop, Founder and CEO of Desktop Metal, stated, "AmPd Labs is one of our standout Super Fleet customers with three or more of our laser-free metal printers, and we're delighted to see them embrace our breakthrough new furnace technology. PureSinter is an exemplary demonstration of the innovation for which Desktop Metal and our engineers are known. We believe this furnace will revolutionise sinter-based AM and the traditional furnace industry."

The recently launched PureSinter furnace is reported to be designed from the ground up to eliminate traditional furnace challenges with an all-new, patent-pending approach. PureSinter features hot walls that prevent contamination buildup and an airtight processing environment to ensure efficient waste exit and the highest levels of purity.

www.ampdlabs.com
www.desktopmetal.com

Desktop Metal's PureSinter furnace is suitable for the debinding and sintering of Binder Jetting parts as well as MIM and PM parts (Courtesy Desktop Metal)

Copper Additive Manufacturing investigated for optimised synchrotron absorbers

The Science Technology Facilities Council's (STFC) UK Astronomy Technology Centre (UK ATC), Edinburgh, and the UK's National Synchrotron Diamond Light Source (DLS), Didcot, have collaborated with the University of Wolverhampton, UK, and university research spin-out Additive Analytics, to investigate the use of copper Additive Manufacturing for synchrotron absorbers.

Copper, known for its desired thermal and electrical properties, is critical in numerous applications, especially in the era of net zero, electrified transportation and green manufacturing. However, its laser processing challenges have hindered its widespread adoption in metal Additive Manufacturing technologies such as Laser Beam Powder Bed Fusion (PBF-LB).

The University of Wolverhampton's Centre for Engineering Innovation and Research (CEIR) and Additive Manufacturing research group have many years of experience in PBF-LB material and process development. In 1999, the university was the first UK institution to install a metal PBF-LB machine.

Utilising the manufacturing freedom offered through its EOS M290 AM machine, the original synchrotron absorber part was redesigned to include conformal cooling channels and gyroid structures for passive cooling and lightweighting. Multiple design adjustments for function and Additive Manufacturing are promising for increased thermal dissipation, reduced material weight and the potential for shorter absorber components.

While further research and testing are still planned for this project, initial prototype simulations show a maximum temperature drop of around 20%, a mass reduction of around 80% and part consolidation from 21 parts to 1. Around 30,000 accelerators and 60 synchrotrons worldwide push the limits of science and could benefit from heritage component redesign using AM.

The thermal performance of the prototypes and associated metrology will be discussed in an upcoming publication.

Professor Arun Arjunan, director of the university's Elite Centre for Manufacturing Skills (ECMS) and Centre for Engineering Innovation and Research (CEIR) shared, "Working with the STFC, UK ATC and Diamond Light Source optimising their synchrotron absorbers using copper 3D printing techniques highlights the potential of Additive Manufacturing and thermal management. By combining our expertise in advanced materials and 3D printing technologies, we will continue to develop innovative solutions that meet the growing demand for efficient thermal management systems across various industries."

www.wlv.ac.uk
www.ukatc.stfc.ac.uk
www.diamond.ac.uk

The synchrotron absorber proof of concept designs, seen here and above, were additively manufactured in pure copper (Courtesy Diamond Light Source/University of Wolverhampton)

The University of Wolverhampton, the UK's Astronomy Technology Centre, and Diamond Light Source, have investigated the use of copper Additive Manufacturing for synchrotron absorbers (Courtesy Diamond Light Source/University of Wolverhampton)

The French Navy validates Meltio's Additive Manufacturing technology

The French Navy is reported to have validated the use of Meltio's Direct Energy Deposition (DED) Additive Manufacturing technology during military manoeuvres carried out in May. The Navy used Meltio's wire-based Directed Energy Deposition (DED) metal AM machine on an experimental basis, after passing adoption tests of the company's AM technology.

It was reported that the French aircraft carrier, Charles de Gaulle, had been experimentally using the Meltio AM machine as part of the Ursa Minor exercise – a high-intensity operational maintenance naval exercise organised by the Fleet Support Service (FSS). As part of the exercise, a special breakdown repair experiment was carried out in the workshops of the French Navy's logistics department in Toulon. Meltio's machine is installed on shore at the Toulon arsenal and was receiving requests for the manufacture and repair of metal parts from the aircraft carrier.

"We are at a point of overcoming technological tests of the Meltio metal 3D printer for the French Navy. Its state of use is experimental. The French Navy is using this Meltio machine on land," stated Jean-Marc Quenez, director of Innovation and Additive Manufacturing at the Service de Soutien de la Flotte (SSF) of the French Ministry of Defense.

"The machine is installed at our naval base, the Arsenal, located in the city of Toulon. After months of preliminary tests at our technology centre in Toulouse, south of France, to test Meltio's wire-laser DED technology, the transfer of the printer to Toulon was approved. The main objective of this transfer is to respond to the Navy ships that are sailing with their repair and manufacturing needs in different metallic materials, mainly stainless steels and Inconel, for which Meltio's Additive Manufacturing system is very efficient in the result of the parts obtained," continued Quenez.

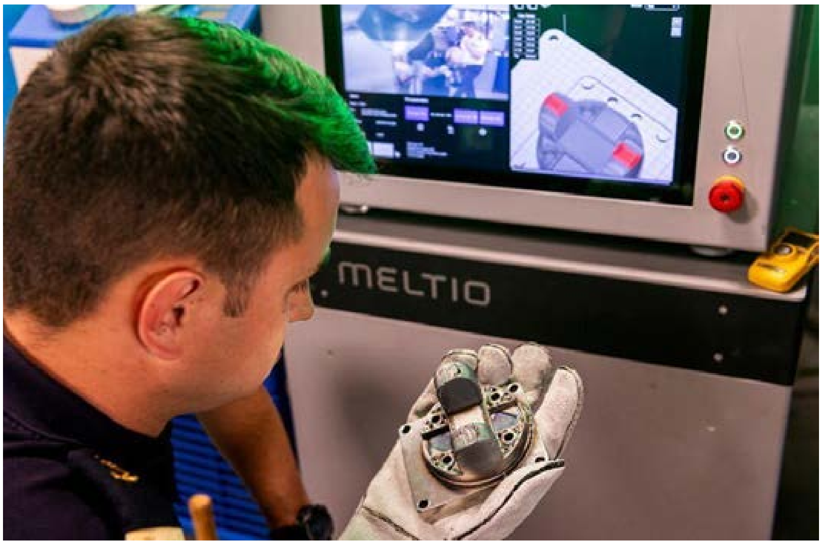
"We chose Meltio for this exercise because it allows us to repair existing metal parts and with this machine, we manufacture test parts with DED technology, not final parts that we then post-process and machine according to our needs. The Spanish brand's metal 3D printer meets our expectations for reliability and is very easy to use by our engineers. We anticipate that this metal 3D printer will continue to be functional and will be part of our experimental Additive Manufacturing usage programme that continues to evolve," he added.

The French Navy is said to already be considering including the technology in upcoming real-life manoeuvres, and may incorporate it on board ships in its fleet in the future.

The announcement marks the third approval of Meltio's metal Additive Manufacturing for the defence sector, with France joining the US Navy (which hosts a Meltio machine aboard a military vessel) and the Spanish Army (which is using the technology for the manufacture and repair of metal parts).

Meltio's hardware, metallic materials and software have passed various technological tests worldwide, allowing the company to become a strategic partner capable of meeting the high demands of different armies around the world with its Additive Manufacturing technology. Currently, armies in other countries are said to be in the process of validating Meltio's AM technology.

www.meltio3d.com



Meltio's metal AM machine was used by the French Navy (Courtesy Marie Bailly, French Navy / Defense, and Jeremy Vacelet, French Navy)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vdm@acerinox.com
www.vdm-metals.com

ASTRO America issues plan for Guam Additive Materials & Manufacturing Accelerator

The Applied Science & Technology Research Organization of America (ASTRO America), Bethesda, Maryland, USA, has announced the Guam Additive Materials & Manufacturing Accelerator (GAMMA) plan. GAMMA is based on three pillars – workforce development and education; component testing and evaluation; and manufacturing business incubation/support on-island.

The corresponding report was developed at the direction of the Guam Bureau of Statistics and Plans (BSP), following ASTRO's previous feasibility analysis undertaken for the Guam Economic Development Authority. Overall, it reflects an initiative by Governor Lourdes A Leon Guerrero over the last two years to evaluate the potential for industrial Additive Manufacturing to advance economic growth in Guam.

"I strongly believe GAMMA can revolutionise Guam's economy, and establish the island as a part-manufacturing hub in the Indo-Pacific region," shared ASTRO President Neal Orringer. "ASTRO America stands committed to helping realise Governor Leon Guerrero's vision, and chart a course for the island's future in on-demand production."

The report stresses that GAMMA's two principal goals should be promoting US national security and helping diversify the economy, in partnership with the federal government. In particular, Guam offers an opportunity to support the readiness and resilience of key American and allied submarine supply chains. Accordingly, the project plan would establish GAMMA as a proponent of the US Navy's Program Executive Office Strategic Submarines (PEO SSBN), which is responsible for US strategic submarines' lifecycle management as well as advancing submarine industrial base health.

GAMMA will thus help drive the development of submarine industrial base capabilities in the Indo-Pacific region, supporting the needs of the United States as well as the UK and Australia in sustaining a technological edge in submarine construction, particularly relative to the military's peer competitors in the region.

The new report explains the project plan jointly announced by Governor Leon Guerrero and PEO SSBN's RADM Scott Pappano in February 2024.

At the outset, the US Navy will serve as the primary customer and funding source for GAMMA, which will encompass a site for workforce training and education, naval ships' part testing and evaluation, as well as prototyping and supply chain maturation. The new infrastructure will provide training and production capabilities on-island that, over the long-term, may also be applied to a broad range of commercial (non-naval) industries across the Indo-Pacific.

The cornerstone of GAMMA is a satellite campus of a mainland US university in Guam, based on the grounds of the University of Guam and Guam Community College entering an agreement with another academic institution reportedly renowned for its leadership in manufacturing education and technical research. This partnership will support the conferring of joint certifications as well as associates, bachelors, and masters degrees for students on-island from UOG, GCC, and the mainland US institution. Additionally, ASTRO will also support the establishment of the only industrial metallic part inspection and validation laboratory within thousands of miles. The plan calls for a GEDA-sponsored facility to be built on campus to house operations supporting each of the three pillars.

"For two years, ASTRO, commissioned by GEDA and BSP, has grown a body of expertise on developing industrial AM capabilities in Guam," said Governor Leon Guerrero. "As we move toward making GAMMA a reality, we will continue to work with our partners to diversify Guam's economy and establish the island as a centre of excellence for Additive Manufacturing, particularly for the United States Navy's submarine force. I am pleased that so much of our island's talent and expertise is being utilised to create new job opportunities for Guam and contribute to America's national security interests."

www.astroa.org

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- Excellent Sphericity
- High Purity
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JSJW Induction heating and Plasma melting Combined Atomization (IPCA)

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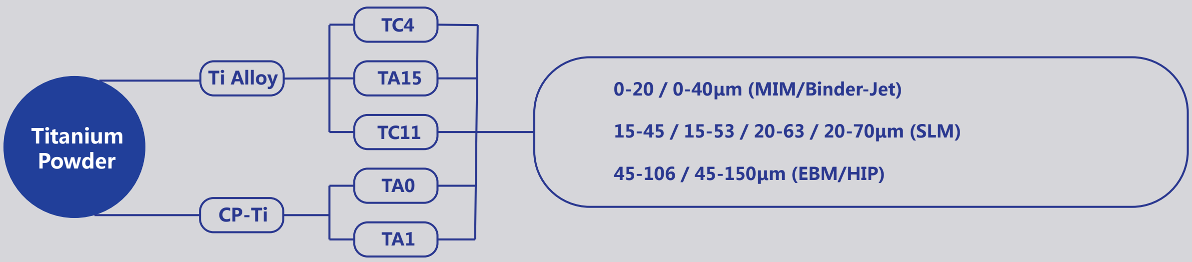
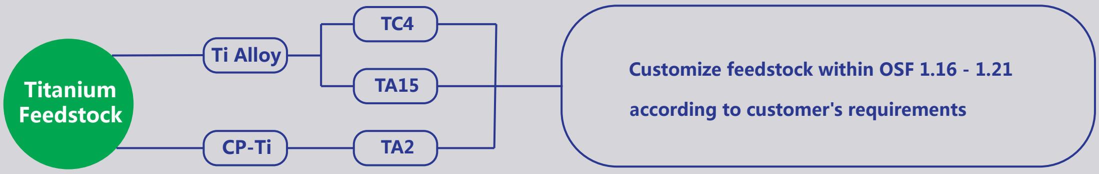
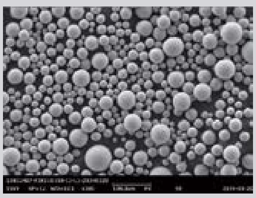
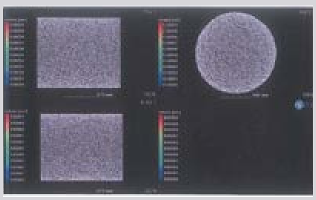


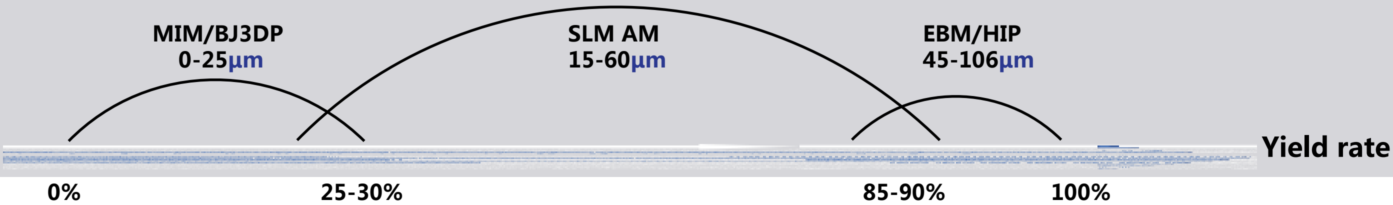
<In addition to the main grades of powders mentioned above, JSJW can also customize the production of multiple grades of titanium alloy powders>







Sample status	Test Temperature	Rm (N/mm^2)	Rp0.2 (N/mm^2)	A (%)	Z (%)	KU2 (J)
Longitudinal annealing	room temperature	1040	998	16.1	56.4	40.0
		1041	998	18.0	57	44.0
Transvers annealing	room temperature	1037	972	15.6	54.8	46.0
		1032	970	15.7	52.9	48.0



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INDO-MIM and HP showcase M2 tool steel for Additive Manufacturing of injection moulding inserts

In a recent webinar hosted by *Metal AM* magazine, Metal Injection Moulding company INDO-MIM, Bengaluru, India, discussed in detail the use of its new M2 tool steel for the Additive Manufacturing of mould inserts. The company is now using Binder Jetting from HP to produce a wide range of tooling.

During the presentation, Harish Irrinki, Sr Applications Engineer and Strategic Account Manager at HP, also provided detailed information on HP's Metal Jet S100 Binder Jetting solution. The Metal Jet S100 has an effective build volume of 430 x 309 x 140 mm and meets MPIF standards for stainless steel with HP Metal Jet SS 316L and HP Metal Jet SS 17-4PH materials. The HP Metal Jet workflow includes a powder management station, the Metal Jet S100 AM machine, a curing station and a powder removal station. Sintering equipment is provided by a third party, giving users the choice of either investing in a furnace or using a toll service for this stage of the process.

INDO-MIM is the world's largest MIM company, with over 3,000 employees producing over 150 million parts annually. Jag Holla, Sr. VP-Marketing at INDO-MIM Ltd, discussed the company's use of Additive Manufacturing to produce mould inserts. Holla talked about how the company began with Laser Beam Powder Bed Fusion (PBF-LB) AM machines but then moved to using Binder Jetting as the preferred production method. This was, in part, due to the speed advantage over PBF-LB, but also enabled the company to use its M2 tool steel powder for the production of mould inserts.

In addition to the design capabilities of AM, such as the inclusion of conformal cooling channels, a key advantage of AM is the speed at which the process can produce the tooling. This can save many weeks, or months, in getting a product to the customer.

Over the last eighteen months, INDO-MIM has produced around 1,800 M2 steel inserts for production use, stated Holla.

Not only is BJT quicker for producing the tooling, it also offers improved properties compared to wrought material. INDO-MIM's M2 shows superior wear and machinability performance, compared to wrought, explained Holla. This can result in a 30-50% tool life improvement, it was stated.

The full webinar can be viewed here: https://bit.ly/3MSTqcs

www.indo-mim.com

www.hp.com

Ensuring safety and reliable oxygen measurement with SIL-capable oxygen analysers

SIL-capable oxygen analysers can play a critical role in ensuring safety and reliable oxygen measurement in metal Additive Manufacturing, explains Process Sensing Technologies (PST), headquartered in Ely, Cambridgeshire, UK. Whether producing aerospace components, automotive parts, or medical devices, manufacturers must manage the significant risks involved in handling reactive materials. The risks of flash fires and explosions make stringent safety measures necessary.

As metal Additive Manufacturing continues to advance, more diverse industries and specialised applications are adopting it; their requirements are the same—safety, reliability, and product quality.

SIL	Risk Reduction
Non-SIL	10
SIL 1	100
SIL 2	1000
SIL 3	10,000

The level of risk reduction achieved with SIL classification (Courtesy Process Sensing Technologies)

In functional safety, Safety Integrity Level (SIL) is defined as the relative level of risk-reduction provided by a Safety Instrumented Function (SIF), i.e. the measurement of the performance required of the SIF. Electric and electronic devices can be certified for use in functional safety applications, according to IEC 61508. There are a number of application-specific standards based on or adapted from IEC 61508, such as IEC 61511 for the process industry sector

The Basic Process Control System (BPCS), alarms, etc., can, at best, only reduce the risk by a factor of 10. Any instrumented system that is reliable enough and required to reduce the risk by a factor of more than 10 automatically falls within SIL regulations. Reducing risk to a 'tolerable' level can be difficult to achieve without including a SIL-rated safety function.

The Ntron SIL02 Oxygen Analyser has been designed to specifically address Additive Manufacturing requirements for a low cost SIL2-rated oxygen analyser for inertisation applications. The complete system (analyser and sensor) meets the requirements of IEC 61508 SIL2. Fast response, high repeatability, and no sensor drift make this analyser a low-maintenance solution that delivers reliable performance for safety-critical process control applications.

The Ntron SIL02 oxygen analyser has been designed for inertisation applications in Additive Manufacturing (Courtesy Process Sensing Technologies)

www.processsensing.com

Malvern Panalytical to acquire Micromeritics

Malvern Panalytical, part of Spectris plc, Egham, Surrey, UK, has agreed to acquire Micromeritics, headquartered in Norcross, Georgia, USA, for $630 million, plus a deferred element of up to $53 million. Micromeritics focuses on analytical instrumentation for the physical characterisation of particles, powders, and porous materials.

With the addition of Micromeritics' suite of analytical technology, Malvern Panalytical aims to provide the broadest material characterisation offering in the market. It will offer a single suite of integrated instruments from a single manufacturer to support the entire customer workflow, thereby improving workflow efficiency and enabling deeper analytical insights. As part of the acquisition, Terry Kelly, president and Chief Executive of Micromeritics, has agreed to join the group as Malvern Panalytical President. Kelly will be a key member of the Spectris Scientific leadership team.

Micromeritics' technologies enable the comprehensive characterisation of particles by detailing their size, count, surface properties and behaviour, for fundamental research, product development and production quality control. "Together, Micromeritics and Malvern Panalytical provide a unique opportunity to create a leading and highly differentiated position and a fully integrated offering in material characterisation," stated Derek Harding, current CFO at Spectris and soon-to-be president of Spectris Scientific. "Micromeritics is an excellent business with a strong track record of growth and innovation and excellent future growth prospects."

"Micromeritics is a world leader in particle characterisation," Terry Kelly added. "Our end markets are strong and growing, and we have a robust new product pipeline. The integration with Malvern Panalytical is powerful. Together our companies will be able to unlock more answers for customers and provide expert applications and technical support that cannot be matched by any other company."

www.malvernpanalytical.com
www.micromeritics.com

NAMI selects multiple AM machines from 3D Systems

3D Systems, Rock Hill, South Carolina, USA, has announced that the National Additive Manufacturing & Innovation Company (NAMI) based in Riyadh, Saudi Arabia, has purchased multiple 3D Systems Additive Manufacturing machines, including the DMP Factory 500 and the DMP Flex 350, to support its collaboration with the Saudi Electricity Company (SEC).

Through this initiative, NAMI will utilise Additive Manufacturing to create a localised supply chain for spare parts for the SEC, reported to be the largest producer and distributor of electrical energy in the Middle East and North Africa. As part of the project, NAMI will create a digital inventory system intended to reduce production time, physical storage requirements and cost.

The combined experience of NAMI and 3D Systems' is expected to help deliver high-performance components such as pump impellers, fuel burners, motor fans, heat sinks, and heat exchangers, while reducing SEC's physical inventory requirements. This will enable SEC to mitigate supply chain risk while lowering costs and driving efficiency.

"Our Additive Manufacturing solutions have demonstrated their value for improving supply chain efficiency and accelerating innovation across a variety of industries," said Reji Puthenveetil, EVP, Additive Solutions and Chief Commercial Officer at 3D Systems. "The combination of reverse engineering designs for obsolete parts and Additive Manufacturing helps extend the uptime and life of equipment. NAMI's engineering and application capabilities combined with the power of our industry-leading 3D printing platforms will be invaluable tools to catalyse the collaboration with SEC. I'm looking forward to seeing how this work will not only benefit SEC but also the services it provides to its customers."

NAMI is a joint venture between 3D Systems and Saudi Arabian Industrial Investments Company (Dussur) to play a pivotal role in realising Saudi Arabia's Vision 2030 to build localised Additive Manufacturing production capabilities with an initial focus on the defence, energy, and manufacturing sectors.

"Since NAMI's inception, we have made significant progress in expanding the use of Additive Manufacturing within the region," added Mohammed Swaidan, Chief Executive Officer, NAMI. "Our collaboration with SEC reinforces our commitment to address the energy sector, and 3D Systems' technology and applications expertise form the foundation of a transformative solution. The work we are doing with SEC will not only enhance the reliability of SEC's supply chain but also drive substantial cost efficiencies and operational improvements."

www.3dsystems.com
www.nami3dp.com

The National Additive Manufacturing & Innovation Company has purchased multiple Additive Manufacturing machines from 3D Systems, including the DMP Factory 500 (left) and the DMP Flex 350 (Courtesy 3D Systems)

ULT introduces LAS 260 H/Ex for extraction of laser dusts

ULT, Löbau, Germany, has announced its LAS 260 H/Ex for removing critical dust during various laser processes. The explosion-proof device was developed for extracting and filtering dry, combustible, and health-endangering pollutants (dust and fumes) that can arise during the laser processing of plastics and metals.

As an ATEX-compliant system designed to be free of ignition sources, the LAS 260 H/Ex is suitable for installation and operation within zone 22 and enables the safe separation of combustible dust. Even the finest particles are separated to 99.995% in a two-stage filter system including a HEPA H-14 filter and safety filter stage.

The safety filter with integrated activated carbon filling ensures the safe operation of the device and removes gases that are hazardous to health. Due to the high level of cleaning, the filtered clean gas can be fed back into the work area even when carcinogenic, mutagenic, or toxic dust is separated (recirculation mode).

In addition to the redundant filter system, the LAS 260 H/Ex provides further user benefits such as high flexibility through mobile utilisation, extremely quiet operation, and low energy consumption.

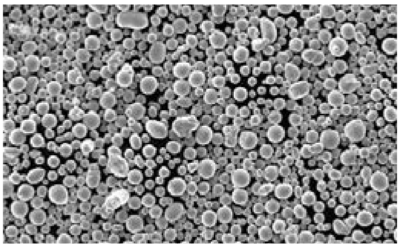
A collection element (hose, pipe, extraction arm) with DN50 can be connected to the extraction and filter system. In addition, an M12 interface is available for system integration or connection for automated operation.

www.ult-airtec.com

Ervin's Amapowder metal powders now available in Europe

Ervin Metal Powders, headquartered in Ann Arbor, Michigan, USA, is now offering a range of Amapowder metal powders, suitable for Additive Manufacturing and Metal Injection Moulding, to customers in Europe through its sales office in Berlin, Germany.

Ervin currently includes 304L, 316L and 17-4 PH stainless steel powders in the Amapowder range. The powders are produced using the company's Rapid Solidification Rate (RSR) and Centrifugal Atomisation technology, reported to create fine-grained (nanometre-scale) and amorphous metals with uniform chemistry and a highly spherical shape. These characteristics are said to give the powders good flow and packing behaviours.



Amapowder 316L is suitable for metal Additive Manufacturing and Metal Injection Moulding, as well as Hot Isostatic Pressing and thermal spray (Courtesy Ervin Metal Powders)

"We are delighted to be able to offer this exciting new range of products and are already collaborating with several Additive Manufacturing companies to help them deliver better quality and value solutions to their customers," stated Florian Götz, Innovation Director for Ervin Europe.

Using RSR atomisation, Ervin states that it has developed a wide variety of metal powders for many industries and applications. The company has been able to collaborate with a range of industries and research professionals to advance spherical metal powder technology.

Ervin also operates several centrifugal atomisation rigs that enable it to produce both small R&D powder batches and maintain the continuous production of powders at large scales.

Amapowder is suitable for a variety of Additive Manufacturing production processes, including Laser Beam Powder Bed Fusion (PBF-LB), Binder Jetting (BJT), and Directed Energy Deposition (DED). In addition to Metal Injection Moulding, it is also suited to thermal spraying and Hot Isostatic Pressing (HIP).

www.ervin.eu

Incodema3D expands Additive Manufacturing capacity with six more EOS M 300-4s

Incodema3D, based in Freeville, New York, USA, has purchased six additional EOS M 300-4 Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing machines from EOS GmbH, Krailling, Germany. The news comes just two months after Incodema3D invested in four EOS M 300s-4's for its shop floor.

"The Incodema3D team is a great example of what can be achieved when extraordinarily talented people work together towards an aspirational goal," stated Glynn Fletcher, president of EOS North America. "We continue to be blown away by what Incodema3D is accomplishing with EOS systems."

Established in 2016, Incodema3D specialises in metal Additive Manufacturing. The company offers advanced technologies for prototyping and serial production, and has undertaken more than 20,000 projects to date.

Once delivered, Incodema3D will have thirty-four EOS machines at its facility.

www.incodema3d.com
www.eos.info

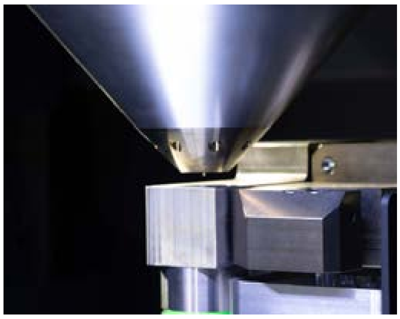
Meltio enters partnership with Jupiter Machine Tool and UnionMT for hybrid CNC machine solution

Meltio, headquartered in Linares, Spain, has announced a new partnership with Jupiter Machine Tool (JMT), based in Galesburg, Illinois, USA and Union MechaTronic (UMT), in Taichung, Taiwan. The companies have signed an Original Equipment Manufacturer (OEM) agreement for the development and sales of hybrid CNC Machines using Meltio's wire-laser metal Directed Energy Deposition (DED) technology.

JMT offers a range of solutions for the advanced manufacturing industry and provides engineering support, process improvement, quality control, service support, and production equipment to leading manufacturers in the automotive, aerospace, defence, medical, agricultural, transportation, 3C, and mining, sectors among others.

"The creation of a global partnership of Jupiter Machine Tool, Meltio, and UnionMT, located on three continents is extraordinary and exciting. Our tri-cultural synergy blended with diverse global technology results in the design and manufacture of three- and five-axis additive-subtractive CNC machine systems," stated Ray Whitehead, CEO of Jupiter Machine Tool.

This new collaboration with Meltio allows the introduction of the Meltio Engine CNC Integration into a Jupiter Machine Tool portfolio to install a metal additive manufacturing solution in several industries.



Meltio has announced a new partnership with Jupiter Machine Tool and Union MechaTronic (Courtesy Meltio)

The Meltio Engine CNC Integration can produce complex metal parts from wire feedstock. The ability to produce parts from wire is said to make its operation and material handling clean, as well as ensuring 100% material efficiency.

www.jupitermt.com
www.unionmt.com
www.meltio3d.com

3DMZ to acquire Freemelt eMELT-iD Additive Manufacturing machine as part of strategic collaboration

Freemelt AB, headquartered in Mölndal, Sweden, has entered into a strategic collaboration with 3DMZ (3D Makers Zone), based in Haarlem, the Netherlands. Within the collaboration, 3DMZ aims to establish a new metal field lab and invest in an eMELT-iD, Freemelt's Electron Beam Powder Bed Fusion (PBF-EB) Additive Manufacturing machine, by Q4 2024.

As a result of its increased commercialisation efforts, Freemelt is reportedly gaining substantial interest and growing demand from European companies. This includes the development of critical tungsten components for defence and energy applications, as well as industries with a high sense of urgency to establish local manufacturing to secure supply chains.

3DMZ is a technology and innovation hub with extensive knowledge and experience in industrial Additive Manufacturing, facilitating a wide range of Additive Manufacturing systems. Through strategic partnerships, 3DMZ supports global industrial companies in the transition from traditional manufacturing to industrial serial production through Additive Manufacturing.

"As a result of our intensified commercialisation efforts, we are experiencing an increased interest from European industrial companies regarding support with material process- and application development," stated Daniel Gidlund, Freemelt CEO. "[This is] why the collaboration with 3DMZ is critical as it will increase our capacity to meet the growing demand to support industrial customers in the transition from traditional manufacturing to AM."

Herman van Bolhuis, 3DMZ CEO, added, "We are thrilled to enter this collaboration. The AM market is maturing, and the manufacturing world is in need of digital supply chain solutions. Freemelt offers the next generation of metal printers. However, there is a lot to learn and to develop at the same time. By shaping this new field lab, the AM Campus Amsterdam will offer additional technology to its scope of solutions already in place. At the same time, several industrial partners will be invited to enter the new field lab ecosystem."

3DMZ will purchase an eMELT-iD Additive Manufacturing machine (Courtesy Freemelt AB)

www.freemelt.com

Incus additively manufactures mace for Yale University

Incus GmbH, based in Vienna, Austria, has additively manufactured a stainless steel 316L part for a ceremonial mace, designed by graduate Jacob Eldred, for Yale University's School of Engineering.

The mace design is said to symbolise the evolution of engineering, showcasing a progression from traditional to modern materials, shapes, surface textures, and manufacturing techniques. The base is hand-carved wood, followed by brass and copper, with increasingly complex shapes at the top made from aluminium and stainless steel using CNC and lithography-based metal manufacturing (LMM) technology, the Vat Photopolymerisation (VPP) AM process developed by Incus.

Near the top of the sculpture is the additively manufactured part, which symbolises the future. This piece, where the trunk of the tree splits into branches, is crucial in holding the structure together. Eldred designed it to showcase Incus' technology's ability to create curves that are impossible with traditional methods.

The Incus part features intricate internal geometries that cannot be machined or cast, and its complex curved surfaces captivate viewers, making them wonder how it was made – especially out of metal.

Incus has additively manufactured a stainless steel 316L part for a ceremonial mace for Yale University's School of Engineering (Courtesy Jacob Eldred and Kristin Wagner)

"As an artist and engineer, I'm fascinated by the reappearance of natural flowing shapes in manufacturing today," said Eldred. "In the past, craftsmen competed to create the most intricate and natural forms from wood, ivory, and silver, as seen in princely collections in Dresden and Vienna, which I was inspired by."

"These organic shapes were replaced by flat planes and cylinders during the Industrial Revolution due to the limitations of early machine tools. Now, with advanced automation and 3D printing, we can create elaborate curves, overhangs, and lattices. By producing these complex shapes with the Hammer Lab35 printer in my sculpture, I'm continuing the tradition of sculptors pushing technological boundaries. I'm excited to see how engineers will begin to think in these complex forms as they adopt advanced manufacturing techniques," Eldred added.

www.incus3d.com | www.yale.edu

Taniobis introduces DIN ISO 14021-certified closed-loop recycling for tantalum

The Taniobis Group, a subsidiary of JX Metals Corporation, headquartered in Goslar, Germany, has furthered its sustainability goals with the introduction of a DIN ISO 14021-certified closed-loop range of materials. The company has developed a 100% recycling route for various tantalum-containing synthetic concentrates, metals, oxides, and chemicals.

"Thanks to our recycling process, we are in a position to recover tantalum from almost all waste containing tantalum, to produce high-purity tantalum metals and oxides to meet customer requirements," stated Guido Klages, Head of HSEQ at Taniobis.

The company is also compliant with all management systems and certified for DIN ISO 9001, DIN ISO 14001, DIN ISO 45001, and DIN ISO 50001. The goal is to demonstrably meet the demands and responsibilities towards customers, employees, and the environment. Requirements are constantly developing and advancing in the areas of the environment, quality assurance, health and safety, and energy and management systems.

"In all cases, certification is not just a one-off process, but rather requires continuity. We look forward to this mission, and we will always continue to develop," explained Klages.

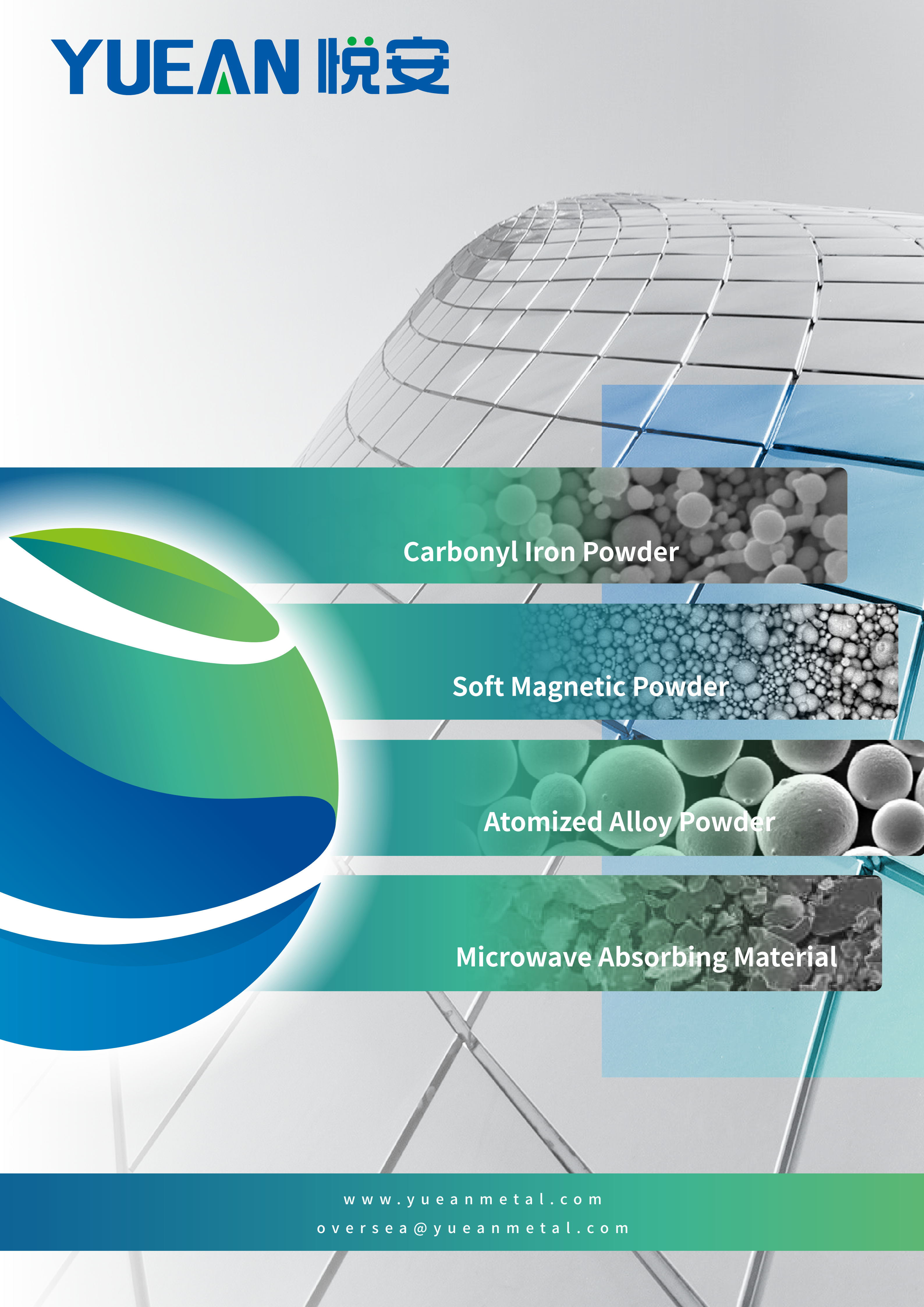
As the leading supplier of tantalum and niobium powders and alloys, Taniobis states that it is working to make progress on issues that are relevant to society through research and development.

The Taniobis Group has a closed-loop range of tantalum materials (Courtesy Taniobis)

For example, tantalum and niobium powders are critical for the manufacturing of biocompatible implants, and high-voltage tantalum capacitor powders are ideal for capacitors used in electronic mobility devices.

"We are working intensively on issues that will determine our future. Therefore, it is only logical for us to make sure we don't take more from the world than we need, and to produce in a resource-efficient manner," concluded Masafumi Ishii, CEO of the Taniobis Group.

www.taniobis.com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www.yueanmetal.com
oversea@yueanmetal.com

Fly-by-wire: How Additive Manufacturing took to the skies with Norsk Titanium

With seven structural titanium parts flying on every Boeing 787 Dreamliner, a Master Supply Agreement with Airbus for the A350, and projects with the likes of Northrop Grumman and General Atomics, Norsk Titanium is setting the pace when it comes to the production of airframe components by Additive Manufacturing. By using wire instead of powder and its own proprietary version of the Directed Energy Deposition (DED) process, the company combines high deposition rates with aerospace-grade materials properties. Martin McMahon visited the company on behalf of *Metal AM* magazine.

In today's metal Additive Manufacturing world, few things could be more on point than saying that Directed Energy Deposition (DED) is on the rise. Becoming ever more prevalent, this category of metal AM technologies may also be the most varied, being able to use both wire and powder as the feedstock, sometimes even simultaneously. This is because DED doesn't rely on just one source of energy, with machine configurations available using lasers, electron beams, electric arc, and plasma. This area of metal AM is also probably the oldest, with each machine leveraging welding expertise that has existed for decades. Even when I started researching blown powder laser cladding processes in 1990 – the start of my AM journey – DED had already been in development for close to a decade, albeit under different names and on a significantly smaller scale.

One company that has been enjoying increasing commercial success using DED is Norsk Titanium. This article explores how being focused on just a singular type of DED technology and material can lead to considerable success. As the name implies, Norsk Titanium primarily works with just one type of metal (titanium) and, more specifically, the Ti-6Al-4V alloy.

Dr Alf Bjørseth, one of Norsk Titanium's two founders, was already a very successful entrepreneur and industrial developer, researcher, and chemist working in Norway. Having spent many years working in the clean energy and advanced

Fig. 1 Exterior view of Norsk Titanium's facility in Plattsburgh, New York (Courtesy Norsk Titanium)

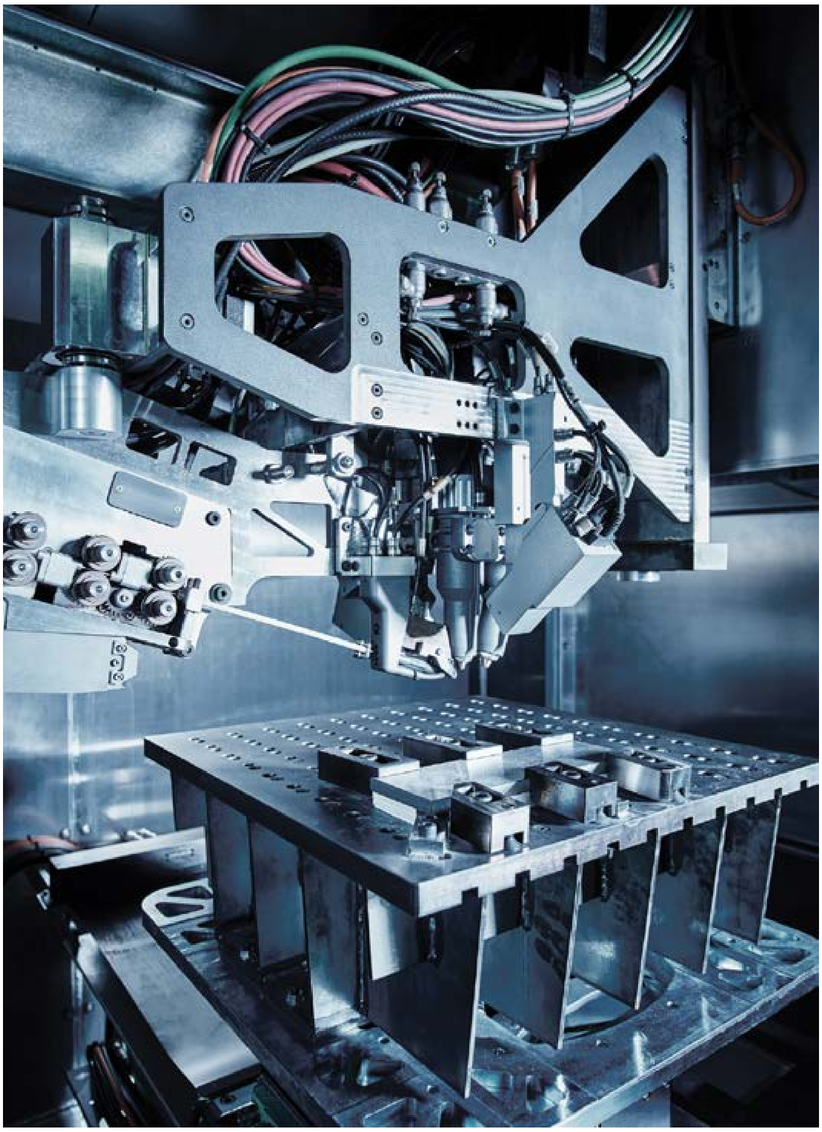

Fig. 2 Interior of one of Norsk Titanium's Merke IV machines with a build plate clamped in place (Courtesy Norsk Titanium)

"The founders didn't waste time in those early days; by 2008, they had built the first machine, referred to as the Gen 1. This was such a convincing prototype machine that, in the following year, a cooperation agreement was signed with Spirit AeroSystems."

materials processing sectors, Bjørseth was well placed to understand the need for more sustainability in the wider manufacturing industry. To complement this, Bjørseth partnered with Petter Gjørvad, who had specialist knowledge of titanium from his formative years in engineering.

In 2007, recognising the high energy cost of producing titanium parts and the subsequent environmental impact, Bjørseth and Gjørvad founded Norsk Titanium to develop and commercialise a new, less expensive way to manufacture aerospace-grade titanium products. The company started on this long before the wave of AM industry development in the decade that followed.

The founders didn't waste time in those early days; by 2008, they had built the first machine, referred to as the Gen 1. This was such a convincing prototype machine that, in the following year, a cooperation agreement was signed with Spirit AeroSystems. More changes happened quickly, with the Gen 1 machine morphing from a machine which, indeed, looked like a prototype, to a futuristic and industrial-looking Gen 2 machine by 2010.

This gave rise to the company's first industrial quality certification, the production of end-use parts; a major cooperation agreement with EADS (formerly a separate entity, now part of the Airbus group of companies); patents for the wire feedstock and the AM process; and eventually, in 2013, the milestone of achieving TRL6 (Technology Readiness Level 6) with Spirit AeroSystems for parts from the Gen 3 machine.

Production machine development

Despite early achievements coming in quick succession, Norsk Titanium continued to evolve and develop its technology rather than resting on the laurels of its early successes. Spurred on by some significant investments – including $125 million from the State of New York in 2015 – it made plans

Fig. 3 The rear of one of Norsk Titanium's Merke IV machines (Courtesy Norsk Titanium)

to build what was believed to be the world's first industrial-scale Additive Manufacturing facility for aerospace production. So began the story of Norsk Titanium US Inc., the US-based entity that has since made significant strides towards commercialising what Norsk Titanium calls Rapid Plasma Deposition (RPD™).

The chosen site in Plattsburg, New York, became the Production Development & Qualification Center (PDQC) for RPD Additive Manufacturing. It is now a state-of-the-art facility housing the latest Gen 4 machines alongside test and inspection systems. Operated by staff with years of experience in the aerospace sector, the PDQC is now the sole location for the development of client-based production programmes and staff training.

In just ten years, Norsk Titanium went from the first prototype Gen 1 machine to the production-ready Gen 4 (Merke IV) machines now installed and fully operational at the Plattsburg site. Few machine OEMs in the AM sector have been able to evolve so quickly and successfully. So, how is it that Norsk Titanium managed this?

"...it is clear that Norsk Titanium's success has its roots in avoiding the temptation to unnecessarily re-engineer sub-systems. Instead, the company relies heavily on integrating off-the-shelf modules to perform essential control processes."

The reality is that the workings of the Merke IV look pretty much like any other well-integrated process control system. Because machine OEMs in AM tend to try and outdo each other with innovation, occasionally reinventing the wheel when trying to keep all developments in-house, I imagined that everything would be designed and built in-house here too. However, from a quick glimpse inside the machine, it is clear that Norsk Titanium's success has its roots in avoiding the temptation to unnecessarily re-engineer sub-systems. Instead, the company relies heavily on integrating off-the-shelf modules to perform essential control processes. Arguably, this is one of the reasons why it has suffered so few technological

Fig. 4 Detail of an as-built component prior to finish machining (Courtesy Norsk Titanium)

> **"...for each machine to be deemed fully installed, Norsk Titanium's production engineers need at least two months. Then, to ensure that the machine is capable of producing parts to the required quality, they need a minimum of four more months."**

setbacks during the evolution of the Merke IV machine and why the machines are so reliable: it uses tried-and-tested regular industrial technology.

One surprising thing I learned during this visit was the length of time Norsk Titanium dedicates to the installation and operational qualification of each machine (IQ and OQ, respectively.) Norsk Titanium has carefully considered its machines' layout, ensuring that each G4B is capable of being packed up in a single standard shipping container. It's understandable to imagine that rolling it out, connecting it up and turning it on to perform the first build job should only take a matter of days. Think again: for each machine to be deemed fully installed, Norsk Titanium's production engineers need at least two months. Then, to ensure that the machine is capable of producing parts to the required quality, they need a minimum of four more months. This should actually offer great comfort to anyone on the fence about adopting metal AM as a production solution.

It was abundantly clear that the number one concern for all employees involved is the quality of the output from the machine. Each machine has to be producing the same level of consistent material as any other machine on site.

More will be said later about the parts that are being produced at Plattsburg, but it was really surprising to see the size of the titanium parts coming out of the fully operational standard machines, referred to as the G4B model. I also saw the first of two G4L machines, which were still undergoing installation qualification. This larger machine uses the same 'back end' as the G4B, and the same wire feed and process control modules, but it offers a significantly increased build volume and more flexible configurations for handling the workpiece. It also has a double cassette loading system, with an option to use a rotating framework platform for deposition on both sides of a plate without having to interrupt the build process.

When showing me around this large installation, Steve Eaton, VP of Operations at Plattsburgh, pointed out that the key advantage of reusing the same control systems was the ability to upgrade any of the existing G4B machines with the large build volume of the G4L.

Interestingly, Laser Beam Powder Bed Fusion (PBF-LB) is used to produce parts for three of the critical components of the patented deposition system. The pre-heat plasma torch, the melting plasma torch and the post-deposition controlled cooling unit are all produced by PBF-LB. This sort of integration is a positive reflection of the realised potential of metal AM technologies as a whole.

It was somewhat surprising, then, that none of the other structural parts used to suspend and configure other components were made by

AM. It was certainly easy to imagine how the RPD process could be used to produce more AM parts for the construction of these machines themselves, and this was not something that was lost on Schuster either. "I'd love to see more RPD parts in the next generation of Norsk Titanium machines," he told *Metal AM*.

RPD technology and its advantages

While walking through the clean and well-organised site, two questions came to mind. Firstly, if the company has managed to nail down so much of the process and is already producing qualified parts for commercial airliners, why hasn't more attention been paid to its success? After all, the reported advantages of the RPD process are that it can achieve a reduction in the buy-to-fly ratio (raw material weight: weight of final component) from 9:1 for conventionally forged and machined parts to anything between 5:1 and 2:1, all at an impressive build rate of 5 kg/h in titanium. Secondly, why aren't these machines being used by others around the world?

Nick Mayer, VP Commercial at Norsk Titanium, was quick to discount the possibility of the latter. While Norsk Titanium has no current plans to market its RPD machines to the rest of the industry, by Mayer's estimate, each machine would sell at around $2 million. This figure alone certainly gives a good insight into the scale of the investment that has been made at Plattsburgh, with its twenty-two current machine installations.

This may appear to be a big price tag but, when compared to large-volume PBF-LB machines, it could just as easily be perceived as a bargain. Straight out of the box, there is a full control system for wire feed, process monitoring, and a large build chamber that is capable of running a high-purity, inert atmosphere. During the tour, miniscule oxygen and moisture levels were observed

Fig. 5 Changing a consumable in a Merke IV machine. The three PBF-LB components used in the deposition system are clearly visible (Courtesy Norsk Titanium)

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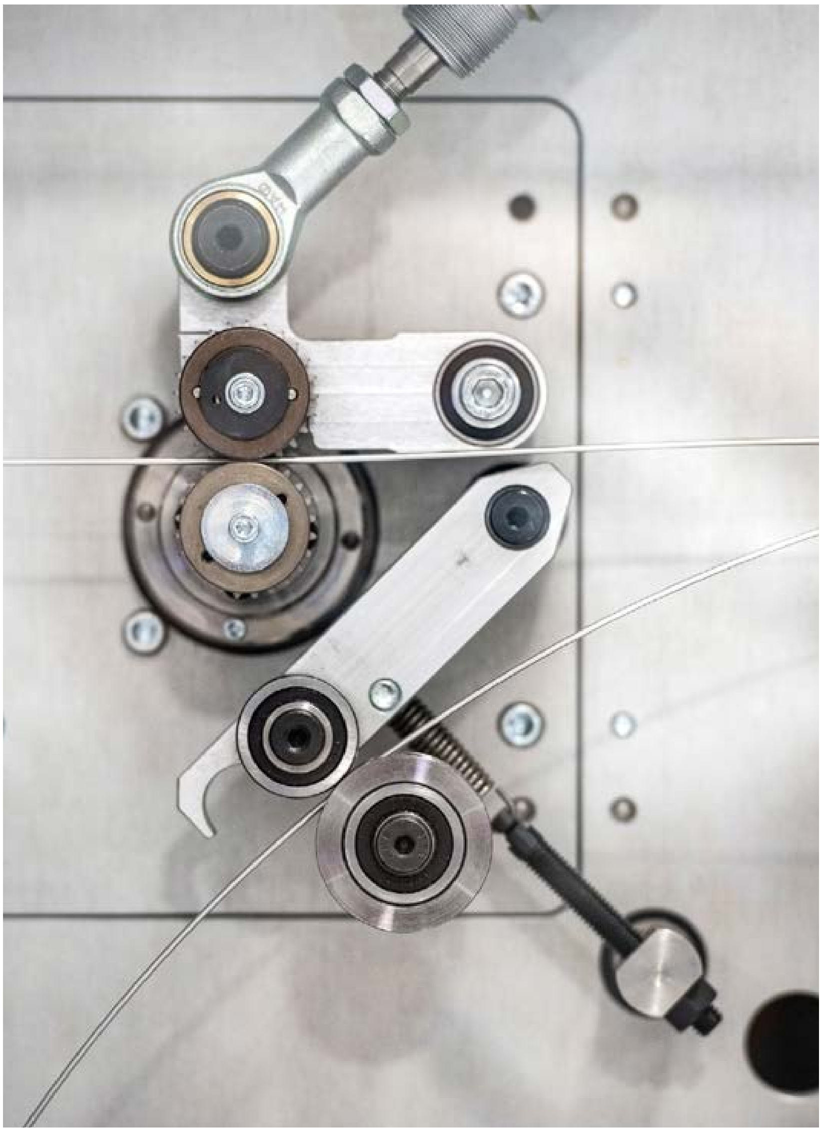

Fig. 6 Detail of the wire feed system in a Merke IV machine (Courtesy Norsk Titanium)

"Norsk Titanium may have patented a method for the production of titanium weld wire used in the RPD process, but it is still an industry standard 1.6 mm diameter. However, as with the sale of machines, there's no current interest in becoming a commodity materials supplier to the AM sector."

on one of the machines. The observed levels would be impressive for any metal AM process that runs under such conditions as standard, but when you consider the volume of the machine, they are exceptional.

Mayer stated, "I can't imagine us wanting to sell the machines. We pride ourselves on the quality of the output, which only we can achieve from our understanding of the process we have developed and how to keep the machines performing at their best. Selling to others to use would mean there is the risk that the quality of the output wouldn't be so high, and that could reflect negatively on us as a company – even though it would not be us producing the parts."

Norsk Titanium may have patented a method for the production of titanium weld wire used in the RPD process, but it is still an industry standard 1.6 mm diameter. However, as with the sale of machines, there's no current interest in becoming a commodity materials supplier to the AM sector. The wire is custom manufactured for Norsk Titanium in the US, enabling the company to control the wire's quality, something that is particularly important for aerospace and defence customers. However, Mayer added that they are seeking alternative, more economical supplies for industrial applications.

The control system houses the whole of the wire feed system. At first sight, it looks as if this system has an elaborate way to straighten the wire but, whilst watching an active build, Steve Schuster, Director of Production Engineering, explained the consequences of the system encountering bent wire. From the expression on the operator's face, one can imagine the severity of the situation. The company, therefore, has tight specifications for the production of its spooled wire. Such is Mayer's confidence in its existing supply chain that, he stated, the wire could be unspooled, laid on the floor, and it would be 'straight as an arrow.' The complexity of the wire feed system, therefore, exists because Norsk Titanium also has very tight control over the wire feed

Fig. 7 Norsk Titanium has a patented method for the production of the 1.6 mm diameter titanium weld wire used in the RPD process (Courtesy Norsk Titanium)

rate. Overfeeding the wire into the plasma torch can be catastrophic for the build if the feed wire attaches to the build itself (note another grimace from the operator).

In discussing the Merke IV machines, one final comment that caught my attention was that the Norsk Titanium team refers to the process as 'welding'. For a long time, many of us have been trying to convince the world that metal AM is nothing more than sophisticated welding; here, I found a company that embraces that fact. Norsk Titanium makes no secret that welding is exactly what is being carried out inside the machines, over and over again. Schuster offered a very clear way of describing the difference between the Norsk Titanium process and PBF-LB, stating, "To make a 1 inch cube from the RPD process takes just 27 inches of welds, but, in Laser Beam Powder Bed Fusion it takes about two miles of welds. Our process is just so much quicker."

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A manufacturing process optimised for speed and efficiency

In the early days of my AM career, I came across an application from a Formula 1 team that showed how one could build a part on a base plate that then became part of the finished component. At the time, however, so little was understood about metal AM that it didn't attract much attention. Fast forward more than a decade and Norsk Titanium has made this ability core to its process, and there is a high demand to incorporate as much of the build substrate as possible from the design stage. The cost benefits are straightforward, even if the price of wrought titanium has been steadily increasing (at the time

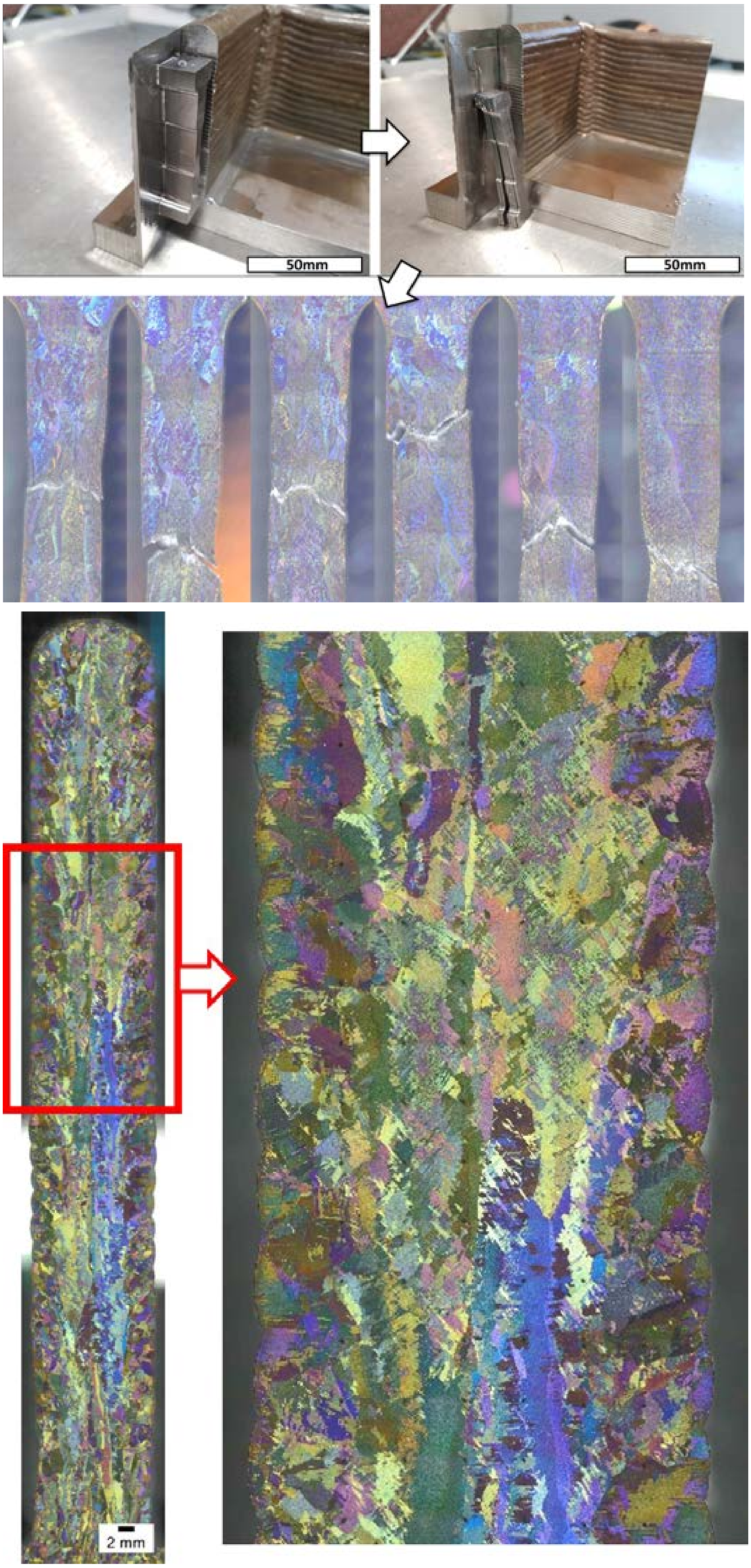

Fig. 8 Norsk Titanium is able to create and maintain the necessary microstructures and materials properties to pass aerospace standards requirements solely with stress relieving thermal processing (Courtesy Norsk Titanium)

of the visit, I was told that the cost of the base plates was approaching that of the wire feedstock). Nonetheless, any processing time that can be saved when simply depositing bulk material inevitably leads to a considerable saving.

Using flat plate wrought titanium is standard practice, and the process builds on these plates by depositing one weld bead after another. To those familiar with welding, this might instantly bring to mind situations where welds are used to fill in large areas, including plates, fillets and flanges. However, we will all probably also recognise that the weld metal microstructure is usually very different from the parts being welded; there are a number of Heat Affected Zones (HAZ) to consider and distortion is a major issue that must be contended with.

In knowing all this, my main interest is about how Norsk Titanium manages to create and maintain the necessary microstructures and materials properties to pass aerospace standards requirements. The immediate assumption is that after a build, and presumably some stress relieving, all the finished jobs are sent off for some Hot Isostatic Pressing (HIP). This is a post-process step that has become something of a norm for metal AM aerospace applications, such is the level of risk aversion in the sector. However, here, Mayer and the team clarified that no HIP is required as the material is at full density and, in the case of RPD, no advantages are gained. They went on to explain that common weld defects are well understood and that process optimisation work centres around avoiding these issues.

Mayer stated, "We can refer back to hundreds, if not thousands, of data points from all the mechanical testing that we have performed for well over a decade, including fatigue results that show that the deposited metal is more than strong enough for the job. The metallurgical analysis has shown that the RPD metal properties are always above customer requirements."

One of the things that sets apart a specialist AM contract manufacturing company and a traditional machine shop sub-contractor is its understanding of metallurgy. It was refreshing to hear the team talk about aspects of microstructure and metallurgy without having to be prompted in that direction. One area of the Production Development & Qualification Center is a dedicated metallurgy lab where a large collection of sectioned workpieces were visible. Picking one up for a closer look, the glint of a dense array of micro-hardness indentations was clear to see. Perhaps not so remarkable to some, but when one considers that the section was the size of the palm of one's hand, it shouldn't be hard to imagine the number of measurements that had been collected from just this one sample.

As we continued the tour, the scale of the operation was rather deceptive because of the seemingly wide open and empty central corridor which is used to move and arrange the large machines. It became apparent that the most important aspect of the development of the RPD process was the operation of the patented deposition head. Norsk Titanium recognised that it needed to control the pre-heating, melting and subsequent cooling steps in order to have control over the material properties. As a result of more than ten years of learning to precisely control all three stages, Norsk Titanium is now able to maintain a very uniform microstructure with relatively little residual heat. Eaton showed no concerns that I would be blinded by the super bright white-hot titanium when opening the safety windows immediately after a deposition run. To my surprise, all I saw was a small orange-coloured glow from the recently deposited metal, even though it was part of an extremely large component. This is in sharp contrast to experiences with long PBF-LB build jobs.

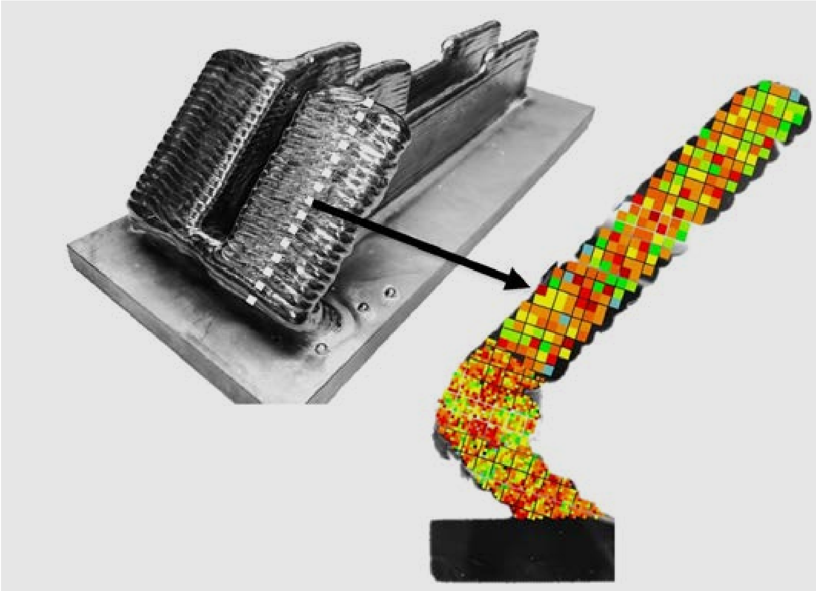

Fig. 9 Hardness mapping results (Courtesy Norsk Titanium)

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The details of the level of control and the steps within the process were not shared, being very much a part of the Norsk Titanium 'secret recipe,' one more reason why Norsk Titanium sees itself as a specialist aerospace contract manufacturing supply company and not a generalist AM sector supply company.

Returning to the fact that Norsk Titanium's expertise is, essentially, in welding, the next obvious question was about distortion – a common problem in any form of welding. Anyone who has tried to learn welding will recall placing a weld bead on a plate and then seeing it curl up at both ends. The Norsk Titanium RPD process is no different, but the team has learned to take advantage of this, and, in most cases, ensure that distortion is well within manageable tolerances. How this is achieved is by planning to use both sides of the build plate, making the build plates become integral to the finished parts. Typically, in the Merke IV machines, when a build is finished on one side, the workpiece is removed from the machine, then remounted on the reverse side before the build continues to add the required features. The company has become so expert at balancing the distortion of these builds that I was able to witness a substantial part as it was being removed from a build with minimal noticeable curvature.

Fig. 10 Twenty-two Merke IV machines are installed at the company's manufacturing facility (Courtesy Norsk Titanium)

Even with this level of expertise, a good margin of extra material is deposited into each part. Whereas with some AM technologies there is a drive to only machine the critical surfaces, the RPD process uses an excess applied all over to allow final machining. In this way, Norsk Titanium produces a more precisely finished part that resembles parts produced using conventional manufacturing methods.

The fact that the team plans to add excess material over the entire geometry also has the advantage that more economical heat treatments processes can be used. These are not only carried out just in air, but have shorter, lower-temperature cycles. In fact, the only step that is required post-build is stress relieving.

To speed up machine finishing, each build plate uses a set of datum tools that are affixed to the side of the plates, meaning there is consistency from build to build, even for completely different geometries. These datum tools are also reuseable, so there is no requirement to plan to build these features, as is common in other AM processes.

It seemed that the philosophy developed by the team at Plattsburgh is one of carrying out its own form of first article inspection during the process development for each customer part to be built. For this, there are various in-house testing and inspection capabilities, including CMM and submerged acoustic 3D scanning. Having a management team that has learned the ropes from inside the aerospace and defence sectors has clearly had a positive impact on the road to success.

"To speed up machine finishing, each build plate uses a set of datum tools that are affixed to the side of the plates, meaning there is consistency from build to build, even for completely different geometries. These datum tools are also reuseable, so there is no requirement to plan to build these features..."

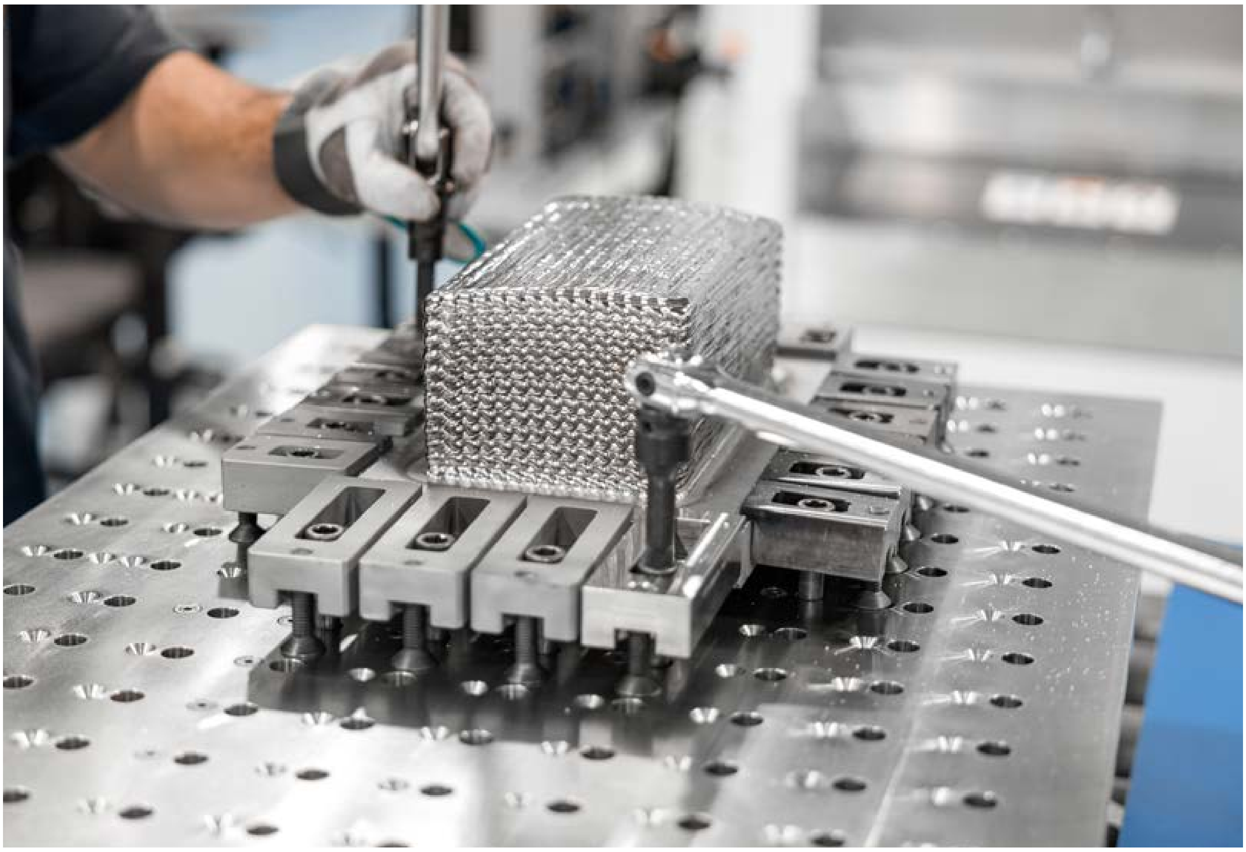

Fig. 11 An as-built 'loaf of bread' being removed from a Merke IV machine (Courtesy Norsk Titanium)

Applications focus

As with any company with a secretive client base, it's not easy for Norsk Titanium to show off how good it is at doing what it does. The reception area did, however, clearly convey its capabilities. Whilst nondescript in terms of its geometry, a huge block of deposited titanium that looked almost exactly like a freshly baked loaf of bread was on display, and it was hard to imagine how this could be accomplished without suffering from residual stress cracks, oxidation, and other common weld defects. There are other mass deposition processes, but none have ever been demonstrated to be so effective at working with Ti-6Al-4V as the RPD process.

"...a huge block of deposited titanium that looked almost exactly like a freshly baked loaf of bread was on display, and it was hard to imagine how this could be accomplished without suffering from residual stress cracks, oxidation, and other common weld defects."

With a clear focus on aerospace, borne out of its early successes with Spirit AeroSystems, it was no surprise that many of the sample parts on display were recognisable as large structural aero parts. Understandably, however, it's not very practical to have large structural wing components in the company reception area of a factory site before even taking into consideration acquiring the necessary permissions from customers. To circumvent this, the Norsk Titanium design team prepared a standout geometry featuring all the aspects of a typical wing structure. Condensed onto a single build plate, this still approached the maximum build capability of the G4B machine and was a dramatic example of just how successful this form of DED is compared to the more commonly used powder bed technologies.

Keen to demonstrate the capability to simplify forged components, even those that would still perhaps start

Fig. 12 Components awaiting post-processing (Courtesy Norsk Titanium)

as primary forgings, Mayer explained that Norsk Titanium's technology wasn't just about creating parts from scratch. "It would be great to have RPD used to bulk up the required features of a ring forged component that just had the minimal required thickness of the main ring. This is where the technology can really make a difference in the production of large parts. Passing the required areas through the smaller deposition workspace allows us to just add the required amount."

He continued "Since forgings usually result in many areas where it's impossible to avoid having an excess of material, the RPD process has a clear advantage in these instances." It is very easy to understand how this process could really speed up the delivery of complex forgings by not only reducing the required forging steps – and obviously significantly reducing tooling costs – but also the subsequent machining steps since there is less metal to remove.

Aerospace successes

Norsk Titanium was able to secure some very important customers from the aerospace sector in its development years. However, there has been a notable recent increase in activity. During 2023 and 2024, a succession of announcements were made about financially promising long-term production contracts that will yield notable revenues going beyond 2026.

One such example is the Airbus Master Supply Agreement signed in April 2024. This will last for at least three years, potentially five, and will see the company continue to deliver parts to Premium Aerotec in Germany for the A350 programme. This agreement was a follow-on from the quality approvals granted to Norsk Titanium by Airbus in December 2023 for the RPD production process on the 4th generation Merke IV machines.

In April 2024, Norsk Titanium also signed a longer-term agreement with Boeing for the continued supply of

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Fig. 13 An aft galley part for the Boeing 787 Dreamliner. Each of these aircraft has seven parts produced by Norsk Titanium (Courtesy Norsk Titanium)

parts for 787 Dreamliner aircraft. This includes the now-familiar aft galley part; in total, this sees seven titanium parts required for each new aircraft. It is probably a first in the commercial aerospace sector for an AM supplier to be so successfully incorporated into passenger aircraft, and it's worth taking a moment to reflect on this, as it is great news not only for Norsk Titanium, but for the whole of the metal AM sector.

As Boeing announces more orders for the 787 – such as the recent order from Japan Airlines for ten of these popular wide-body jets with the option to increase this to twenty – this can only lead to greater adoption of metal AM technologies. The parts that Norsk Titanium is producing for Boeing vary in size, but with between twenty-eight and thirty-five parts required per month at the current Boeing delivery rate, it is a substantial success for the business, which will only lead to further growth in the coming years.

Fig. 14 Detail showing an as-built and machined galley part for the Boeing 787 Dreamliner (Courtesy Norsk Titanium)

Fig. 15 DED Ti-6Al-4V landing gear structural component as an as-built preform and post-machined, delivering significant cost and lead-time savings compared to the legacy component. Note the double-sided use of the build plate for efficient fabrication (Courtesy General Atomics Aeronautical Systems Inc (GA-ASI))

"From various other sources, it's possible to estimate that the current open order book for 787 aircraft is perhaps just under 800 aircraft. This will see Norsk Titanium producing well over 5,000 more parts for this programme alone."

According to an article by *Forecast International* [1], the 787 programme is experiencing increased deliveries. In January 2024, the production rate of the 787 reached five aircraft per month, and it is expected to steadily increase to a target of ten aircraft per month by 2025-26. From various other sources, it's possible to estimate that the current open order book for 787 aircraft is perhaps just under 800 aircraft. This will see Norsk Titanium producing well over 5,000 more parts for this programme alone.

Beyond these, there were announcements of projects with General Atomics on an undisclosed programme to produce a large wing splice. In June of this year, the increased capacity at Plattsburgh attracted a contract from the US Department of Defense (DoD) for an undisclosed programme. Back in March, there was also an announcement relating to a development contract for Northrop Grumman (the company where Mayer himself spent a large part of his career before joining Norsk Titanium in 2015) after having the RPD method classified under the special process approval scheme of the DoD.

Norsk Titanium plans to have delivered parts for flight testing by the time this article is published. This project has involved one of only two of the newer G4L machines installed at Plattsburg. The larger-format machine has enabled Norsk Titanium to build parts for one aerospace and defence company that are 1.4 m (4.6 ft) long, though the machine itself can go up to 1.9 m (6 ft) long.

Non-aerospace applications

It's not always wise to have just one string to its bow, and Norsk Titanium has been working on the development of other industrial applications almost since its beginning. A consequence of this was announced in June 2024, when Hittech, the systems integration and factory automation specialist based in the Netherlands, added to existing contracts originally signed in early 2023.

Hittech, which supplies components to one of the world's foremost semiconductor wafer processing businesses, had already confirmed a two-year extension back in February of this year. However, this long-term project has its roots as far back as 2012, showing that it's not only aerospace that has long product development lifecycles for introducing new technologies into production processes.

The interesting thing about this large carrier tray part is that it also incorporates at least one other metal AM part, made via Laser Beam Powder Bed Fusion by 3T-AM in the UK. Very little is publicly known about this application, but perhaps this is an indication that this industrial trailblazer has its sights set on even more developments using metal Additive Manufacturing. Time will tell, but, for Norsk Titanium, this type of industrial supply work is expected to account for 15% of revenues in 2024.

Looking to the future

The site at Plattsburg has grown in the past two to three years, not only with the building of a completely new factory unit dedicated to the production of end use parts, but also in the continuation of process development activities within the original building. Staffing has increased from ten in 2017 to more than sixty employees, with active recruitment ongoing. Running a two-shift pattern over four days and running five machines out

Fig. 16 Large structural component designed and built towards use in a next-generation UAS platform (Courtesy GA-ASI)

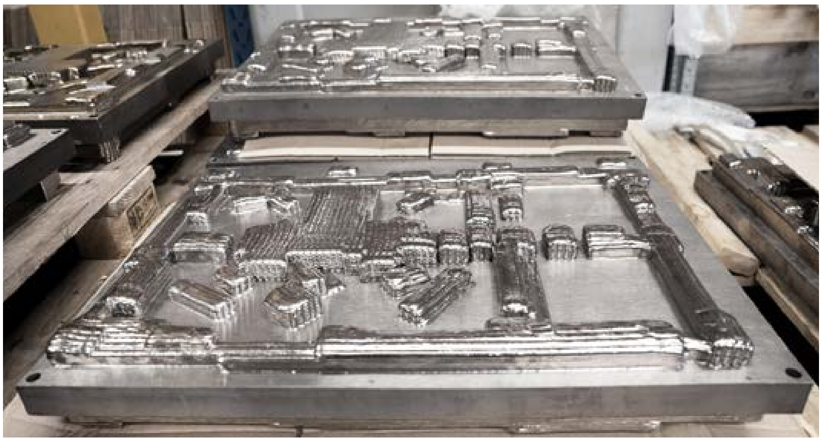

Fig. 17 Semiconductor carrier trays produced by Norsk Titanium for Hittech [4] (Courtesy Hittech)

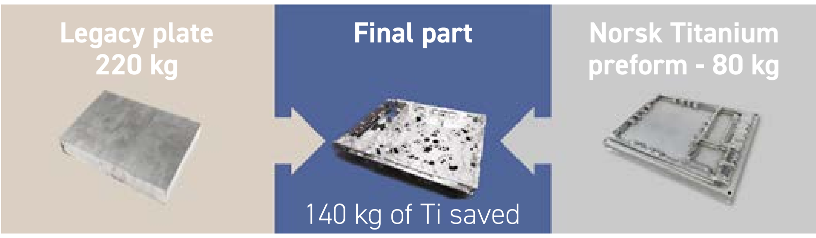

Fig. 18 Illustration of the potential savings when using AM for semiconductor applications (Courtesy Norsk Titanium)

Fig. 19 The Merke IV machine in operation (Courtesy Norsk Titanium)

"The fact is, Norsk Titanium has been rather quiet about its growth expectations in comparison to some others in the sector. It doesn't come across as a company that has been a victim of the hype that has afflicted others working in Additive Manufacturing, nor has it struggled to gain traction with early-stage adopters."

of fourteen concurrently, Norsk Titanium has significantly increased output from the initial 1 tonne/month when the site was first established.

This follows on from the announcement earlier this summer that, across both plants in Plattsburg, the company has twenty-two of the 4th generation machines. This translates to a production capacity of up to 700 tonnes of titanium parts per year.

The current list of in-production parts is close to thirty, and the company stated in its recently published half-year report for 2024 (and previously in the annual report for 2023) that it believes it can double this in 2025, and again in 2026, to reach a target of having sixty production parts coming out of Plattsburgh.

From the recent agreements with Airbus, Boeing and their Tier 1 supply chain, the US Department of Defense, Northrup Grumman, General Atomics, and Hittech, it seems that Norsk Titanium has good grounds for being so bullish. Its own forecasting sees the company going from annual recurring revenues of $11 million in 2024 to total revenues of $150 million by 2026 [2].

Norsk Titanium predicts that 80% of that revenue will come directly from sub-contracted parts manufacture. By its own estimates, the size of the addressable commercial aerospace sector is $13 billion, with another $5 billion each in defence and other industrial sectors. So, even though Norsk Titanium has initially aligned to just two industry sectors from which it expects to receive the bulk of the business from high-complexity commercial aerospace parts, it's plain that the company has just scratched the surface of its capabilities. It is even looking to diversify its materials, having recently completed a project for the US Navy which involved collaboration with QuesTek to develop the RPD process for nickel alloys.

It now remains to be seen if it can indeed achieve similar significant growth from industrial markets other than aerospace and defence. With just one major industrial customer, Hittech, this may seem like a steep hill to climb in just two years. Perhaps this is the reason why Norsk Titanium doesn't totally discount the possibility of revenues from selling its machines, licencing IP, or even entering joint ventures.

The fact is, Norsk Titanium has been rather quiet about its growth expectations in comparison to some others in the sector. It doesn't come across as a company that has been a victim of the hype that has afflicted others working in Additive Manufacturing, nor has it struggled to gain traction with early-stage adopters.

Norsk Titanium has chosen to be a service-based company rather than a capital equipment and materials supply company. There are certainly very few in the sector that have developed an AM process that doesn't lead to the latter, and Norsk Titanium's success to date, with its form of DED, has taken a completely different path to virtually all of the successful PBF-LB machine developers. DED has, of course, been in development for a lot longer than PBF-LB; perhaps that is why it constitutes a lower-risk approach for eventual end users. After all, it is simply welding with a wire, albeit in a rather elegant fashion. Who wouldn't put their faith in tried-and-tested welding technologies?

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Dynamic beam shaping: Unlocking productivity for cost-effective Laser Beam Powder Bed Fusion

In the race to improve the productivity of PBF-LB Additive Manufacturing, machine OEMs have generally taken the path of adding more lasers. nLIGHT takes the view that it's not necessarily just more lasers that are needed, but beam-shaping lasers. By using dynamic beam shaping technology, significant increases in the productivity, stability and metallurgical capabilities of PBF-LB have been demonstrated. Given the technology's recent commercial success, with adoption by Aconity3D, AMCM, EOS and DMG Mori, we asked the nLIGHT team to review beam shaping technology and its potential impact on the AM industry.

As the leading modality for metal Additive Manufacturing, Laser Beam Powder Bed Fusion (PBF-LB) is transforming many industries, including commercial aviation, satellite deployment, defence technology, and personalised medicine. However, for PBF-LB to be adopted in a wider range of high-volume markets such as industrial tooling, consumer products, and automotive manufacturing, significant improvements in productivity are required to lower part costs. Current PBF-LB machines need to become considerably more productive for PBF-LB to compete with forging, casting, and CNC machining technologies.

In recent years, original equipment manufacturers (OEMs) have begun to add more lasers to each AM machine to improve productivity. While these multi-laser machines offer a productivity advantage compared to single-laser machines, simply adding more lasers to a machine offers diminishing returns on productivity and increases the total cost of ownership to a point that is limiting their adoption. Furthermore, the AM industry has been utilising a Gaussian laser beam shape that is fundamentally limited in its scalability. This article describes how dynamic beam shaping (Fig. 1) is enabling the development of metal AM machines that are able to produce high-performance parts, but at a cost that competes with conventional manufacturing and, therefore, opens new markets.

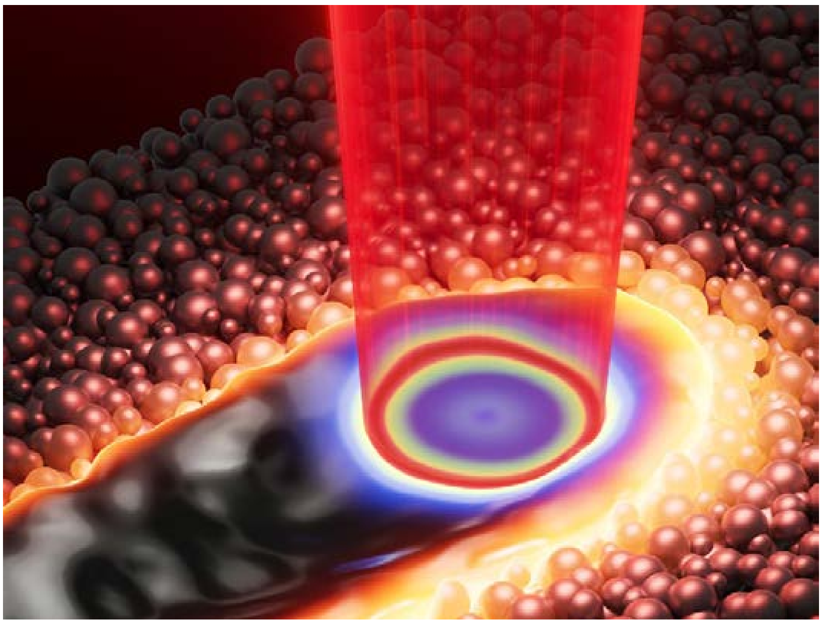
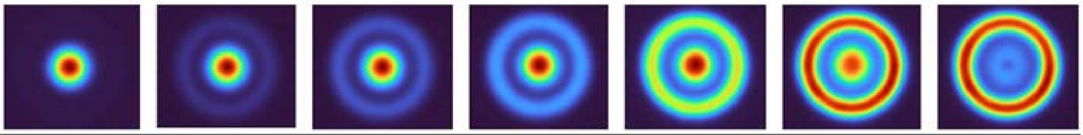


Fig. 1 Dynamic beam shaping is enabling the development of metal AM machines that are able to produce high-performance parts, but at a cost that competes with conventional manufacturing (Courtesy nLIGHT)



Index	0	1	2	3	4	5	6
Power % (core/ring)	95/5	75/25	65/35	50/50	30/70	20/80	10/90

Fig. 2 Core vs ring intensities in index settings 0–6 for nLIGHT's Corona™ AFX laser (Courtesy nLIGHT)

The evolution of lasers for Powder Bed Fusion

Modern Powder Bed Fusion machines for metal AM generally employ single mode, ytterbium-doped (Yb), fibre lasers with an emission wavelength of nominally ~1,070 nm, and they're often paired with two-, three- and even four-axis galvo-based scanners. The low divergence and exceptional focusing characteristics of a single-mode beam enable the smallest possible spot size for creating fine features, even with small aperture optics and at long distances. Over the past twenty-five years, continuous wave Yb fibre lasers have emerged as the preferred light source for most PBF-LB machines.

The power output of single-mode fibre lasers has kept pace with the demands of the metal AM market. In the early 2000s, PBF-LB machines started with 100-200 W lasers, then migrated to 400-700 W lasers in the 2010s. For typical focused spot sizes, 100 µm diameter, 500 W single-mode fibre lasers were determined to be sufficient for most processes and materials.

By 2020, OEMs were able to implement 1 kW single-mode lasers by either enlarging the spot delivered to the powder by a zoom lens, or by using a defocus function from the scanner. These strategies had the effect of increasing productivity by increasing the hatch spacing. This was sometimes combined with increasing the layer thickness. While this technique has proven to be effective for increasing productivity when fine spatial resolution is not required, it made implementation of the laser into the AM machine complex and cumbersome for a variety of reasons:

- Zoom optics add cost, complexity and increased risk of contamination when more optical surfaces are introduced
- The defocus strategy suffers from the inherent reproducibility challenges of working off-focus where small defocus errors result in quadratic differences in power density
- Gaussian intensity profiles remain with zoom and defocus.

The same superheating and extreme temperature gradients under these Gaussian profiles simply get expressed over larger melt pools that have a greater tendency to become unstable. So, whenever high beam quality is not required, such as printing featureless bulk material, Gaussian beam profiles become a burden, not a benefit.

The challenge facing the industry was clear: for PBF-LB to move to a higher productivity, lower cost, and more reliable and repeatable process, a new laser approach had to be found.

"The challenge facing the industry was clear: for PBF-LB to move to a higher productivity, lower cost, and more reliable and repeatable process, a new laser approach had to be found."

Early attempts at using beam shaping

Early investigations of beam shaping were focused on experimenting with various beam shapes and intensity distributions that would 'flatten' the temperature field of the molten material under the footprint of the beam. Flat-top beam profiles seemed to be an obvious choice. Unfortunately, beam quality degrades quickly when a Gaussian profile is transformed into alternative intensity profiles. Switching between a single-mode beam and a larger, non-Gaussian profile is desired, but the beam quality must not be so corrupted that transmission through

Fig. 3 Choosing the right beam shape for the geometry (objects shown are for illustrative purposes only) (Courtesy EOS GmbH)

the scanner is compromised.

Gaussian-to-flat top beam transformation optics were commercially available but were problematic to implement with scanning beam delivery systems. Critical roadblocks included:

- Extreme alignment sensitivity requiring frequent maintenance intervals
- Short depth of focus requiring frequent z-calibrations for the working distance
- Incompatible beam quality for typical scanner optics
- Contamination risk posed by introducing additional optics
- The cost and complexity of quickly switching the beam shape with free-space optics between single mode and flat top

In addition to numerous engineering challenges, flat-top profiles produced only marginal improvements over the Gaussian intensity problem. This was to be expected since heat transfer under flat-top beam profiles still produces steep temperature gradients across the melt pool, just not quite as extreme as for Gaussian profiles.

Ring beam profiles were researched as an alternative to flat top and Gaussian beams for higher-powered lasers in PBF-LB machines. A ring beam solves the challenge of Gaussian beam profiles where there is an excess of central intensity and heat, and instead offers the inverse as a solution by distributing the intensity to the outer perimeter of a ring. Researchers at the Technical University of Munich confirmed this thesis, demonstrating single-track welds with a 316L material [1]. A ring beam profile can also produce a focused spot size that is 250% larger than the single mode beam, leading to a considerable gain in productivity.

nLIGHT introduces Corona™ AFX

Introduced in 2020, the Corona AFX laser from nLIGHT became the first fibre laser capable of switching between single-mode Gaussian and six other beam profiles, some of which are up to three times larger. AFX lasers can operate as a true Gaussian beam, known as index 0, but, unlike conventional lasers, they have the ability to move power into an outer ring, as illustrated by Fig. 1. The power in the 'core' vs the ring is always proportional, and as the index setting increases, power moves in a stepwise fashion from the core out to the ring. While the total power from index 0-6 can be the same, the power density, or the power per area, reduces as more power is moved into the ring (Fig. 2).

The ability to switch from a true Gaussian to a ring profile within one laser, on a microsecond timescale, without any compromise in beam quality, is referred to as dynamic beam shaping. Using AFX-enabled dynamic beam shaping, a beam shape can be selected depending on the application and build requirement. Fig. 3 from the EOS Group shows a part with representative geometries that would call for different beam shapes. For example, a small spot index of 0 can be used for contouring and high-resolution detail, and a larger spot with an index of 6 can be

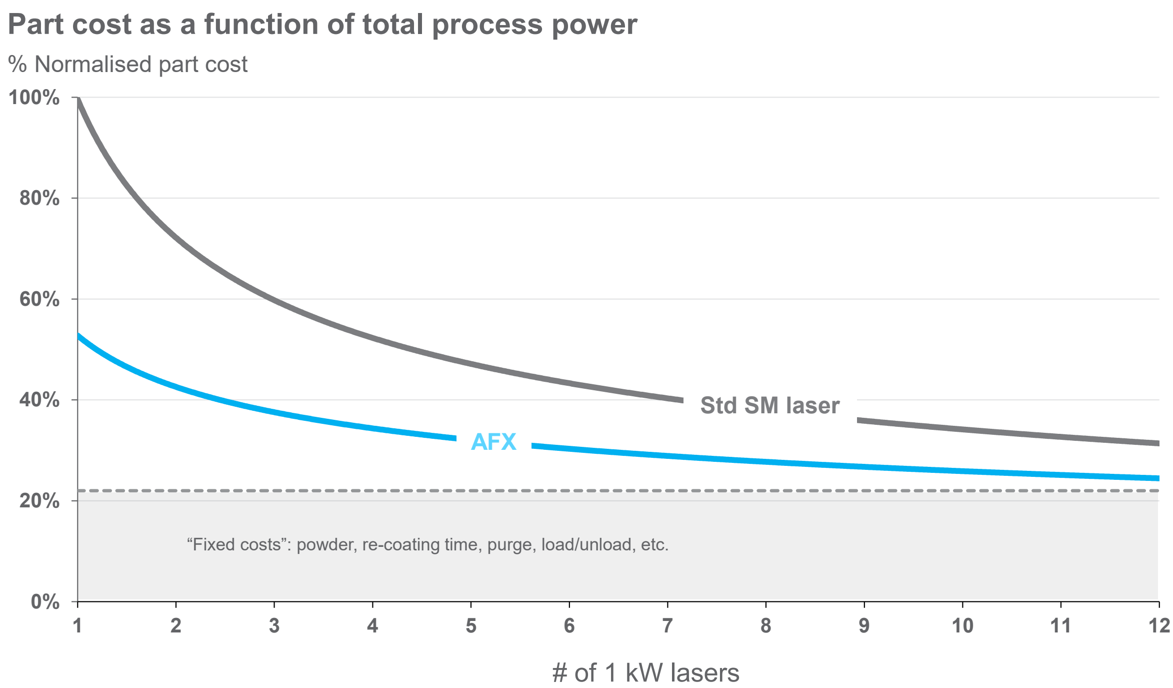


Fig. 4 Dynamic beam shaping with nLIGHT AFX shifts the cost curve for PBF-LB (Courtesy nLIGHT)

used where the ring-beam shape can more efficiently melt and consolidate the material, thereby increasing overall productivity by allowing for larger hatch spacing. Likewise, intermediate indices can be used for equivalent geometries.

A simple analogy to using beam shaping in PBF-LB is painting a portrait: productivity would be low if the painter was constrained to only using a single fine-point paintbrush. While the fine-point paintbrush is the tool of choice for fine features, the painter should use a wider brush to cover larger areas.

Fig. 4 shows the calculated decrease in PBF-LB part cost with the introduction of 1 kW AFX lasers compared with 1 kW standard lasers. Productivity gains are realised via dynamic beam shaping, using a larger spot and wide hatch spacing for large-area manufacturing. In this example, the cost per part achieved with one AFX laser is equivalent to four standard lasers. There is a plateau towards a set of fixed costs as successive lasers are added, with these fixed costs relating to recoating and other machine operations.

"A simple analogy to using beam shaping in PBF-LB is painting a portrait: productivity would be low if the painter was constrained to only using a single fine-point paintbrush. While the fine-point paintbrush is the tool of choice for fine features, the painter should use a wider brush to cover larger areas."

Dynamic beam shaping fundamentals

The difference between a Gaussian beam profile and a ring beam can be seen in Fig. 5, where a planar view of the in-focus beam intensity is presented, along with the corresponding cross-sectional laser intensity profile. The Gaussian beam exhibits a central intensity peak, with steep edges and a small spot size, typically 80 µm at the powder bed. The melt pool produced has a narrow, semi-spherical shape.

In contrast, the ring beam produces a double peak in the cross-section intensity profile, but the resultant temperature profile in the melt pool is much flatter and wider. A typical spot size for the ring beam

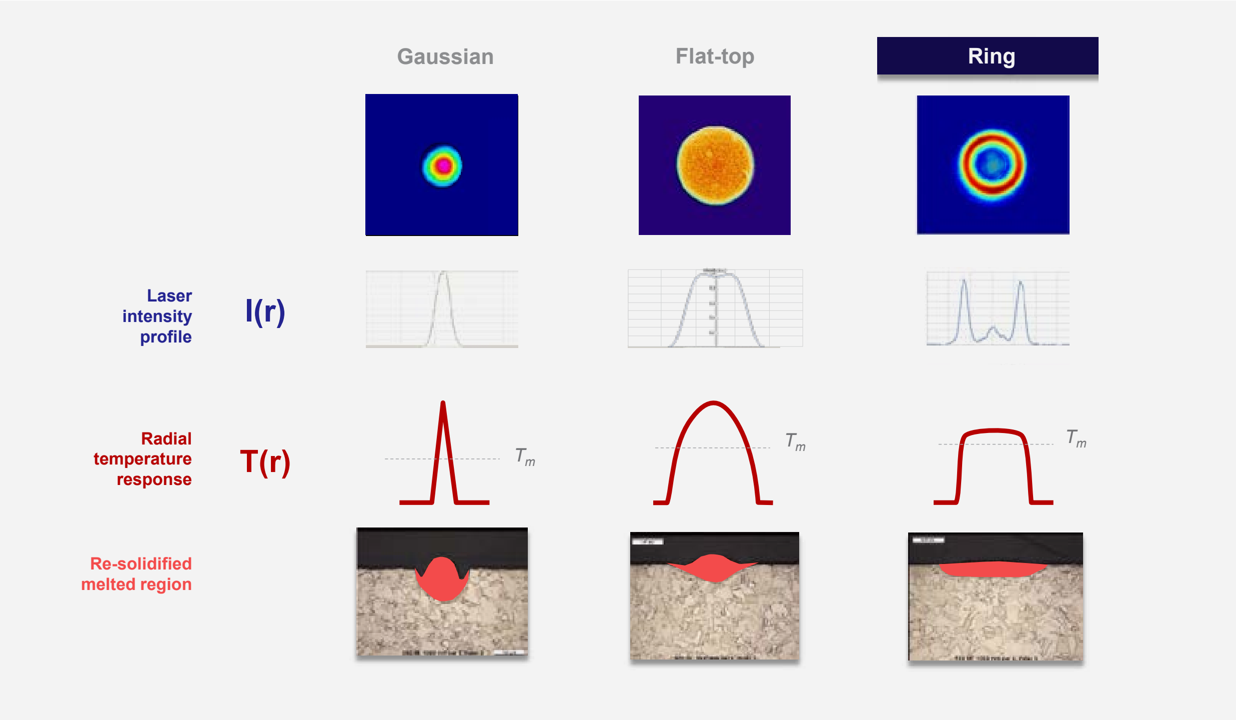


Fig. 5 Beam profiles, notional temperature responses, and resulting melt pool shapes with Gaussian, flat top and ring beams (Courtesy nLIGHT)

is 240 µm. With the Corona AFX fibre laser, the temperature profile can be optimised for the local geometry, the material system, and the scan speed.

The ability to productively use higher powers in a ring beam is due to the fundamental stability of the melt pool. Fig. 5 is illustrative of some of the challenges with Gaussian beam processing, as the central intensity peak can lead to problematic melt pool instability, creating downward forces within the molten material that lead to the ejection of molten droplets, known as spatter, into the build chamber environment. The high central intensity of the laser also overheats the centre of the melt pool, vapourising the molten metal further, adding to the downward pressure in the melt pool and hence increasing the spatter.

"Due to the consistency of the melt pool profile resulting from ring-beam melting, a more precise intensity and, therefore, temperature can be applied to the powder bed to ensure melting just above the melting temperature of the alloy."

Additionally, other defects can be observed, such as balling or humping around the melt pool track [2]. If laser intensity is too high, the downward forces within the melt pool cause the melting to move from conduction mode to keyhole mode, causing a large depression in the molten material, often leaving a trail of vapour pores. Melt pool anomalies, spatter, and keyholes are the leading cause of porosity and defects in PBF-LB machines and are the reason that process windows are so limited for Gaussian beams at higher powers.

In contrast to the temperature profile imparted to the powder bed from a Gaussian intensity profile, a flat top beam profile improves this slightly, but the temperature profile still exhibits a central peak. Transferring power from the centre of the beam to the ring allows the temperature profile to be flattened, as shown for the ring beam [3].

Due to the consistency of the melt pool profile resulting from ring-beam melting, a more precise intensity and, therefore, temperature can be applied to the powder bed to ensure melting just above the melting temperature of the alloy. Dynamic beam shapes change the temperature response

Fig. 6 An example of the economic advantages of dynamic beam shaping. The study conducted by Aconity3D GmbH, using geometry provided by Access e.V. and B&B-Agema GmbH (Courtesy Aconity3D GmbH)

within the melt pool and thus the cross-section of the solidified PBF-LB track, as illustrated in Fig. 5.

Industry validation

A study by Aconity3D in which turbine blades were manufactured in Inconel 718 demonstrated that switching from a Gaussian-only mode to a build strategy optimised for beam shaping dramatically reduced the overall build time and, therefore, cost. As shown in Fig. 6, build preparation, inerting, and recoating times were consistent between the two builds, but a steep reduction in 'laser on' time reduced overall build time by 82%. This was directly due to the wider hatch spacing enabled by a ring beam.

Furthermore, the study showed that layer thickness can be successfully increased from 50-100 µm using beam shaping thanks to the higher melt pool stability (Fig. 7). This layer thickness increase led to further productivity gains that reduced the build from three days to half a day, which resulted in a corresponding 75% reduction of the build cost of those parts (Fig. 6).

Another study, conducted by DMG Mori USA, compared the productivity of a DMG Mori machine using a single 1 kW AFX laser processing a nickel-based alloy to eight industry-standard PBF-LB machines using two to twelve lasers each (Fig. 8). The other machines delivered parts that cost two-to-six times more than DMG Mori's platform in which the single AFX 1 kW laser was utilised.

The research community has also verified the productivity gains achieved with beam shaping using AFX lasers. Cozzolino *et al.*, demonstrated a 23% increase in productivity when using a ring beam compared to a Gaussian beam for Inconel 718 [4]. Likewise, Grünewald *et al.*, demonstrated that the PBF-LB processing of 316L can be accelerated by a factor of about two thanks to the higher scanning speeds and enlarged hatch distances enabled by AFX [2].

Dynamic beam shaping enables stable, high-power processes

Productivity is not the only advantage of ring beam processing with AFX lasers. The melt pool produced by a ring shape has an intrinsic stability that gives rise to several processing and metallurgical benefits.

One important effect of a stable melt pool is a wider process window, expanding the parameter set that can be utilised while still producing high-quality, fully dense parts. Multiple research groups have demonstrated increased productivity and larger process windows across several material systems. A study conducted at the Technical University of Munich using 316L stainless steel showed that the process window can be significantly enlarged if an AFX-1000 is used with a ring-shaped beam profile instead of a Gaussian beam profile (Fig. 9).

An important aspect of a wider process window is the tolerance for higher-power lasers when using ring beams. The ring shape distributes the heat input more evenly across the bed and reduces the overall energy density. Ring beams, therefore, make processing with over 1 kW of power in PBF-LB machines achievable. In 2022, nLIGHT released a 1.5 kW Corona AFX, followed in 2024 by a 2 kW Corona AFX. The 2 kW AFX has been demonstrated with a commercial customer who has verified build rates previously considered to be unattainable for high density parts.

A study by Jan Johannsen of Fraunhofer IAPT comparing Gaussian and ring beam processing of AlSi10Mg showed a reduction of soot and spatter by 75% when using the same power and parameter sets. Using AFX, it was found that there were finer ejections in the spatter, fewer large, oxidised particles in the melt pool, and less balling on the melt pool tracks. The reduced spatter ultimately leads to

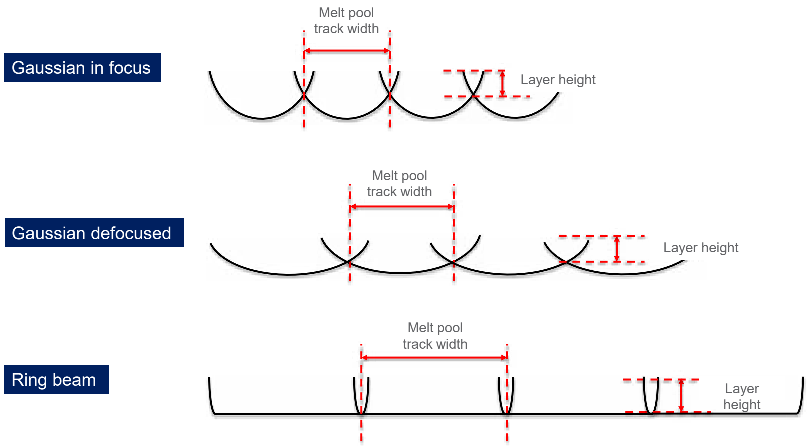


Fig. 7 Ring beams enable a larger hatch distance and increased layer thickness (Courtesy nLIGHT)

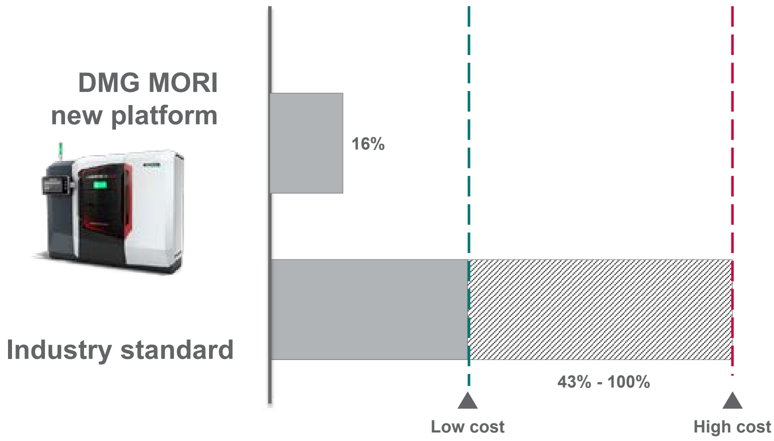


Fig. 8 Part cost achieved with a single AFX 1 kW laser compared with industry-standard machines without beam shaping, based on a study carried out by DMG Mori USA (Courtesy DMG Mori USA)

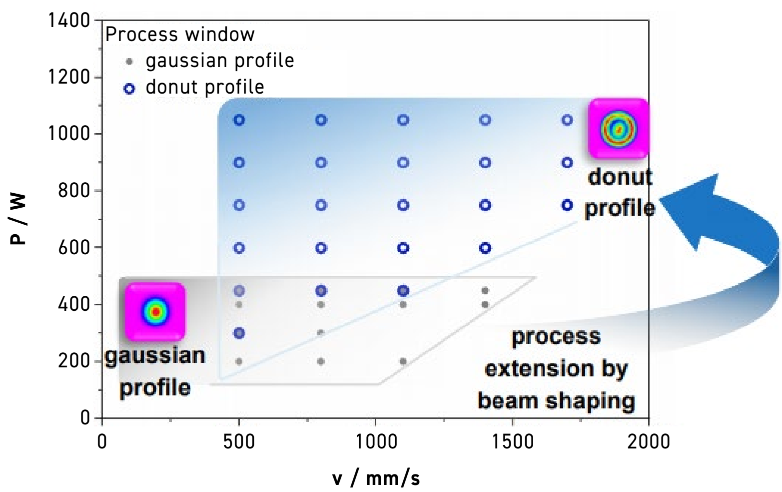


Fig. 9 Process windows for Gaussian and AFX beams (Courtesy TU Munich)

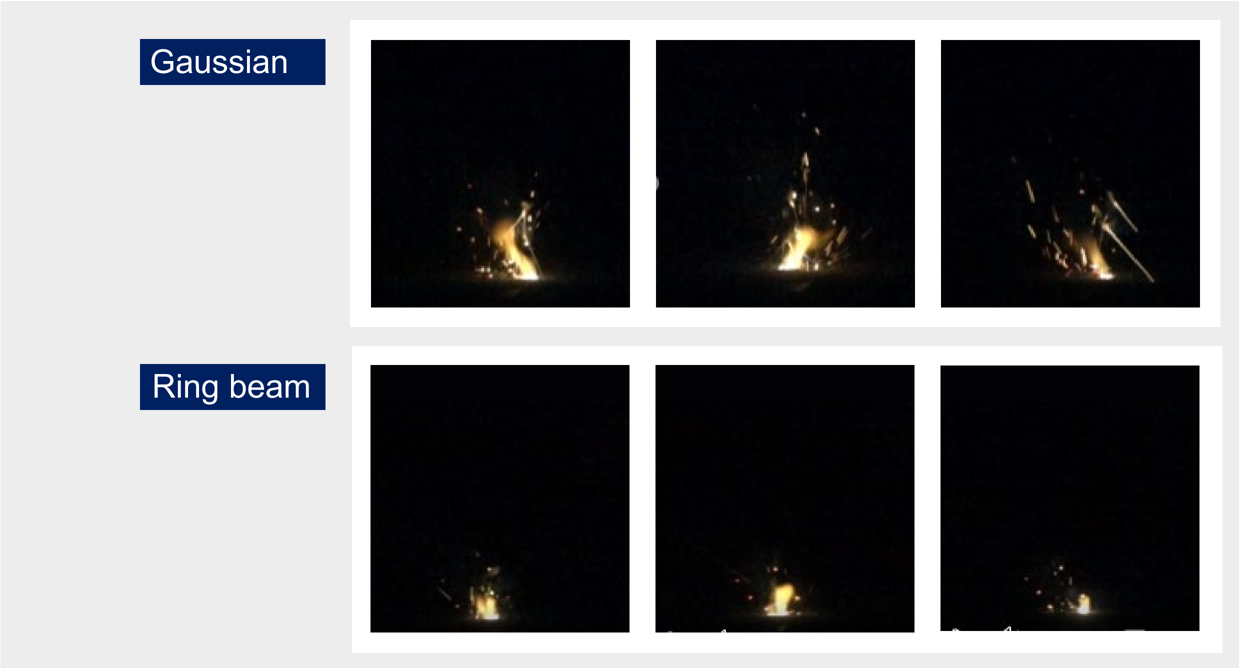


Fig. 10 Ring beam processing shows a 75% reduction in soot and spatter for AlSi10Mg (Courtesy Fraunhofer IAPT)

> *"Beam shaping has the potential to make materials previously considered as 'hard-to-weld' processable using PBF-LB. Candidate materials include nickel-based alloys, tool steels, aluminium alloys, and refractory alloys."*

less powder bed contamination and a longer filter life when using AFX (Fig. 10).

The high temperature peak associated with a single mode beam can exceed a material's boiling point, which, for certain alloys, can lead to the vapourisation of lighter, lower-boiling-point elements (e.g. magnesium and zinc). In addition to generating smoke or soot inside the build chamber, porosity and other defects are a direct result of this vapour being trapped in the melt pool. Furthermore, excessive vapourisation of the lighter components causes compositional variances, which can be so severe that the final part no longer conforms to the alloy specification.

As mentioned earlier, an example of where metal vapourisation can be particularly problematic is in keyhole welding. Keyhole welding is often unavoidable when processing highly reflective alloys such as aluminium and copper. Keyholes made with a Gaussian beam often collapse and leave vapour-entrained pores deep in the part.

In many instances, the need to move from conduction to keyhole welding is avoided when processing with ring beams. For example, Baldi *et al.*, demonstrated widened process windows when processing pure zinc for future battery electrodes with AFX, attributable to a shallower penetration depth that avoided the keyholing phenomenon [5].

The future of PBF-LB metallurgy with beam shaping

Many metallurgical benefits of ring beam processing have been explored in the academic and research communities and the resulting innovations will soon make their way into the AM industry. Beam shaping has the potential to make materials previously considered as 'hard-to-weld' processable using PBF-LB. Candidate materials include nickel-based alloys, tool steels, select aluminium alloys, and refractory alloys. While there are many factors that lead to a lack of weldability,

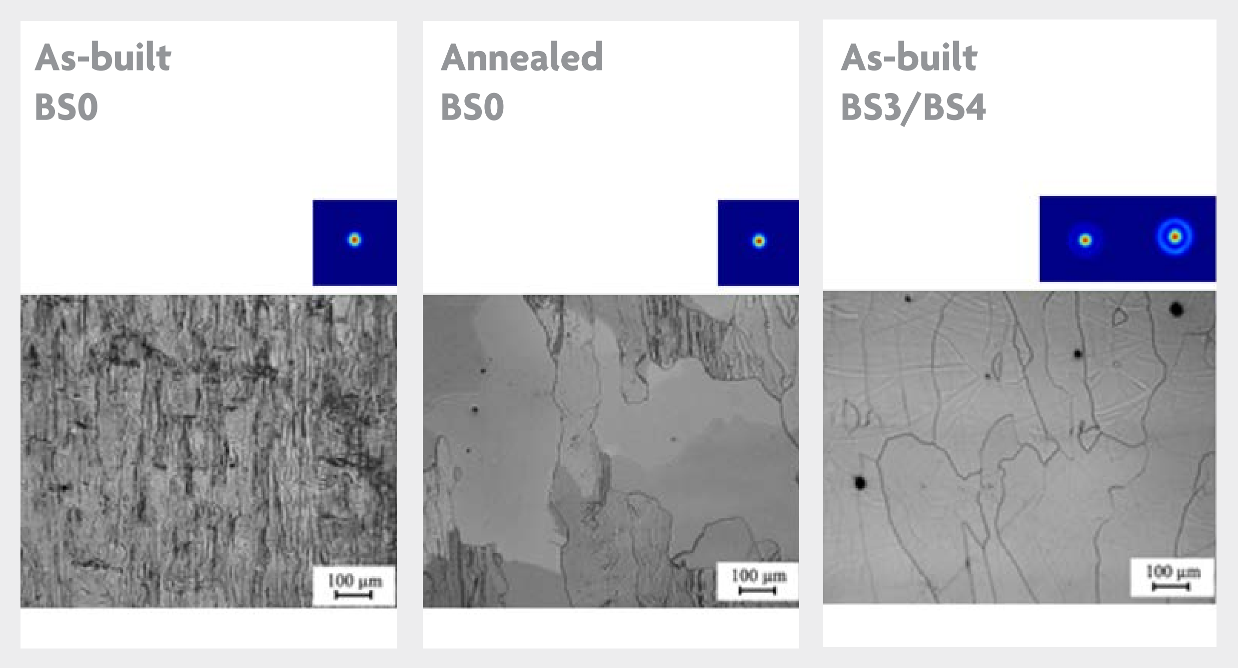


Fig. 11 Laser beam shaping is shown to promote more homogenous, equiaxed microstructures in as-built parts, similar to what is observed post-heat treatment [6, 7] (Courtesy Politecnico di Milano)

hot cracking is a leading factor. Ring beam profiles enable greater control over the melting process in terms of peak temperatures, spatial gradients of temperature, as well as transient heating and cooling rates.

Having the ability to use different beam profiles allows for control of the microstructure and, thus, the local material properties, providing previously unattainable performance and functionality from PBF-LB parts.

In addition, controlling the microstructure results in less part-to-part variance and introduces the possibility of reducing post-processing steps. Reducing post-processing steps could significantly improve the economics of metal AM, which is critical for the broader adoption of PBF-LB as a standard, large-scale manufacturing process.

Galbusera *et al.*, demonstrated the possibility of eliminating post-process annealing when processing iron silicon alloys, an important material system for next-generation electric motors, with AFX beam shaping [6, 7]. The ring-shaped beam promoted a more homogeneous, equiaxed microstructure, which is crucial in order to maximise the magnetic permeability of the iron silicon material system (Fig. 11).

In addition, Pérez-Ruiz *et al.*, studied beam shaping for tailoring the mechanical properties of Inconel 718 and concluded that processing with the ring-shaped AFX beam can significantly increase the range of mechanical properties in the material [8].

The turbine blade pilot study completed by Aconity3D to showcase productivity (Fig. 6) also included microstructure tuning across the part for achieving mechanical properties optimised for its intended use. The turbine blades experience high stress at the base, so a more equiaxed microstructure could be incorporated here for increased strength, whereas the middle and upper sections were optimised for productivity and longitudinal strength, illustrating

"The turbine blades experience high stress at the base, so a more equiaxed microstructure could be incorporated here for increased strength, whereas the middle and upper sections were optimised for productivity and longitudinal strength."

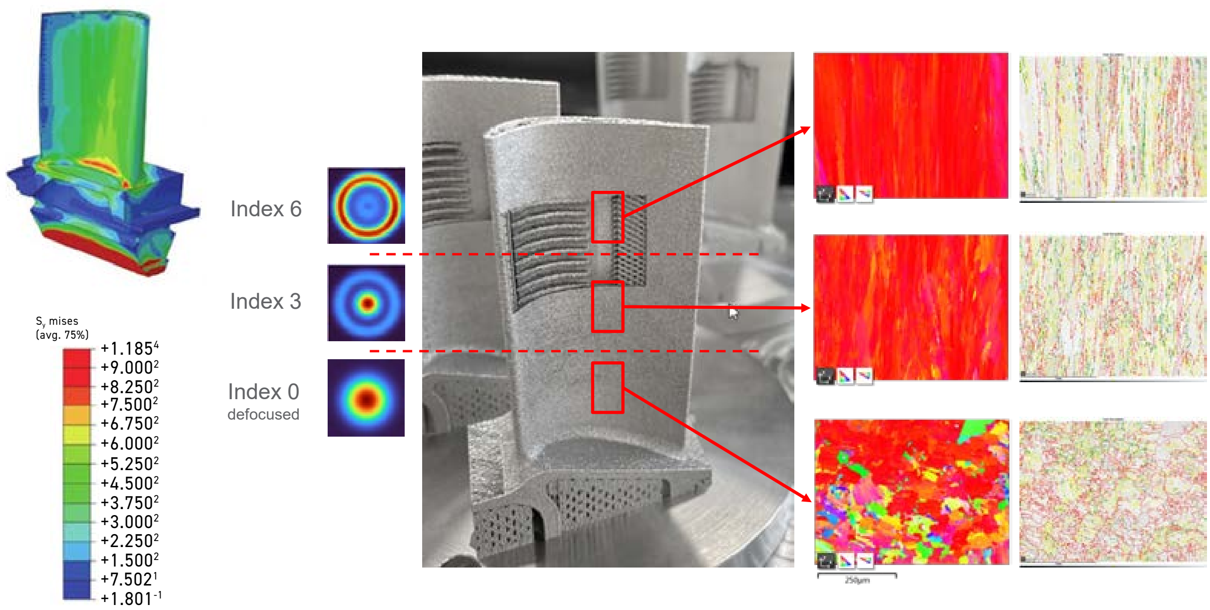


Fig. 12 Applying beam shaping to locally optimise microstructures for the enhanced functional performance of a turbine blade (Study conducted by Aconity3D GmbH, using geometry provided by Access e.V. and B&B-Agema GmbH)

how microstructures can be adapted to the different load cases in different areas of a part (Fig. 12).

The shape of the future

For PBF-LB to be broadly adopted across a wider range of industries, the economics simply have to make sense. We need an economical and repeatable way to boost productivity in PBF-LB machines, and Gaussian beam profiles have met their limit. Beam shaping will drive productivity levels, process stability, and metallurgical capabilities in PBF-LB machines in a way that cannot be achieved with standard single-mode lasers, irrespective of how many lasers are used.

nLIGHT's Corona AFX lasers are the first industrially robust and economically reliable beam shaping lasers developed specifically for PBF-LB. These lasers are already deployed in commercial PBF-LB machines, from single- to large-format multi-AFX platforms, and are finally delivering the productivity and quality required to drive part costs down to enter new markets. Considering the productivity economics and metallurgical possibilities, dynamic laser beam shaping is poised to become the new standard for PBF-LB.

"Beam shaping will drive productivity levels, process stability, and metallurgical capabilities in PBF-LB machines in a way that cannot be achieved with standard single-mode lasers, irrespective of how many lasers are used."

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Acknowledgements

The authors would like to acknowledge the contributions from Aconity 3D, DMG Mori USA, EOS GmbH, AMCM GmbH, Technical University of Munich, Politecnico di Milano, Fraunhofer IAPT, and FLOW-3D.


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Enabling the fusion energy revolution: Mastering tungsten with PBF-EB Additive Manufacturing

There is a growing interest in additively manufactured pure tungsten, primarily propelled by the expected demand for tungsten components in future fusion power plants. Here, Additive Manufacturing veterans and PBF-EB enthusiasts, Ulf Ackelid and Ulric Ljungblad – both of Sweden's Freemelt AB – provide insights into the AM of tungsten and the benefits of using an electron beam as the energy source. This article is a standalone continuation of previous PBF-EB articles in *Metal AM*, published in the Summer 2020, Autumn 2022, and Summer 2023 issues.

Tungsten is an element with Swedish and Spanish heritage. The famous Swedish chemist, Carl Wilhelm Scheele, identified tungsten (the name is a portmanteau of the Swedish words for heavy stone, 'tung' and 'sten') in 1781 as the major constituent of the ore scheelite, later identified as calcium tungstate ($CaWO_4$). Two years later, the Spanish chemist brothers, José and Fausto de Elhuyar, found a reduction process that isolated pure tungsten metal from its wolframite ore. To this day, tungsten maintains its original Swedish name in major languages such as Spanish, English, and French, whereas the Swedes have adopted the German word 'wolfram.' The name wolfram is the origin of tungsten's chemical symbol W.

Tungsten has several outstanding material properties that make it industrially useful. It is classified as a refractory metal and has the highest melting point of all elements, 3,422°C, making it extremely heat resistant. It also has the lowest thermal expansion of all elements. Its density is as high as gold and seven times higher than aluminium. The X-ray shielding properties of tungsten are excellent, better than lead and without the environmental concerns and toxicity. Tungsten is also a good conductor of heat and electricity, is non-magnetic and has high hardness, and excels in wear resistance as well as corrosion resistance. All in all, tungsten is a unique metal.

Tungsten and tungsten alloys are used in a multitude of applications, such as heat resistant metal components, medical X-ray shielding equipment, X-ray sources, rocket

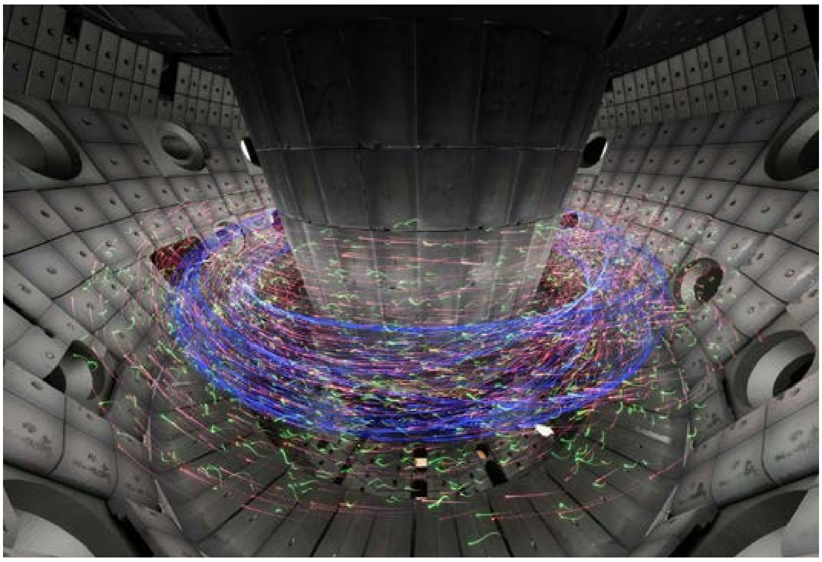

Fig. 1 Tokamak fusion reactor cladded with tiles (Copyright 2024 EPFL/ Laboratory for Experimental Museology (EM+) - CC-BY-SA 4.0)

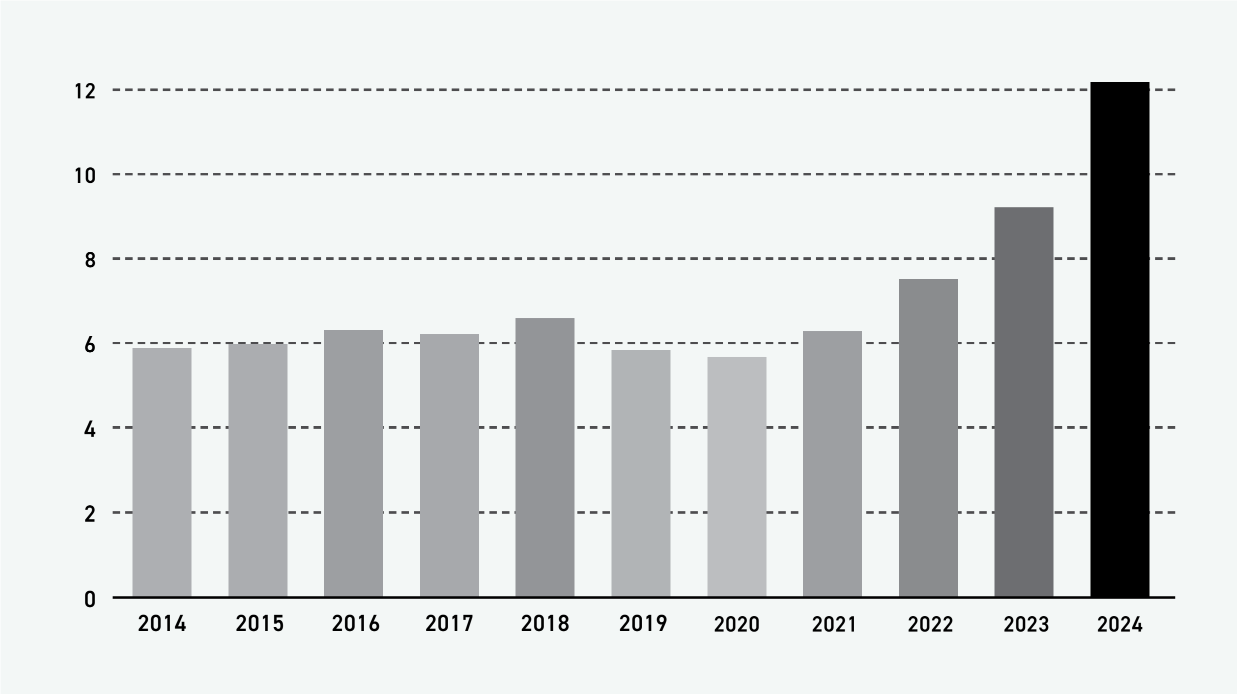

Fig. 2 The yearly percentage of academic papers containing 'Additive Manufacturing' that also contain 'tungsten' (Derived from Google Scholar search data)

engine parts, heating elements in furnaces, ammunition and armour-piercing projectiles, counterweights/ballasts for vehicles and aircraft, jewellery and welding electrodes. Tungsten is also important industrially as a constituent in tungsten carbide tools and other applications for metalworking, but that is beyond our present scope.

More relevant to our current audience is the fact that fusion energy is gaining increasing interest, and tungsten has crystallised into the prime candidate for plasma-facing components of fusion reactors (Fig. 1). This might be a reason tungsten has doubled in popularity in academic AM publications in the past three years, as indicated by Google Scholar data (Fig. 2).

Bulk tungsten metal is virtually impossible to produce via conventional hot melting technology such as casting, simply because there are no solid materials heat resistant enough to enclose molten tungsten safely and inertly. Tungsten is, therefore, consolidated via Powder Metallurgy (PM) methods and non-melt processing such as rolling or swaging. Fig. 3 summarises the conventional routes for wire, bar, and plate production, using either tungsten ore or tungsten metal scrap as the raw material (it should be noted, however, that it is difficult to machine complex shapes from tungsten barstock). The figure also shows the more recent AM route where tungsten powder can be used either in its chemically extracted form or after plasma spheroidisation. Spherical powder shape is preferred in most AM technologies due to its spreadability and packing density, but on the other hand, the spheroidisation of tungsten powder adds substantial cost

Conventionally made PM tungsten is not all milk and honey, however; some drawbacks have hampered widespread industrial use. PM tungsten often has substantial residual porosity and the material is brittle and notoriously difficult to machine at room temperature. The brittleness is partly inherent in the

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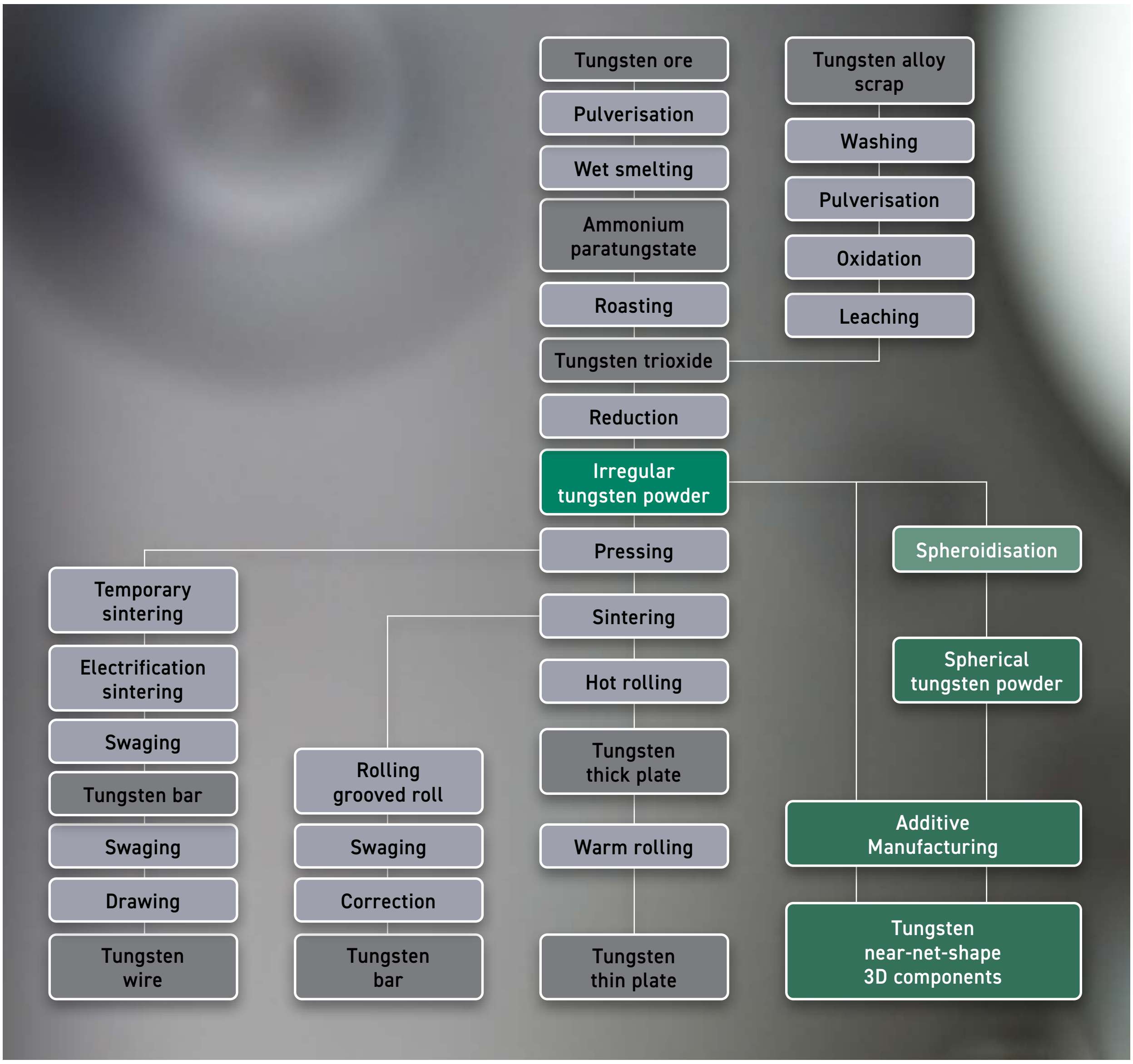

Fig. 3 Tungsten metal production flowchart. Grey = the conventional production route of bulk tungsten metal. Green = the Additive Manufacturing route (Courtesy Freemelt)

slip-resistant body-centred cubic crystal structure of tungsten, but is also due to the fact that non-melt PM fabrication always leaves some impurities such as oxygen and carbon. Impurities tend to segregate to grain boundaries and further contribute to brittleness. It should be noted, however, that tungsten becomes ductile at elevated temperatures. The ductile-to-brittle transition temperature (DBTT) has been reported in the interval 200-800°C, depending on microstructure, texture, and impurity level.

"Conventionally made PM tungsten is not all milk and honey, however; some drawbacks have hampered widespread industrial use. PM tungsten often has substantial residual porosity and the material is brittle and notoriously difficult to machine at room temperature."

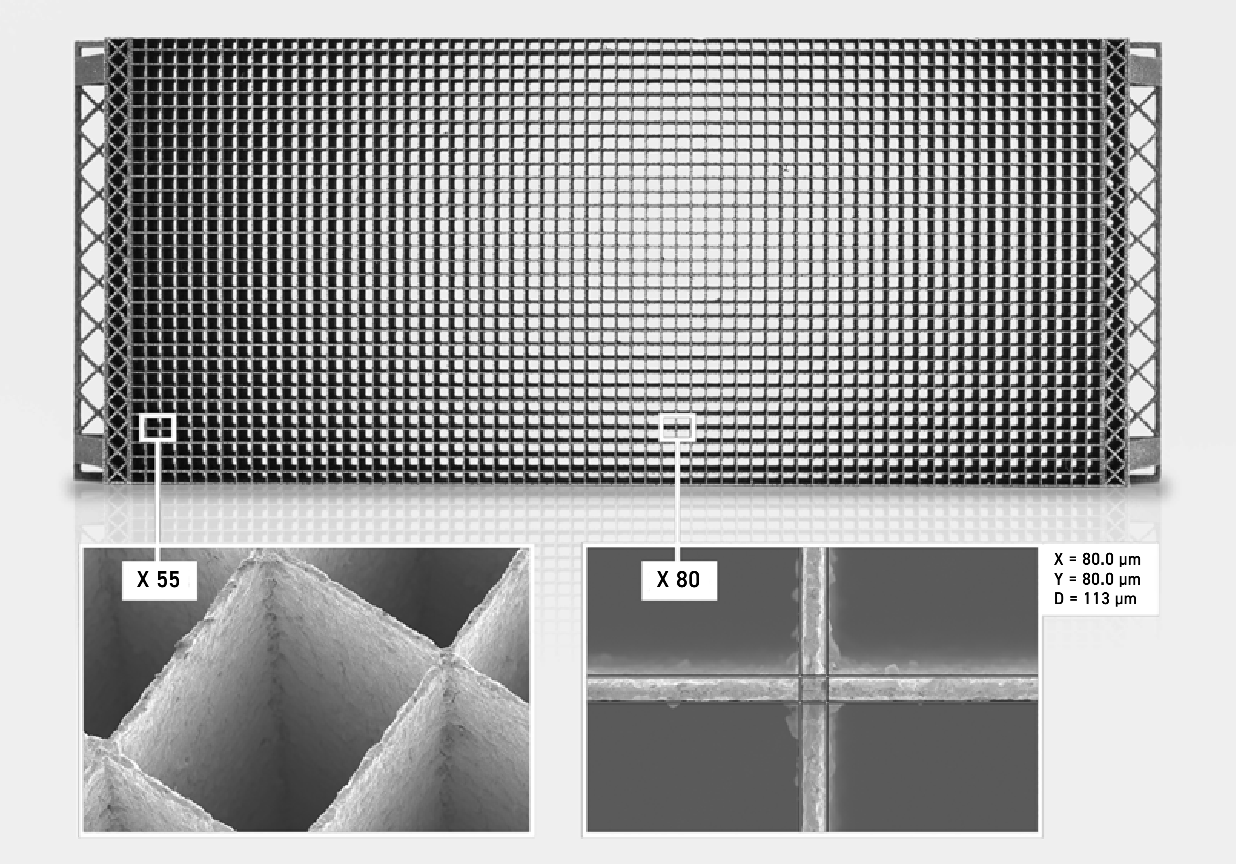

Fig. 4 Antiscatter grid made by PBF-LB (Courtesy Dunlee)

Pure tungsten processed by Laser Powder Bed Fusion (PBF-LB)

Industrial tungsten manufacturing by PBF-LB has been around for more than a decade. A well-known PBF-LB tungsten manufacturing facility is that of Dunlee in the Netherlands. Dunlee started providing its tungsten Additive Manufacturing services to the market in 2012 and successfully secured a major customer for serial production in 2014. Since then, Dunlee's business has grown with several successful tungsten applications being added to their portfolio. Their most well-known product is antiscatter grids for X-ray CT systems used in medical imaging, as shown in Fig 4. These grids are designed to absorb the X-ray scatter before reaching the detector, ensuring enhanced image quality, and they contain walls in pure tungsten as thin as 70 µm. It is obvious that such detailed geometries could not be produced by conventional PM routes. Without knowing their exact number of PBF-LB machines, it is believed that Dunlee operates the largest fleet of AM equipment dedicated to tungsten in Europe, and possibly in the world.

"There is a clear consensus that, while PBF-LB can make submillimetre thin-wall tungsten structures such as shown in Fig. 4, it struggles with dense material in thicker and bulkier shapes."

On the PBF-LB research side, there have been numerous studies exploring tungsten manufacturability [1-6]. There is a clear consensus that, while PBF-LB can make sub-millimetre thin-wall tungsten structures such as shown in Fig. 4, it struggles with dense material in thicker and bulkier shapes. As PBF-LB parameters are optimised for low bulk porosity, microcracks appear in PBF-LB tungsten, and the main reason is accumulated stress as the melt pool cools down to the brittle temperature regime of tungsten, far below the DBTT. Fig. 5 shows an example of such cracks. A few attempts have been described where the PBF-LB build platforms were heated up to 1,000°C [7], but some cracks persisted even at such high build temperatures. A hot build platform introduces another problem: the high propensity of hot tungsten to pick up impurities from the shielding gas in the PBF-LB machine. As already mentioned, impurities in tungsten will further increase its brittleness.

In conclusion, the authors are unaware of any established solution for manufacturing dense and crack-free parts of arbitrary bulky shape in pure tungsten using PBF-LB.

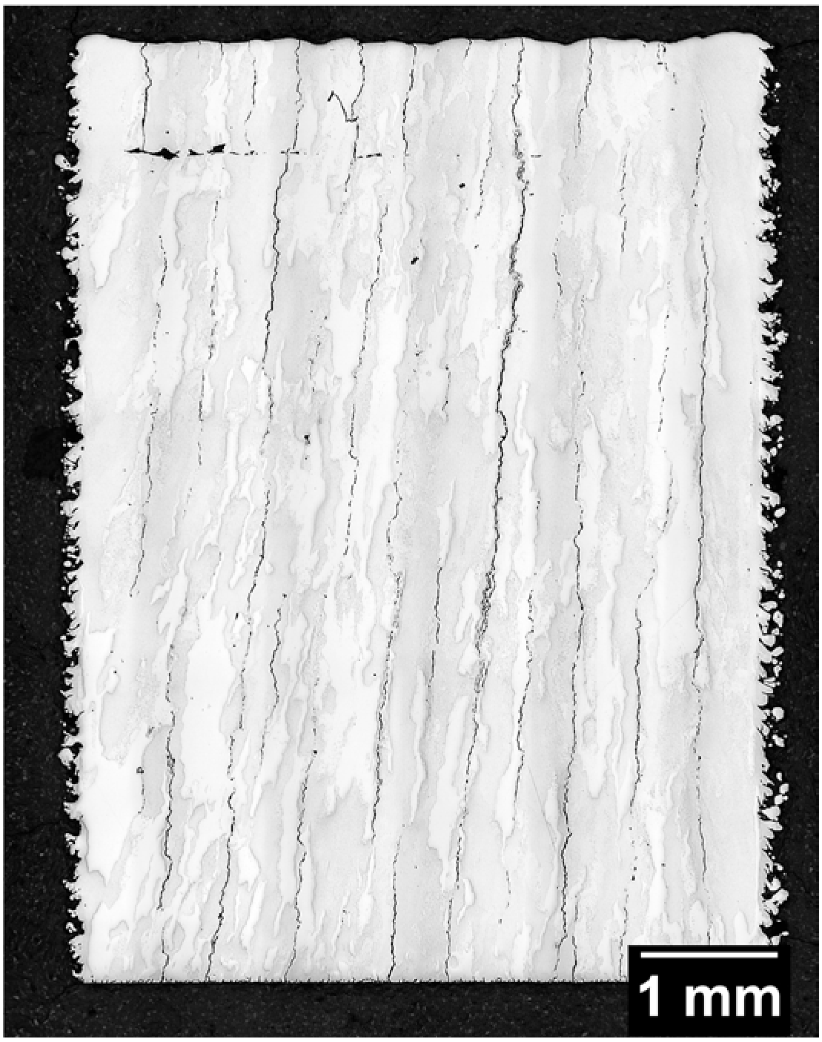

Fig. 5 Microstructure cross-section of a 5 mm thick tungsten specimen fabricated with PBF-LB, illustrating the characteristic network of intergranular cracks commonly described in the literature (from [4], with permission).

Pure tungsten processed by Electron Beam Powder Bed Fusion (PBF-EB)

PBF-EB distinguishes itself from PBF-LB by some features that could be beneficial for tungsten. Thanks to the heat insulation of the vacuum used inside PBF-EB machines, the powder bed can easily be kept at glowing hot temperatures to relieve stress and reduce the risk of cracking, and the vacuum is also a very clean environment helping to keep the tungsten free of impurities.

There are some good review papers covering PBF-EB tungsten studies [2, 3, 6]. The pioneer was Jonathan Wright at the University of Sheffield in the UK, who processed pure tungsten in 2015 as the start of his PhD project [4]. His project involved a direct comparison between PBF-EB and PBF-LB using the same plasma-spheroidised powder of typical laser size (25-45 µm). For PBF-EB, high-density and crack-free tungsten was successfully produced with the build platform temperature continuously maintained at ≈1,000°C. For PBF-LB, high density specimens could also be made at the maximum beam power of 400 W, but at the expense of cracks (Fig. 5). Wright's PhD thesis also provided the first demonstration of

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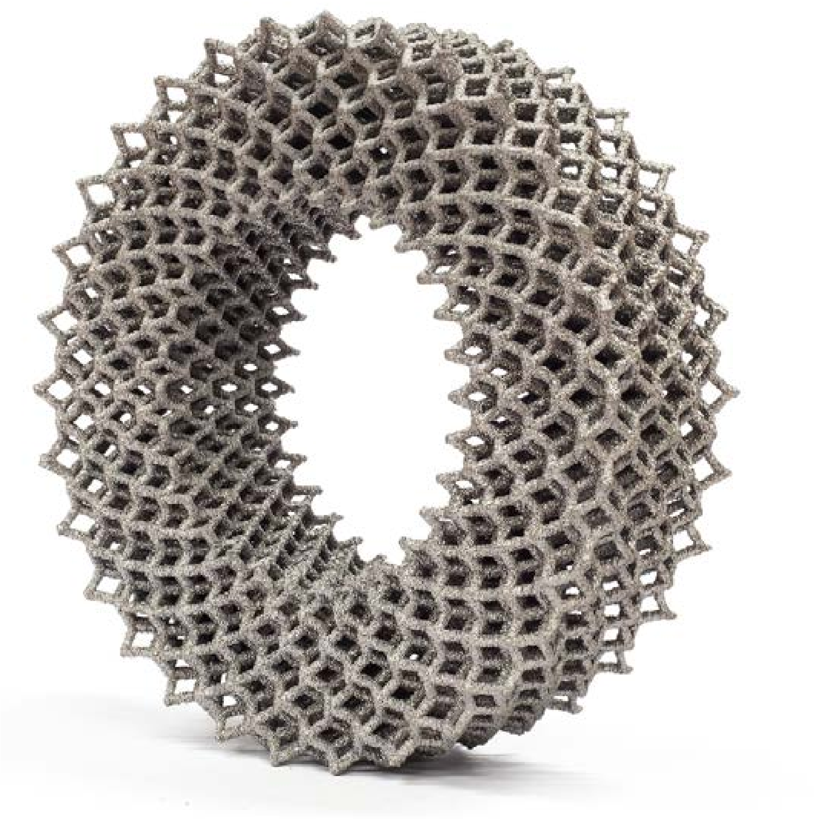

Fig. 6 Early demonstration lattice toroid built with PBF-EB at the University of Sheffield in 2016. The outer diameter is 80 mm (from [4] with permission)

more complex PBF-EB geometries, such as the beautiful tungsten lattice toroid in Fig. 6. All Wright's PBF-EB work was done in an Arcam S12 machine.

Another institution that has contributed significantly to PBF-EB tungsten development is Oak Ridge National Laboratory (ORNL) in Tennessee, USA. ORNL is the largest national laboratory under the US Department of Energy, and one of its focus areas is sustainable energy sources of the future, such as fusion power. ORNL has been continuously active in PBF-EB materials research for 15 years and refractory metals have been the main effort for the past five years.

ORNL has explored powder bed temperatures as high as 1,800°C to find the optimum conditions for tungsten processing. The team has seen that the oxygen content drops as the tungsten powder is fused by the electron beam, and single ppm levels of oxygen have been reported in the built material. This seems very promising to counteract brittleness. The organisation further reports that its dense and crack-free PBF-EB tungsten has good tensile properties at high temperatures, resembling high-quality PM tungsten in its annealed and recrystallised state.

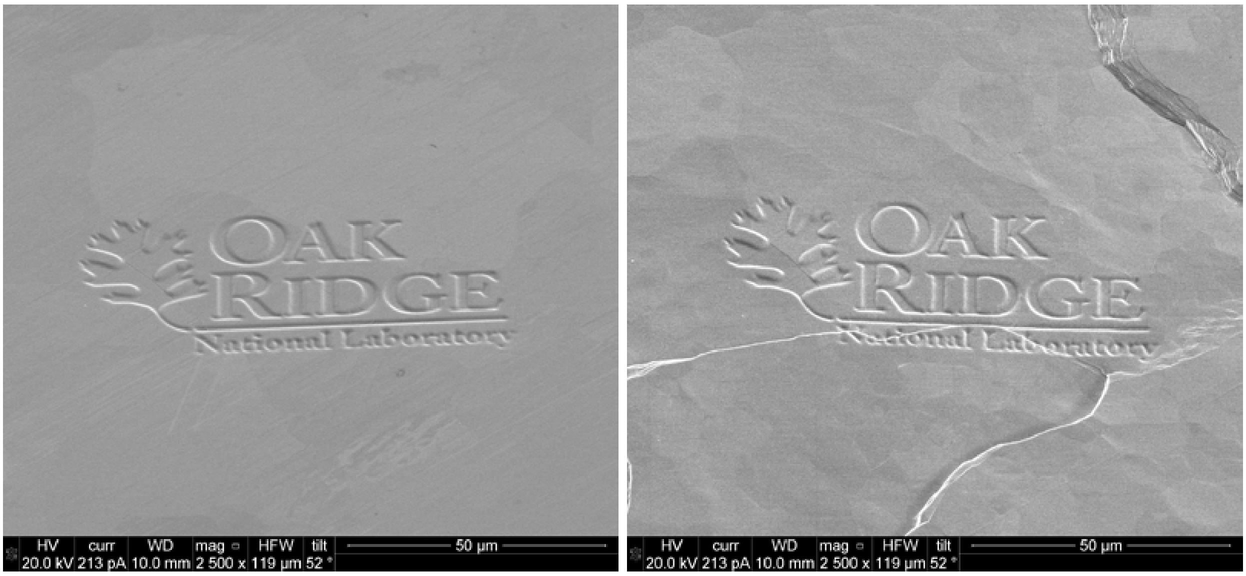

Fig. 7 PBF-EB tungsten specimens exposed to high heat flux fusion plasma at the DIII-D National Fusion Facility. Before exposure (left) and after exposure (right) (Courtesy of ORNL and Sandia National Laboratory - photos taken by J Coburn and R Kolasinski)

In May 2023, PBF-EB specimens built by ORNL were exposed to combined high heat and particle fluxes in the DIII-D National Fusion Facility in San Diego, to assess their plasma-facing material response in comparison with conventionally made recrystallised tungsten of high purity [9]. Fig. 7 shows scanning electron micrographs before and after the exposure. PBF-EB tungsten exhibited some surface roughening, grain growth and crack initiation, but less severe than the reference specimen. The PBF-EB specimens did not exhibit unique failure modes such as flaking or material ejection. In conclusion, PBF-EB tungsten demonstrated comparable or better results in terms of thermo-mechanical response and surface damage.

ORNL has also demonstrated its tungsten processing capability in test geometries relevant to fusion energy. Fig. 8 shows hexagonal tile geometry, which represents a tile for potential use in the diverter or inner wall of a Tokamak fusion reactor. The tiles are mounted on additively manufactured rods with internal passages for flowing cooling gases to the tiles.

The plasma-facing properties of PBF-EB tungsten have also been investigated recently in Europe, within the framework of the EUROfusion Consortium [10]. A team led by Karlsruhe Institute of Technology in Germany fabricated tungsten specimens via PBF-EB and combined them with novel copper cooling structures (Fig. 9). The tungsten specimens were exposed to various tests simulating fusion reactor conditions. They survived thermal shock testing in the JUDITH facility in Jülich without macroscopic failure. They also withstood the exposure to high heat fluxes at the GLADIS facility in Garching, with some near-surface grain growth as the only concern. A new test campaign with optimised geometries and improved cooling structures is in the pipeline.

Note that [10] also contains a general material characterisation of PBF-EB tungsten compared with reference material in rolled PM

Fig. 8 PBF-EB built diverter geometry with tungsten plasma facing tiles (Courtesy ORNL)

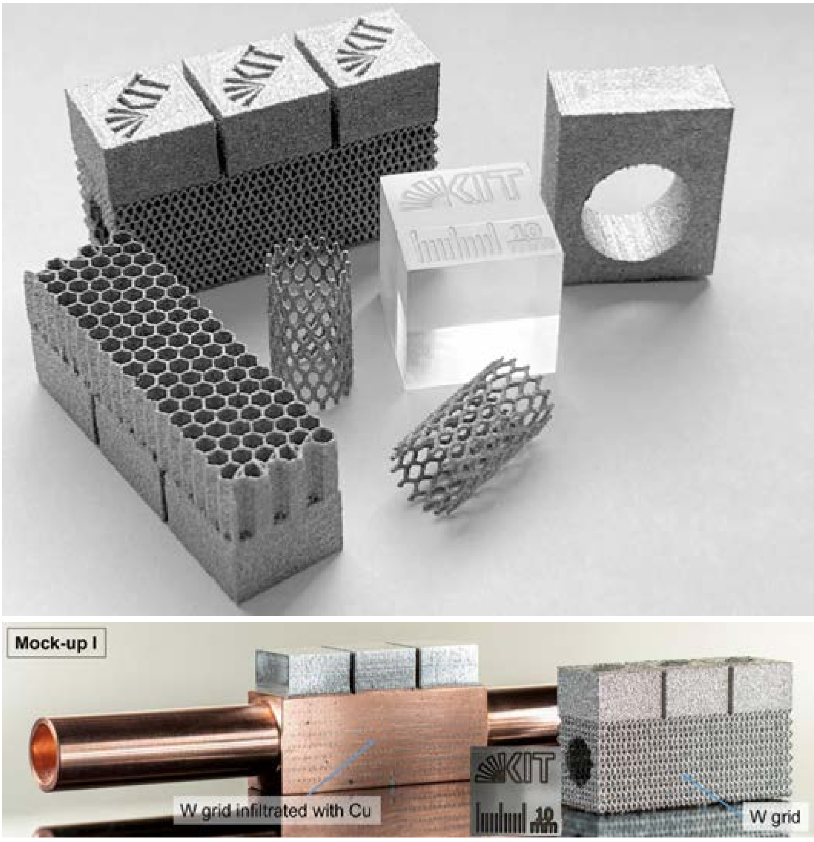

Fig. 9 PBF-EB tungsten samples built in the EUROfusion study (top photo). Mock-up for high-heat-flux testing, made by PBF-EB tungsten and copper infiltration (above photo) (Copyright © 2024 Karlsruhe Institute of Technology, CC-BY-4.0 [10])

Fig. 10 The new eMELT®-iD system from Freemelt (Courtesy Freemelt)

Fig. 11 Tungsten cube, 30 x 30 x 30 mm, built in Freemelt ONE®. The side surfaces have been polished afterwards and do not show any porosity or cracks. The density is estimated at >99.8% based on density measurements of similar cubes (Courtesy Freemelt)

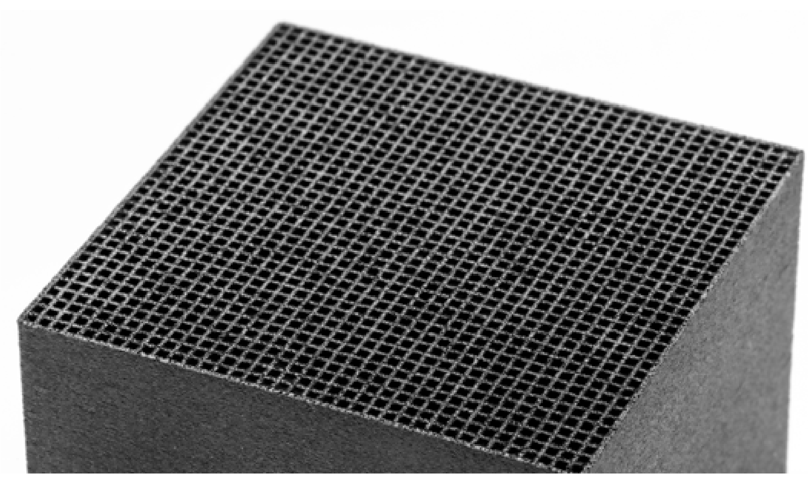

Fig. 12 Mockup of a thin-walled tungsten grid with square cells, built in Freemelt ONE (Courtesy Freemelt)

tungsten. The density was 99.8% and the microstructure was columnar and crack-free. Thermal conductivity and thermal diffusivity were similar to the reference material. Hot tensile testing at 600-1,000°C showed ductile behaviour with extraordinary elongation up to 80%.

Freemelt's approach to tungsten AM using PBF-EB

Freemelt AB is an AM technology supplier founded in 2017 in Mölndal, Sweden. The founding team had profound experience of PBF-EB from previous employment at Arcam AB (later GE Additive, now Colibrium Additive). Freemelt's initial business idea was to develop a small and powder-lean PBF-EB machine with open-source software, targeting universities and research institutes. This machine – the Freemelt® ONE – was launched in 2019 and has since been sold to several R&D users in Europe, North America and Asia. Freemelt ONE has many tailored features for advanced AM research, such as freely programmable beam scanning and multiple ports for user-defined process monitoring, and it can be operated with powder quantities as small as two kilograms.

Freemelt tried tungsten powder in Freemelt ONE for the first time in 2021 and quickly got promising results. At the same time, development commenced on a new PBF-EB machine series, e-MELT®, based on the same core technology and open-source platform as Freemelt ONE. eMELT is targeting serial production and is based on progress with tungsten processing and, based on an increasing number of enquiries for the material, tungsten was selected as a priority material for this machine. The eMELT-iD, shown in Fig. 10, the first machine in the eMELT series, has recently been delivered to Italy and a second order has been received from the US. eMELT-iD is intended for application development and initial production and will be followed by an even more productive machine.

Freemelt machines are capable of manufacturing high-density, crack-free tungsten parts with thick and thin cross sections. Fig. 11 shows a tungsten cube that has been post-polished to mirror finish on the side surfaces. Despite its basic geometry, this cube attracted a lot of attention in the Freemelt booth at Formnext 2023, simply because nobody had seen such a massive piece of AM tungsten before. Further examples of thin-walled tungsten geometries are seen in Fig. 12 and Fig. 13. There are several features in the eMELT machines that make them particularly suited for PBF-EB production of tungsten parts.

A grid-less electron gun based on a 'diode' design

Freemelt has developed its own grid-less electron gun based on a 'diode' design which has a stable beam spot size over the full beam power range from 0-6 kilowatts, as shown in Fig. 14. This is in contrast to the common 'triode' electron gun used in other PBF-EB machines, which has its sweet spot at low beam power and gradually deteriorating beam quality at higher beam power [11]. The diode electron gun is an advantage for tungsten processing, since the tungsten powder bed temperature is kept above 1,200°C. The diode electron gun can melt the powder layers at higher beam power which also contributes to the heating needed to maintain the powder bed at 1,200°C. Thus, less beam time will be needed for the heating sequence normally used in hot PBF-EB processes. This translates to higher productivity.

Active cooling of the build tank during and after the process

To the authors' knowledge, the eMELT machines are the first on the market to offer active water cooling of the build tank during and after the process. This contributes to higher productivity for two reasons. By continuous cooling during the process, even higher melt power and higher melt speeds can be used without the risk of overheating

Fig. 13 Tungsten nozzles built in eMELT® (Courtesy Freemelt)

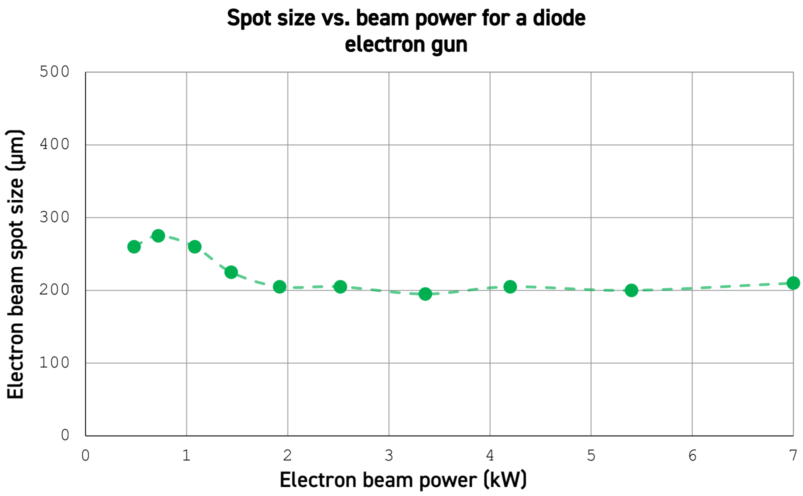

Fig. 14 Typical spot size vs beam current for a diode electron gun, illustrating the remarkable spot size stability at high beam power (Courtesy Freemelt)

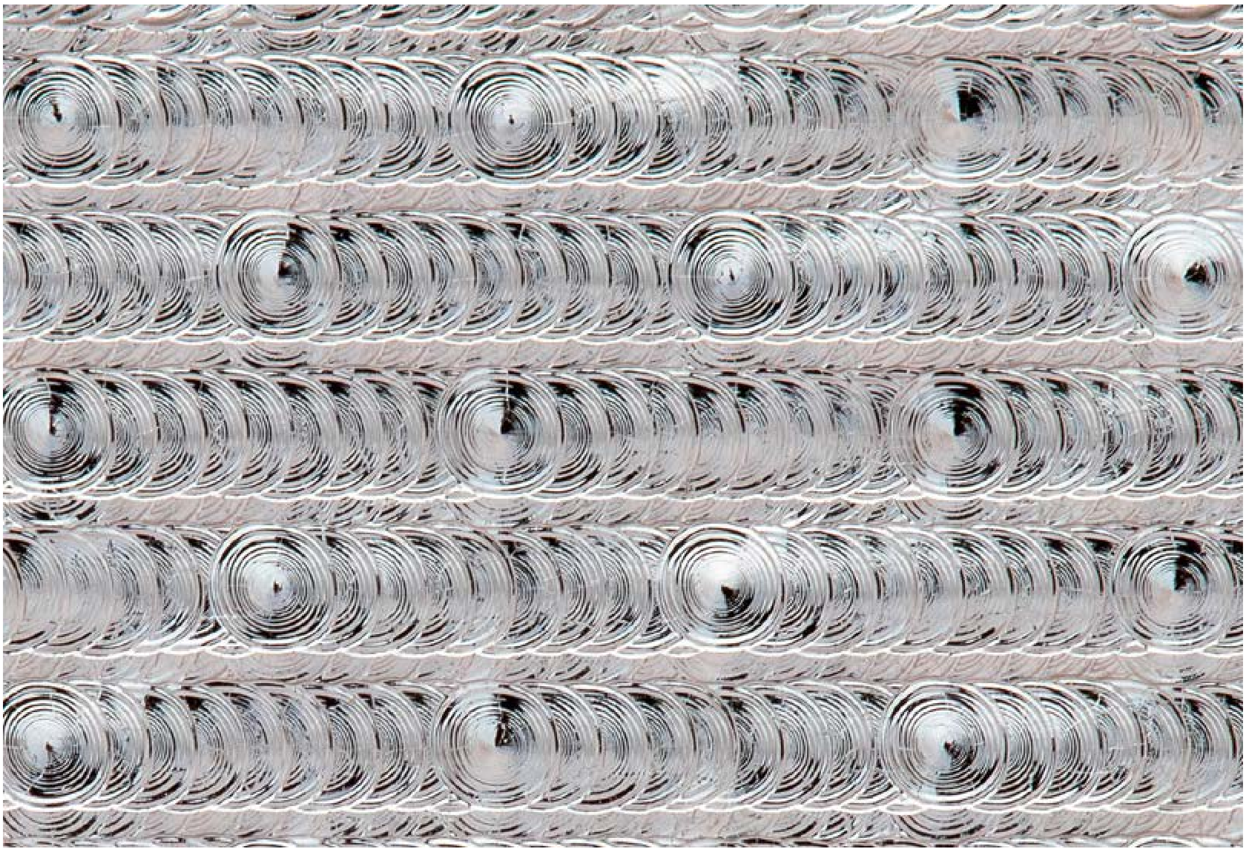

Fig. 15 An ordered Pixelmelt pattern of melt pools on the top surface of PBF-EB tungsten, imaged by optical microscopy (Courtesy Freemelt)

the powder bed. After the build is completed, the water cooling drastically reduces the post-cooling time down to room temperature. A common argument against PBF-EB in the past has been that post-cooling requires many hours of unproductive time. With active water cooling, the post-cooling time is reduced to ≈ 30 minutes for a build run at 1,200°C, if desired. This cooling principle is particularly efficient for tungsten, because of tungsten's very high thermal conductivity. The heat accumulated in the tungsten powder bed is quickly conducted to the water-cooled walls of the build tank.

A modular approach

Unique to eMELT is a dockable build module, as depicted in Fig. 10. The build module is a separable unit containing the build tank as well as the powder feeding system. An eMELT machine can be equipped with double build modules, so that one module can be in use for building tungsten parts while the second module is emptied, reloaded with powder and prepared for the next build in a standalone turnaround station. This docking concept helps to reduce the dead time between builds to a minimum and, of course, it contributes to higher productivity.

"A common argument against PBF-EB in the past has been that post-cooling requires many hours of unproductive time. With active water cooling, the post-cooling time is reduced to ≈ 30 minutes for a build run at 1,200°C..."

The importance of vacuum quality

An advantage when processing tungsten is superior vacuum quality. As previously mentioned, hot tungsten easily picks up oxygen from uncontrolled processing environments, jeopardising the material quality. The eMELT series offers the smallest vacuum chamber volume on the market, equipped with double turbomolecular pumps. This translates to a very short pump downtime and a processing vacuum as low as 10^{-5} mbar. This is an extremely clean environment, orders of magnitude better than a high-purity inert gas typically used in a PBF-LB machine. It should also be noted Freemelt technology allows tungsten to be processed without the small helium or argon bleed that is commonly used in other PBF-EB solutions. It has been observed that our clean PBF-EB vacuum conditions not only prevent oxygen pickup in tungsten – they actually purify the tungsten from oxygen as the material is fused. Single ppm levels of oxygen have been reached in the final tungsten material, which is remarkable and promising for maximum cracking resistance.

Spot melting technology

An electron beam can be scanned at very high speed (kilometres per second) over a powder bed. This opens up the potential of 'spot melting' for tungsten processing. In the past, PBF-LB and PBF-EB have traditionally employed so-called 'line melting' or 'raster melting,' where the powder layer is melted along adjacent lines using a continuously moving melt pool.

In spot melting, the electron beam melts the powder layer in a discrete fashion, creating sub-millimetre melt pools that solidify individually. The time to create one melt pool is typically in the microsecond to millisecond range, and beam jumping between melt pools is virtually instantaneous. Thus, the electron beam can create thousands of melt pools in one second.

Freemelt has developed a software solution called Pixelmelt® that assists in creating various spot melting algorithms. Figures 15 and 16 show different Pixelmelt patterns used in its tungsten builds. Fig. 15 is an ordered pattern where melt pools were created at constant beam jump distance from each other. Fig. 16 is a seemingly unordered pattern where the melt pools were distributed according to user-defined rules. Spot melting is beneficial for tungsten because it can distribute the heat evenly over the melt area, which reduces the risk of residual stress. Spot melting also eliminates the risk of macroscopic swelling that could appear for conventional line melting at very high beam powers. And, even more exciting, different spot melting algorithms will produce different microstructures in tungsten, opening up the possibility of site-specific microstructure tailoring. Based on all these benefits, it is expected that spot melting will become mainstream in PBF-EB in the near future.

Fig. 16 A quasi-random Pixelmelt pattern of melt pools on the top surface of PBF-EB tungsten, imaged by scanning electron microscopy (Courtesy Freemelt)

"In spot melting, the electron beam melts the powder layer in a discrete fashion, creating sub-millimetre melt pools that solidify individually. The time to create one melt pool is typically in the microsecond to millisecond range, and beam jumping between melt pools is virtually instantaneous. "

In-situ process monitoring

Freemelt machines are equipped with an electron detector that collects electrons backscattered from the powder bed during processing. The electron signal is converted to an image, according to the same principle as in scanning electron microscopes. Tungsten has a very high electron emission due to its high atomic number (Z=74), and thus

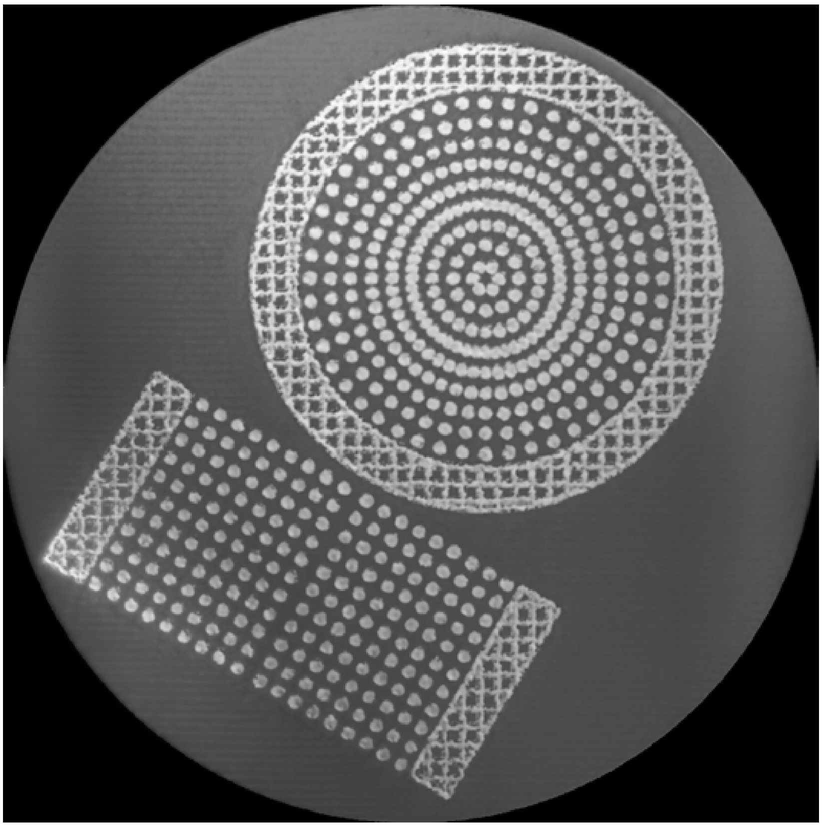

Fig. 17 A layer image from an arbitrary tungsten build, recorded with the electron detector in eMELT-iD. The bright areas are fused tungsten and the grey areas are unfused powder. The fused tungsten has a higher backscatter yield of electrons (Courtesy Freemelt)

tungsten produces excellent electron images with high contrast and good signal-to-noise ratio. An example of an electron image is shown in Fig. 17. Such images stacked on top of each other can produce a 3D image of the whole build, showing internal porosity and other potential problems. This is particularly useful for tungsten which is notoriously difficult to examine ex-situ with non-destructive testing methods such as X-ray computer tomography. Electron imaging is a robust technology that copes well with the demanding conditions in a tungsten PBF-EB machine where heat radiation, metal vapour and X-rays prevail.

> *"Additive Manufacturing opens up new possibilities of manufacturing complex 3D parts in tungsten. There is also a great potential to improve chemical purity and the density, and eliminate the defects seen in tungsten made by conventional Powder Metallurgy. "*

A new level of interest in the AM of tungsten

In the past year, Freemelt's tungsten development has entered a new phase. A number of collaborations have been initiated with institutions and companies to further explore and accelerate PBF-EB tungsten opportunities for fusion energy and other strategic areas. In Europe, projects are running together with the UK Atomic Energy Authority, the Nuclear Advanced Manufacturing Research Centre at the University of Sheffield, Mid-Sweden University, Sandvik and WEAREAM, just to name a few. In North America, Georgia Tech Manufacturing 4.0 Consortium, Texas A&M Engineering Experiment Station and North Carolina State University are collaborators, together with several undisclosed private initiatives. It is uplifting and encouraging to see such a wide interest in additively manufactured tungsten, and new results from Freemelt partners are expected to be published in the near future.

Summary and outlook

Tungsten has a rich history, unique material properties and a multitude of potential uses. Tungsten applications related to sustainable energy production and defence are attracting particular interest these days, for obvious reasons, but tungsten is unfortunately a difficult material in terms of conventional fabrication and machining. With this background, it is not surprising that tungsten is on the rise within the worldwide AM community. Additive Manufacturing opens up new possibilities of manufacturing complex 3D parts in tungsten. There is also a great potential to improve chemical purity and the density, and eliminate the defects seen in tungsten made by conventional Powder Metallurgy.

In this article, ongoing efforts to develop PBF-LB and PBF-EB technology for pure, unalloyed tungsten have been described.

"We do believe that Additive Manufacturing will revolutionise tungsten manufacturing, and we see that the present knowledge favours PBF-EB to some extent. Only time will tell where we are going. "

Arguments in favour of PBF-EB have been made, particularly for thicker tungsten parts where PBF-LB has struggled with microcracking, porosity and low productivity. Plasma-facing tiles for fusion reactors are a great example where PBF-EB tungsten could excel in the future. That said, PBF-LB may still be a good choice for tungsten applications requiring thin walls, fine details and the highest resolution, particularly if volumetric build rate is not an issue.

Yes, one could argue that we are biased since we are working for a PBF-EB technology supplier, but we are also keen scientists closely following the AM progress at R&D institutions around the world. We do believe that Additive Manufacturing will revolutionise tungsten manufacturing, and we see that the present knowledge favours PBF-EB. Only time will tell where we are going.

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Patents and Additive Manufacturing: What insights can mining PBF-EB data reveal about the industry and the technology?

Patents have had a major impact on the evolution of the Additive Manufacturing industry. They offer intellectual property protection, yet they also force the disclosure of expertise. Registering a patent also comes at a high cost, yet for those who are found to infringe a patent, the costs are even higher. But what can the data generated by the global patenting process tell us about AM? Here, Joseph Kowen and Gil Perlberg use Electron Beam Powder Bed Fusion (PBF-EB) technology as a case study to discover what patent data can reveal.

Intellectual Property (IP) protection is an important competitive tool in the arsenal of companies wishing to maximise the value of the product development in which they have invested much effort and many resources. Patents are a central mechanism to protect the value of any technology development. Many Additive Manufacturing companies, including startups short on resources, actively seek to patent their key inventions. However, companies often make a mistake in over-patenting, putting a strain on budgets without any apparent return on the investment. After all, patent protection requires resources.

Because the very notion of patents involves revealing an innovative idea, companies often submit patent applications at an early stage and leave the decision whether to go through the often-slow process of getting them granted – let alone enforcing them – to a later stage. It is well known that one needs deep pockets to enforce patents. That does not mean, of course, that one should avoid applying for them at all; indeed, investors often expect broad-scale patent protection to mitigate the risks of investment. Instead, a sensible and well-thought-out strategy should be considered the first step in patent protection.

While not all technologies warrant patent protection, those that do must undergo global patenting processes, to which companies contribute a significant and detailed amount of data about their technologies. Analysis of the data can reveal trends and trace technological relationships

Fig. 1 Patents are a central mechanism to protect the value of any technology development and many AM companies, including startups short on resources, actively seek to patent their key inventions (Image Feng Yu/Adobe Stock)

"The rate of patent applications and awards is a useful indicator of trends in an industry. Because patenting often occurs well before products are launched, patents can also be an indicator of the industry's future health and prospects."

that extend well beyond the dry legal and procedural mechanics of the patenting process. The mountain of data contains aggregated, global information on what companies and researchers are doing, and the ability to mine this data allows companies to understand the nuances of their colleagues' work and any market trends.

Why patents?

So why do companies apply for patents, and what do they hope to get out of them? Applying for patent protection offers several strategic advantages, including:

Exclusivity
A patent gives the inventor exclusive rights to use, produce, and sell the invention and prevents others from copying or using the invention without a licence.

Competitive advantage
Patent protection allows a company to establish a monopoly on its technology, thus an edge over competitors.

Revenue
Patents can be licenced to others, creating a potential revenue stream and potentially increasing the value of a business for investors and other stakeholders.

Credibility
Patents can cement a company's reputation and demonstrate its commitment to innovation.

Attracting investment and raising valuation
Patents can help attract funding from investors seeking a unique product or business idea to fund. Patents can also raise a company's valuation.

Strategic relationships
Patents often enable companies to form partnerships, joint ventures, or collaborations by ensuring protection of assets.

History of patent protection in AM

Patents have always been an important factor in the development of the Additive Manufacturing industry, with the first key patent awarded in 1986 for the Vat Photopolymerisation process of stereolithography (Fig. 2). The value of patents in safeguarding a nascent technology was illustrated by the Material Extrusion (MEX) process, of which Fused Deposition Modelling (FDM) was the first commercial offering when introduced by Stratasys in 1992. Twenty years after those MEX patents began to expire, the Additive Manufacturing industry experienced its first hyper-growth period, based on a flood of companies entering the market using the MEX process.

The number of patents applied for and awarded in the AM area also started showing high rates of growth in 2012. One factor was the ending of the monopoly on Stratasys' basic patent; new entrants began developing ideas that followed from that original technology, sparking greater interest in wider Additive Manufacturing and leading many newcomers into the industry. The rate of patent applications and awards is a useful indicator of trends in an industry. Because patenting often occurs well before products are launched, patents can also be an indicator of the industry's future health and prospects.

The *Wohlers Report* includes the number of US patent applications and awards. In 2012, fewer than 300 patents were awarded, and about 150 applications were filed. Five years later, in 2017, the number of AM-related patents awarded reached almost one thousand. That same year, the number of US patent applications outstripped the number of awarded patents by 100%. By 2020, the number of AM patents granted in the US peaked at more than five thousand, a compounded annual growth rate of almost 43% over eight years. In 2021, the number of awarded patents plateaued and has declined slightly each year since then.

Disputes and infringements

With patents so integral to the industry, there have, of course, been several disputes punctuating the history of the AM industry. Most recently, Stratasys announced that it was suing Bambu Labs – an up-and-upcoming desktop polymer MEX AM machine manufacturer – for infringement of certain patents. Recently, Continuous Composites filed a claim agaist Markforged. Markforged eventually settled the dispute in September 2024 and agreed to pay $25 million in licencing fees in exchange for a cross licence, allowing it to continue sales of its products. In the metals area, a 2018 jury case found that Markforged had not infringed patents awarded to Desktop Metal; that case has been well documented and analysed in the literature [1], so will not be covered here.

In earlier times, 3D Systems was known to avidly protect its intellectual property, which effectively maintained a competitive edge in stereolithography. Notably, Japanese companies that had begun to develop machines based on this technology in the 1980s and 1990s were blocked from selling their systems outside of Japan.

The patent data system

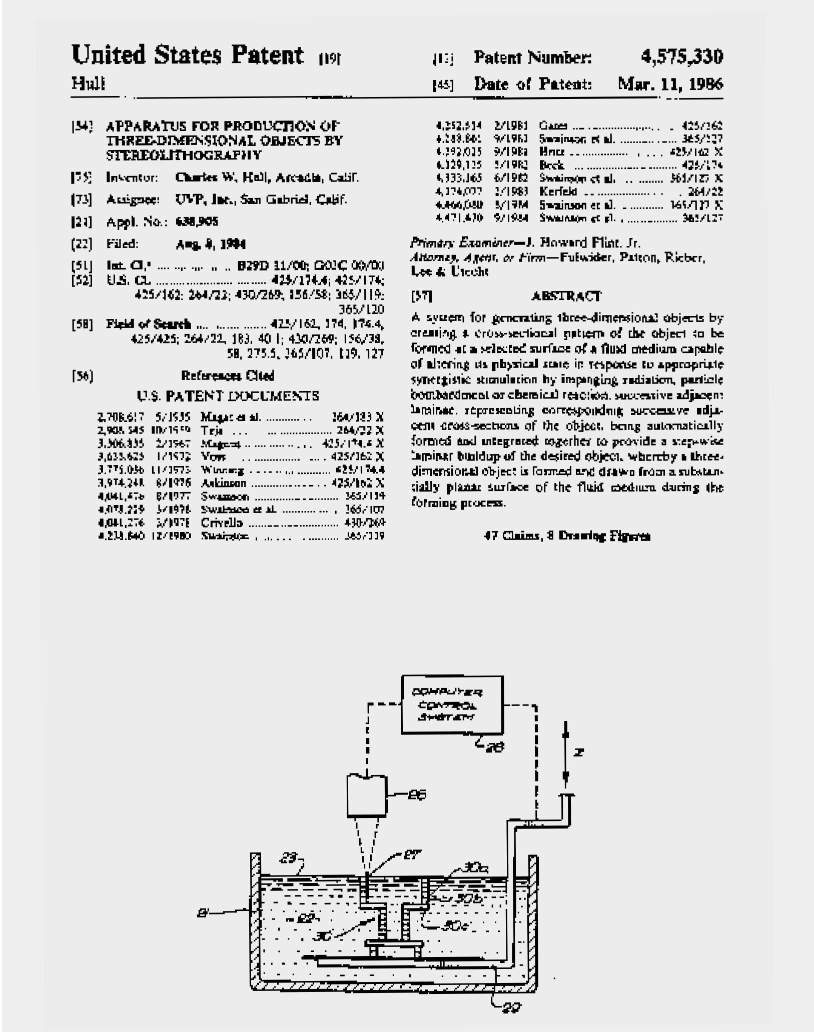
The international patent processing system is a framework that takes copious technical data and squeezes it into an established format. While each country has its own process, under international agreements such as the Patent Cooperation Treaty, an application in one country is recognised as valid and shares a priority date with patent systems in all member countries. To gain actual protection in a particular country, however, the applicant has to go through a 'national phase' in the jurisdictions of interest where it makes sense to invest in patent protection. Each jurisdiction has its own rules, filings and fee structure, which is what makes international patent protection so expensive and favours inventors from companies with deep pockets.

The filing contains a number of different kinds of data:

- Bibliographical information, including application and patent numbers, inventor information, filing dates, priority dates, and where the patent is filed
- Technical data such as the title of the invention, abstract, description, claims and drawings
- Legal status data such as filing status, date of the grant, and expiry date.

The content of the patent describes the innovation for which protection is sought. Patent offices have highly developed patent classification systems; International Patent Classification (IPC) is a common hierarchical one with different levels of detail, while the Cooperative Patent Classification (CPC) system is more detailed. The CPC was developed jointly by the European Patent Office and the United States Patent and Trademark Office to provide better accuracy and detail.

The established format for data classification and publication is what allows modern data processing methods to extract insights from data published by patent systems across the world. Most of this information is available digitally after publication which, depending on the jurisdiction, is typically eighteen months after filing. Several patent data processing and analysis products are available to ease the task of sifting through



United States Patent [19]
Hull

[11] **Patent Number: 4,575,330**
[45] **Date of Patent: Mar. 11, 1986**

[54] **APPARATUS FOR PRODUCTION OF THREE-DIMENSIONAL OBJECTS BY STEREOLITHOGRAPHY**

[75] Inventor: **Charles W. Hull**, Arcadia, Calif.

[73] Assignee: **UVP, Inc.**, San Gabriel, Calif.

[21] Appl. No.: **638,905**

[22] Filed: **Aug. 8, 1984**

[51] **Int. Cl.**[4] **B29D 11/00; G03C 00/00**

[52] **U.S. Cl.** **425/174.4**; 425/174; 425/162; 264/22; 430/269; 156/58; 365/119; 365/120

[58] **Field of Search** 425/162, 174, 174.4, 425/425; 264/22, 183, 40 1; 430/269; 156/38, 58, 275.5, 365/107, 119, 127

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Primary Examiner—J. Howard Flint, Jr.
Attorney, Agent, or Firm—Fulwider, Patton, Rieber, Lee & Utecht

[57] **ABSTRACT**

A system for generating three-dimensional objects by creating a cross-sectional pattern of the object to be formed at a selected surface of a fluid medium capable of altering its physical state in response to appropriate synergistic stimulation by impinging radiation, particle bombardment or chemical reaction, successive adjacent laminae, representing corresponding successive adjacent cross-sections of the object, being automatically formed and integrated together to provide a step-wise laminar buildup of the desired object, whereby a three-dimensional object is formed and drawn from a substantially planar surface of the fluid medium during the forming process.

47 Claims, 8 Drawing Figures

Fig. 2 The first commercially significant AM patent, awarded in 1986 for the Vat Photopolymerisation process of stereolithography

"The established format for data classification and publication is what allows modern data processing methods to extract insights from data published by patent systems across the world. Most of this information is available digitally after publication..."

Company Name	Country	Electron beam experience
GE Additive/Arcam/Collibrium Additive	Sweden	Founded 1996
Freemelt	Sweden	Founded 2017
Tada Electric (Mitsubishi Electric group)	Japan	Various applications since 1947
Wayland Additive	UK	Founded 2015
JEOL	Japan	Ebeam welding since 1949
pro-beam	Germany	Ebeam welding since 1996
Xi'an Sailong Metal Materials Co., Ltd. ("Sailong")	China	Founded 2013
Tianjin Qingyan Zhishu Technology Co., Ltd. (Qbeam)	China	Founded 2013

Table 1 The commercially active PBF-EB companies analysed for this study

vast amounts of descriptive text data and aggregate them to provide a picture of who is doing what in a particular area.

The patent system is designed to protect innovation, and so explaining how the claimed innovation differs from previously filed or granted patents is a key element of how patents are written. These new patents will, therefore, reference a previous patent for the purposes of differentiation or will be cited by patent examiners during an office action on new patents as relevant for determining the nature of the innovation. Similarly to academic papers, important prior patents will be cited more frequently than less important patents. As shall be illustrated, this serves as an indicator of the technological value and importance of the patent being cited. Big data processing methods are able to display a picture that is much more nuanced and insightful than simply listing patents having a particular CPC code.

Throughout this article, the authors have used the Lexis Nexis Patent Sight data processing platform to conduct patent analysis.

Case study: Patent analysis of Electron Beam Powder Bed Fusion (PBF-EB)

To demonstrate how complex patent data from the global patenting system can be mined for insight and prediction, we will look at a relatively compact subsection of metal AM: PBF-EB. This technology accounts for between 4-8% of sales of metal AM machines in the industry today. For comparison, the leading AM technology – Laser Beam Powder Bed Fusion (PBF-LB) – accounts for 80-90%. PBF-EB is the ISO-ASTM designation of the process, but, in the industry, and also in patent filings, the technology may be referred to as electron beam melting, EBM, Ebeam, Electron Beam Additive Manufacturing (EBAM), and Electron Beam Selective Melting (EBSM).

Laser and electron beam PBF share some common elements: the selective fusing (or melting) of metal powder in a powder bed, spreading (or recoating) a new layer of metal powder onto a previously melted layer (after the fused layer has been lowered by one layer), and then selectively melting the next layer.

While the basic technology of the electron beam was not invented for AM, the combination of melting powder by an electron beam source to selectively build a design layer by layer is the innovation of PBF-EB. Some companies active in electron beam technology for welding and electron microscopy have, in recent years, expanded into PBF-EB as a new business opportunity. This fact will require some understanding when

CPC B33Y

ADDITIVE MANUFACTURING, I.E. MANUFACTURING OF THREE-DIMENSIONAL [3-D] OBJECTS BY ADDITIVE DEPOSITION, ADDITIVE AGGLOMERATION OR ADDITIVE LAYERING, E.G. BY 3-D PRINTING, STEREOLITHOGRAPHY OR SELECTIVE LASER SINTERING

Fig. 3 The search criteria, limited to Additive Manufacturing CPC B33Y

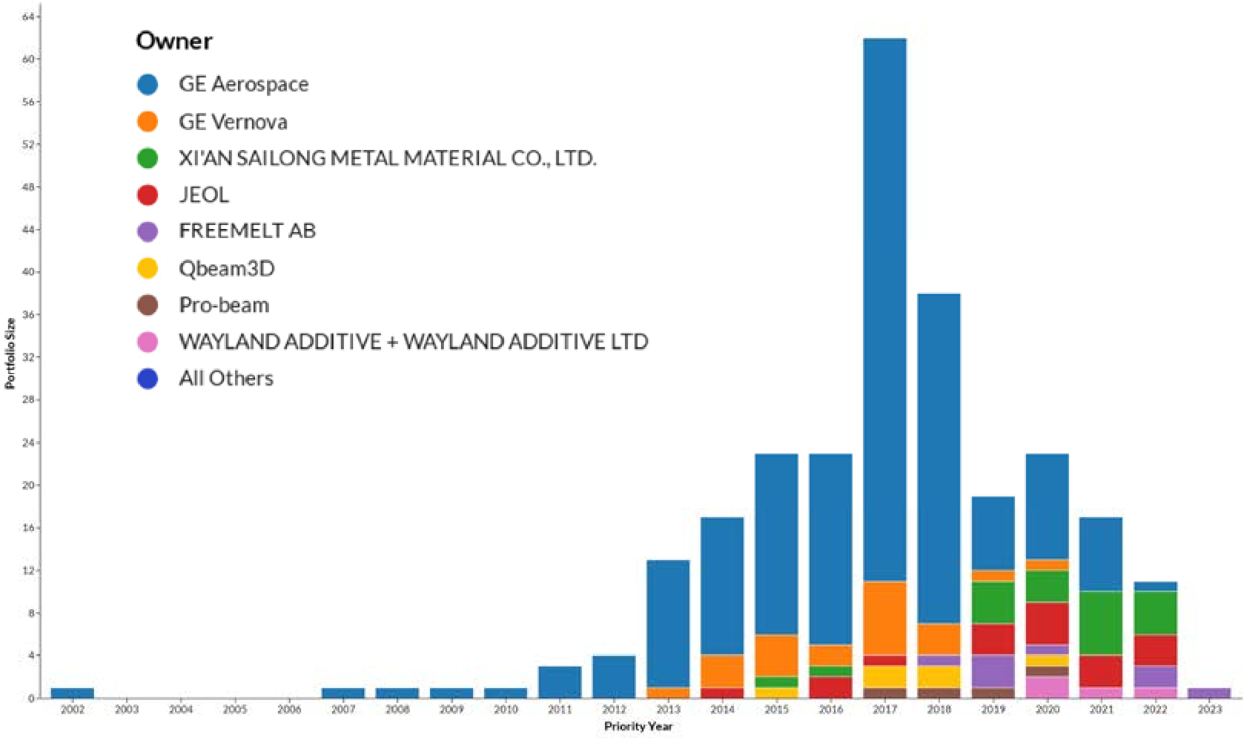


Fig. 4 AM portfolio ownership over time

searching the patent data bases, because simply searching the term 'electron beam melting' will include areas not related to AM.

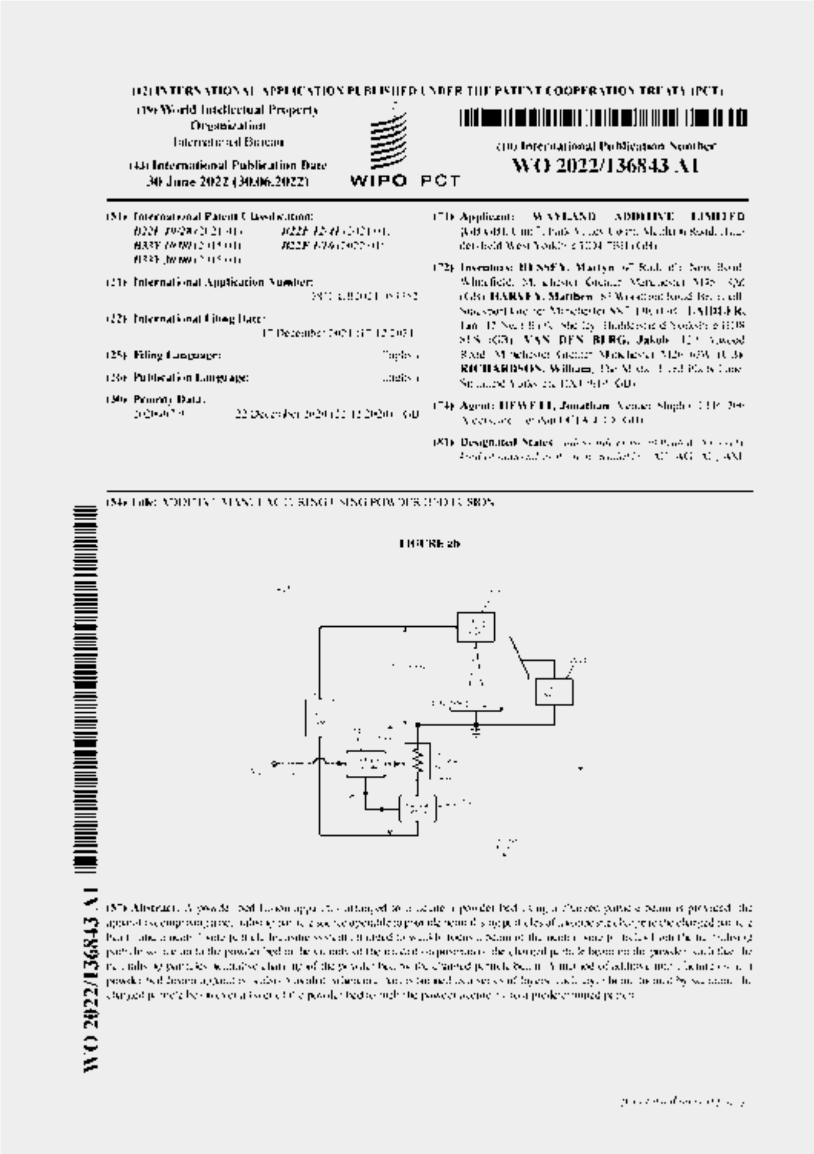
> *"The filings, as expected, were dominated by GE Aerospace or GE Vernova, the successor corporate entities that acquired Arcam and its patent portfolio. The next biggest patent filers were Chinese companies QBeam and Sailong, which began their patenting activity in around 2015."*

Selecting a portfolio

The way we began analysing the patent landscape in PBF-EB is to begin with the companies that are currently active in this area. The use of electron beam technology for AM was pioneered by Sweden's Arcam, starting in 1997. In 2016, Arcam was acquired by GE Aerospace, which established a business unit called GE Additive to manage its AM activities. In 2024, GE Additive was renamed Collibrium Additive. The patent landscape analysis also reveals M&A activities and change of ownership status. Table 1 shows the companies from around the world commercially active in PBF-EB and which were analysed for this case study.

Patents filed

A search was conducted to show the patent activity of the portfolio of companies active in the space. To filter out patent filings from large companies just as GE Aerospace and JEOL, the search was limited to Additive Manufacturing CPC B33Y (Fig. 3). To allow for filings connected to other Additive Manufacturing technologies, the search was limited to filings containing variations of the text 'electron beam' or 'particle beam.' A total of 272 applications were identified. The filings, as expected, were dominated by GE Aerospace or GE Vernova, the successor corporate entities that acquired Arcam and its patent portfolio. The next biggest patent filers were Chinese companies QBeam and Sailong, which began their patenting activity in around 2015. Starting in 2018, we find patent activity starting to appear from PBF-EB start-up company Freemelt. In 2020, newcomer Wayland Additive began to appear in the filings (Fig. 4).


(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 June 2022 (30.06.2022)

WIPO PCT

(10) International Publication Number
WO 2022/136843 A1

(51) International Patent Classification:

(21) International Application Number:

(22) International Filing Date:
17 December 2021

(25) Filing Language:

(26) Publication Language:

(30) Priority Data:
22 December 2020

(71) Applicant: WAYLAND ADDITIVE LIMITED

(72) Inventors: HARVEY, Matthew; VAN DEN BERG, Jakob; RICHARDSON, William

(74) Agent: HEWETT, Jonathan

(81) Designated States

(54) Title: ADDITIVE MANUFACTURING USING POWDER DISPERSION

FIGURE 2b

(57) Abstract:

WO 2022/136843 A1

Fig. 5 Wayland Additive's innovation has generated quite a bit of attention since its filing at the end of 2020 in the UK

> ***"A deeper understanding of the filings is revealed when we examine what is known as 'External Technology Relevance.' This measure is calculated to answer the following question: How frequently are patents of a particular company cited in subsequent patent applications by all other applicants?"***

A deeper understanding of the filings is revealed when we examine what is known as 'External Technology Relevance.' This measure is calculated to answer the following question: How frequently are patents of a particular company cited in subsequent patent applications by all other applicants? A surprising result in technology relevance is Wayland Additive. Although Wayland has to date filed only five electron beam patents (they may have filed other applications relating to mechanisms and devices in their machine, such as powder handling), the external technology relevance is already relatively high, suggesting that their innovation has generated quite a bit of attention since its filing at the end of 2020 in the UK in filing 2020407.9 (GB) (Fig. 5).

Based on what the company has announced and what has been published in past issues of *Metal AM* magazine, it developed a method of neutralising charged particles in the powder bed, a well-known issue in PBF-EB technology. The commercial expression of this innovation is called NeuBeam. It turns out that in the patenting world, this patent application garnered a great deal of attention.

Relevance over time

One would expect that a patent or patent application that has been around for a long time would be cited more frequently than a new patent application. Therefore, a patent garnering more attention closer to its filing date should be considered a significant patent.

Fig. 6 reveals that the youngest patent application plotted against external technology relevance is a filing by Chinese company Sailong. Even though it was filed only two years ago, it has attracted a relatively significant amount of attention. The patent is entitled 'A method for improving surface quality of an Additive Manufacturing part and an Additive Manufacturing device.' The industry has evidently taken note.

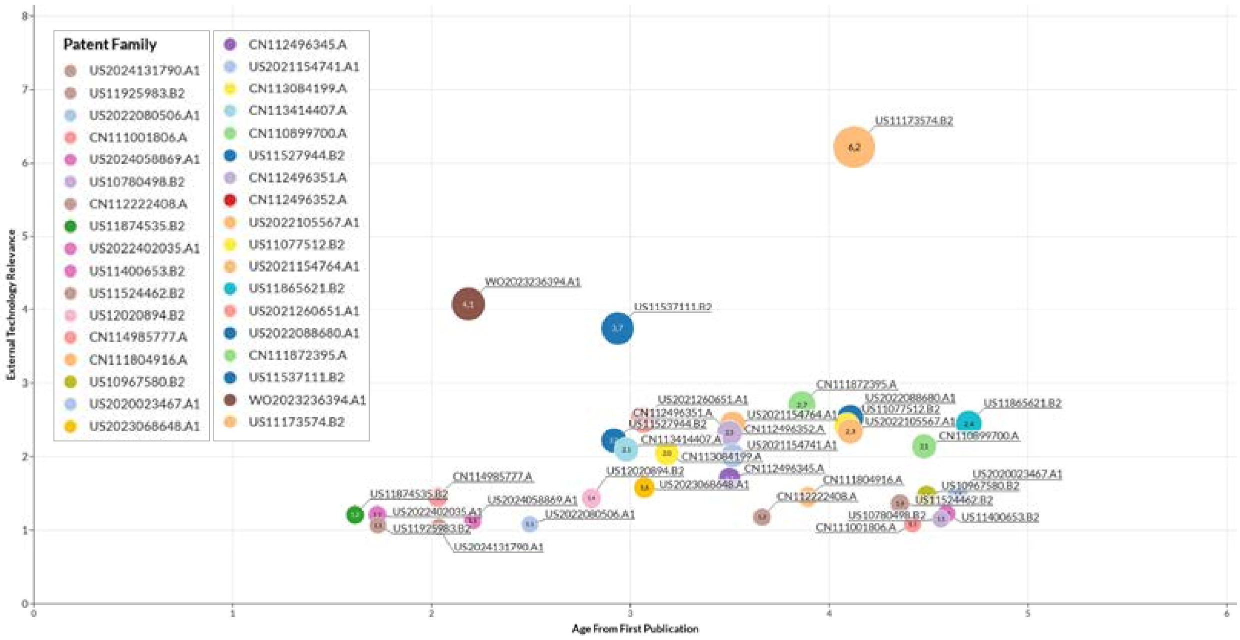
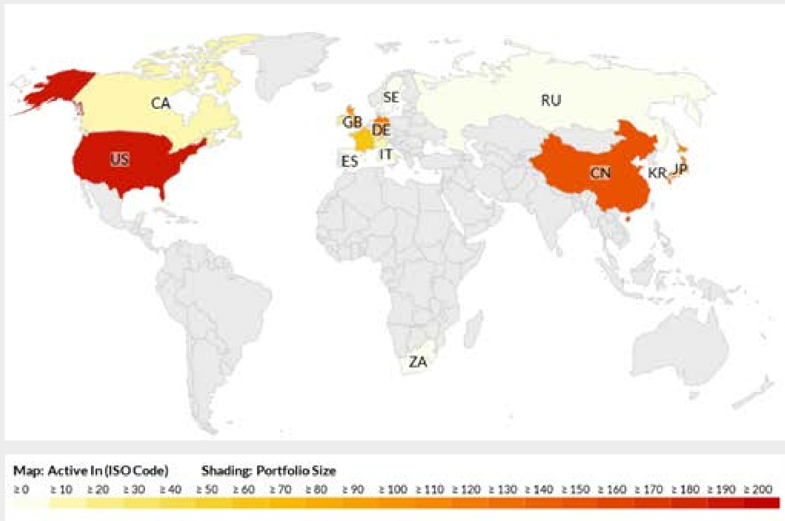


Fig. 6 Patent quality over time – five year analysis

Where did the applicants seek protection?
As expected, the US dominated when searching where the PBF-EB portfolio was active. China showed very active patenting applications, more than in either Europe or Japan (Fig. 7).

Patents in PBF-EB: taking a broader view
Who else is patenting more broadly in this field, even though there is probably no intention to commercialise the invention as a standalone product? Processing from the patent data set indicates that the academic segment is quite active in this space.

This analysis uses a CPC classification to limit the search to patents only relating to the making of articles using metal powder. This classification (B22F) includes patents for Powder Metallurgy, such as Metal Injection Moulding. To filter out the general Powder Metallurgy or metal Binder Jetting patents, the search was limited to those patents referencing electron beam technology.



Filed in	Portfolio size
USA	222 (81.9%)
China	198 (73.1%)
EPO	190 (70.1%)
Japan	139 (51.3%)
Germany	137 (50.6)
United Kingdom	123 (45.4)
Switzerland	117 (43.2)
Ireland	115 (42.4%)

WIPO	100 (36.9%)
Liechtenstein	75 (27.7%)
France	72 (26.6%)
Canada	17 (6.3%)
Italy	16 (5.9%)
South Korea	10 (3.7%)
Brazil	8 (3.0%)
Sweden	7 (2.6%)
Russia	6 (2.2%)

Fig. 7 Geographical relevance

CPC B22F

WORKING METALLIC POWDER; MANUFACTURE OF ARTICLES FROM METALLIC POWDER; MAKING METALLIC POWDER (MAKING ALLOYS BY POWDER METALLURGY C22C); APPARATUS OR DEVICES SPECIALLY ADAPTED FOR METALLIC POWDER

Fig. 8 A CPC classification to search for patents relating to the making of articles using metal powder. This classification (B22F) includes patents for Powder Metallurgy related processes

It turns out that 135 academic institutions have filed for patents touching upon PBF-EB in some way. Of the eleven institutions in this area with a portfolio size of more than ten patents, ten are from China. Fraunhofer is the only institution from western countries that makes the listing of top patenting institutions in PBF-EB. Among smaller portfolio sizes (less than ten patents per institution), we start to see additional western institutions.

However, when one ranks filings by academic institutions according to relevance, a different picture emerges: only three Chinese institutions make the top fifteen.

This finding supports the relatively well-known fact that Chinese institutions and the Chinese government encourage researchers and companies to file patents. Since the patent process is expensive, without budgetary support, many of these patents would probably not be filed. Time will tell how many of these applications are worth anything. One thing is clear, though: once an idea has been included in a patent application anywhere, it effectively becomes common knowledge. If not claimed, the patent owner does not have a monopoly. The ideas revealed in patent filings can, therefore, be used by anyone, meaning that competitiveness relies on who actually makes a good product that uses the innovation and who can produce it more cost-effectively.

Invented in China

Since China seems to be an up-and-coming market, where patents are being filed both by Chinese organisations and international companies seeking patent coverage in China, we can zoom in to get greater clarity on the China patent landscape in recent times.

The data reveals that forty-one organisations have filed at least three patent applications in the electron beam area in the last three years. Of them, twenty-three were universities or research institutes, and sixteen were companies; the remainder was the government. Among the companies, Sailong was by far the most active in patenting technologies, with thirty-three patent applications since January 2021. The other commercially active company offering a PBF-EB machine, Qbeam, has not appeared to have filed applications since 2021.

The second most active company was the China Aviation Industry Corporation. Since there is no evidence that this company plans to offer a PBF-EB machine, we can assume that their patenting interest relates to applications of PBF-EB for the aerospace industry.

Active in PBF-EB

Worldwide, several companies are active in PBF-EB patenting, even though they are not directly involved in the development of machines and, instead, are probably mainly interested in applications of the technology.

Table 2 lists companies with at least eight patents in PBF-EB AM. The usual suspects, such as GE, JEOL and Sailong, appear here. A second group of companies, such as Siemens Energy, RTX, Stryker and Boeing, use the technology for their own businesses.

Another group of companies consists of AM suppliers of PBF-LB machines, including EOS, Trumpf, Sodick and Nikon. Could these companies be planning in the future to expand to PBF-EB? Could they be considering acquisitions? Could they merely be covering their bases by adding electron beam to their core PBF-LB businesses? The patent data can tip us off to further examine what companies' plans may be in the space.

Proterial is a diversified Japanese industrial manufacturing concern that has roots in Hitachi Metals, with annual sales of $7.9 billion in 2023. Could it be interested in expanding its position in AM, possibly via acquisition in the footsteps of Nikon? Could IHI Corp, a $9 billion Japanese company also be interested in AM? INEOS is a Japanese company active in the oil and gas segment with annual sales of more than $100 billion. What is their interest in AM?

Another company to note is Matsuura, primarily a manufacturer of traditional machine tools, although one that has also dabbled in AM in the past several years with laser-based hybrid machines. Could it be planning to develop an offering in PBF-EB machines?

Divergent 3D is well known in AM circles for its automotive manufacturing technology, where PBF-LB is an important component. Could it also be considering an expansion into Electron Beam? It would certainly be interesting to review the ten patents it has in its portfolio to try and find out.

Several names not usually associated with AM also pop up on the list, and it is intriguing to understand what connection, present or future, they have to the PBF-EB segment.

In conclusion

Smart mining of patent data can be insightful for AM industry competitors, analysts and investors. It can show us the technology leaders and highlight the most important or relevant patents. It can reveal territorial strengths and weaknesses. New companies can be revealed, or existing companies' plans to enter the market might be divulged. Technology mavericks owning the most cited patents can be identified. Potential collaborative efforts or business combinations can be planned.

The patent data system is a rich ecosystem containing a large amount of information. In some cases, we may not be able to learn all the answers from the data on a company's plans and business strategy, but it can certainly guide us in asking the right questions.

Company	Patents
GE Aerospace	112
Siemens Energy	33
RTX Corp	28
Sodick	23
EOS GmbH	20
Trumpf Gruppe	20
Proterial	16
IHI Corp	16
Matsuura Machinery	15
Boeing	14
Xian Sailong Additive Tech	14
Nikon	12
GE Vernova	12
Siemens	12
XI'AN Sailong Metal Material Co., Ltd.	11
Collins Aerospace (in: RTX Corp)	11
AVIC	11
Divergent 3D	10
JEOL	10
Additive Industries	10
Stryker	9
Constellium	9
ENEOS Holdings	9
China Aerospace Science & Industry	8

Table 2 Companies with at least eight patents in PBF-EB

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Processing of patent data for this article was performed using LexisNexis PatentSight+

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Additive Manufacturing for Semiconductor Capital Equipment: Unlocking critical supply chains

The global semiconductor supply chain is under immense strain as a result of geopolitical and economic factors, putting significant pressure on Semiconductor Capital Equipment (SCE) manufacturers. In this article, Emily Godsey interviews Texas A&M's Prof Alaa Elwany and Jiahui Ye, and Veeco Instruments Inc's Dr Ahmed El Desouky, to explore the benefits of metal Additive Manufacturing technologies for semiconductor manufacturing and the SCE supply chain.

Semiconductors are critical for the fabrication of the chips and microelectronics that power nearly all modern systems, serving as the brains behind a wide range of technologies, enabling everything from smartphones to autonomous vehicles. Semiconductors are not just crucial for present-day technology; they are also foundational building blocks for future advancements in areas like AI, quantum computing, advanced robotics, and biotechnology. As these fields continue to expand, the demand for semiconductors will also rise exponentially, but meeting this demand presents challenges as more pressure is placed on supply chains.

The strain placed on the global semiconductor supply chain has been exacerbated by geopolitical factors, economic factors, and natural disruptions such as the COVID-19 pandemic. On the critical path in these chains is the production of Semiconductor Capital Equipment (SCE), the highly specialised machinery required to manufacture semiconductors. SCE involves intricate components and precision tooling, making its production costly and complex. As chip manufacturers face increasing pressure to produce more semiconductor chips, they are hampered by supply chain bottlenecks like SCE.

To overcome these challenges, SCE manufacturers are exploring the use of innovative manufacturing technologies to streamline their operations and increase supply chain flexibility. While Additive Manufacturing has, indeed, been

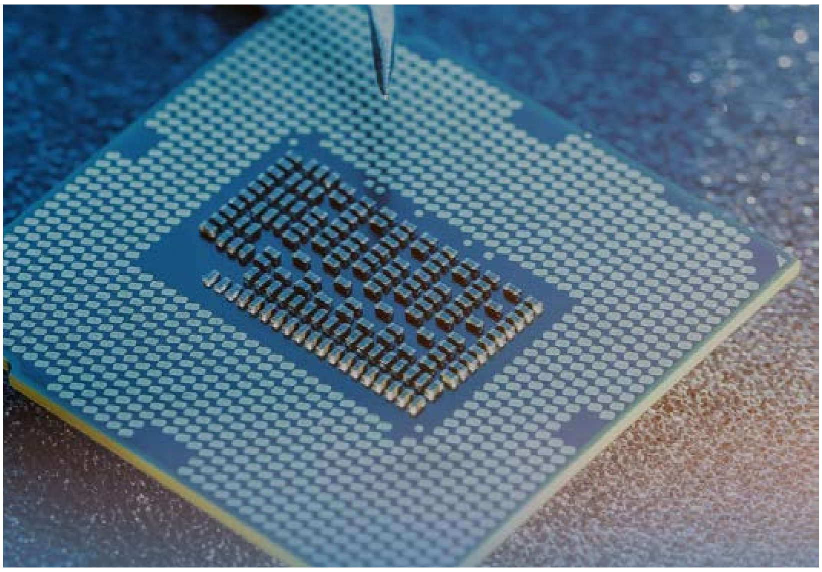

Fig. 1 The strain placed on the global semiconductor supply chain has been exacerbated by geopolitical factors, economic factors, and natural disruptions such as the COVID-19 pandemic (Courtesy Veeco Instruments Inc)

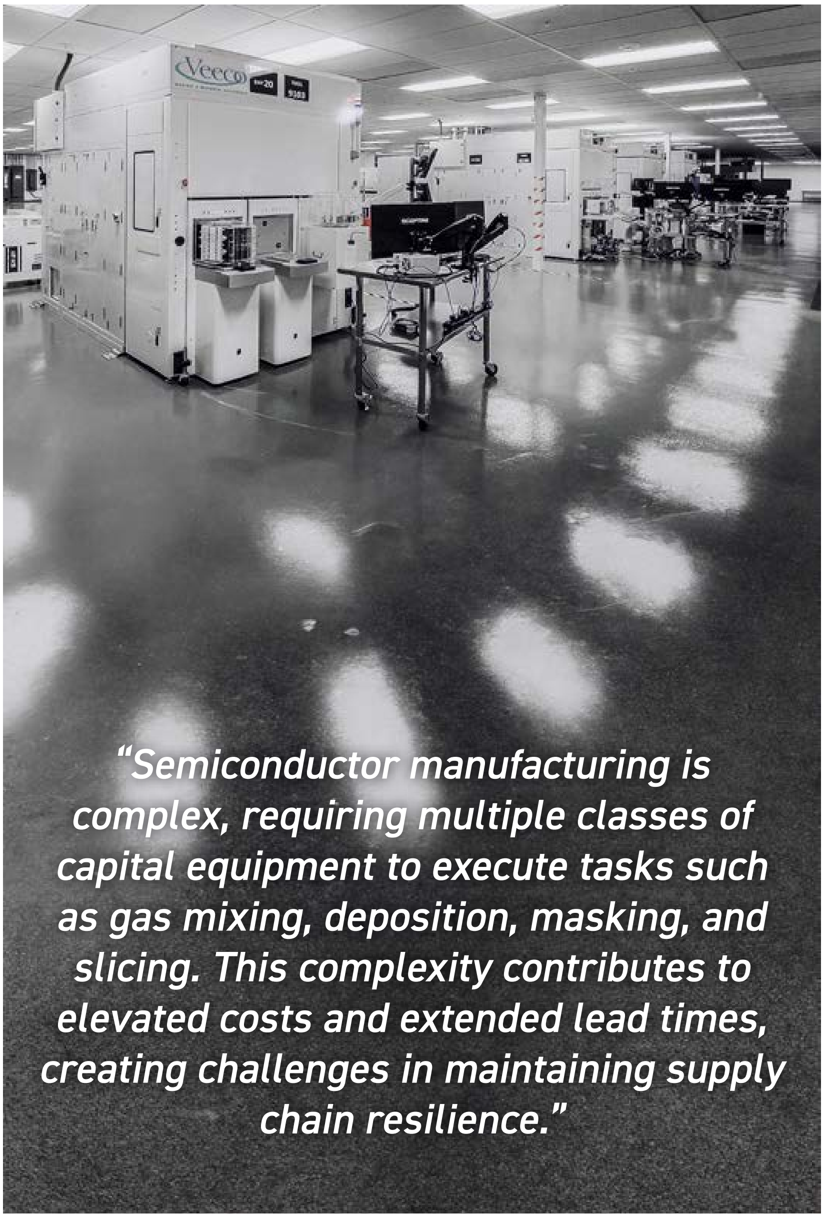

Fig. 2 Semiconductor Capital Equipment at a Veeco facility (Courtesy Veeco Instruments)

investigated for its potential use in the semiconductor industry, much of the research to date has focused on the direct manufacture of electronic components, such as printed circuit boards or conductive materials. However, a relatively underexplored application is using AM to produce critical components for SCE.

This emerging intersection of AM and SCE holds great promise for transforming the industry. Additive Manufacturing enables rapid prototyping, reduces lead times, and allows for the creation of geometrically complex components that are well-suited to the demands of modern semiconductor manufacturing, especially for components like tooling, jigs, fixtures, and highly specialised machine parts. In particular, the ability to quickly produce custom parts for SCE may help address the production bottlenecks that are currently hindering semiconductor manufacturing at a global scale.

Dr Alaa Elwany, a professor at Texas A&M University, and PhD candidate Jiahui Ye, in collaboration with Dr Ahmed El Desouky, Director of Additive Manufacturing at Veeco Instruments Inc, are at the forefront of exploring the potential of AM in the semiconductor industry and have published on the topic [1].

Addressing challenges in semiconductor manufacturing

Semiconductor manufacturing is complex, requiring multiple classes of capital equipment to execute tasks such as gas mixing, deposition, masking, and slicing. This complexity contributes to elevated costs and extended lead times, creating challenges in maintaining supply chain resilience.

With the extensive outsourcing of semiconductor manufacturing over the past three decades, the US has faced significant supply chain disruptions, particularly during the COVID-19 pandemic. In response to these supply chain issues, the US government passed the CHIPS and Science Act of 2022, a $52.7 billion investment aimed at revitalising domestic semiconductor manufacturing capabilities and mitigating future disruptions.

"The US is working to reclaim its leadership in semiconductor manufacturing. While we have consistently led and continue to lead the world in the design and innovation of semiconductors and microelectronics, we have lost our edge in manufacturing over the past few decades," Elwany said. "Our goal now is to rebuild our domestic capabilities in this critical industry and bring semiconductor manufacturing back to the US.

“As the US seeks to restore this leadership in semiconductor manufacturing, the need for advanced manufacturing technologies, particularly AM, becomes increasingly important,” he added.

The role of Additive Manufacturing

Additive Manufacturing has emerged as a critical technology to address many of the challenges faced by

Fig. 3 Integrating Laser Beam Powder Bed Fusion (PBF-LB) AM parts in semiconductor capital equipment can be challenging due to stringent clean room standards (Courtesy Veeco Instruments)

the semiconductor manufacturing industry as SCE manufacturers are increasingly exploring the potential of the technology to create parts that are lighter, more durable, and easier to manufacture. The ability of AM to create intricate internal structures, such as cooling channels within wafer handling systems or lattice structures within heat exchangers, opens up new possibilities for optimising the performance of SCE. In addition, AM allows for the rapid prototyping and customisation of parts, enabling manufacturers to quickly iterate on designs and bring new products to market faster.

"The use of AM in the semiconductor industry is still in its early stages," said Ye. "Both AM and semiconductors are advanced technologies, and synergistic collaboration between the two could greatly enhance the US semiconductor supply chain."

"The high-mix, low-volume nature of parts used in SECs makes them ideal for adopting AM," added El Desouky. "Major SECs have complete ownership of their systems design, which is a significant advantage considering the design freedom that AM offers. This allows for optimal performance design without the boundary constraints typically encountered when designing single parts or small assemblies for AM."

"The ability of AM to create intricate internal structures, such as cooling channels within wafer handling systems or lattice structures within heat exchangers, opens up new possibilities for optimising the performance of SCE."

Below are some of the most promising applications of AM in the design and production of SCE.

Wafer handling systems
Wafer handling systems (WHS) are critical in the semiconductor production process, as they transport, clamp, and manipulate wafers during fabrication. Wafers, thin slices of semiconductor material such as silicon, are the foundation for microelectronic devices. Throughout their production, wafers must be carefully handled to prevent contamination, ensure flatness, and maintain temperature control.

Fig. 4 Computational design (left) and a complex additively manufactured gas delivery manifold solution (right) for thin-film processing equipment (Courtesy Veeco Instruments)

Wafer chucks – essential tools for maintaining wafer flatness and preventing contamination – are a place where AM is already making strides. Traditional wafer chucks are typically machined from metal blocks, a process that can be both time-consuming and wasteful. By contrast, AM allows for the creation of wafer chucks with conformal cooling channels, which enable more efficient heat dissipation, improve the overall performance and reduce wafer deformation.

As semiconductor devices become more complex and their processing demands increase, the need for more advanced wafer handling systems will continue to grow. AM offers a promising solution to meet these demands.

Thermal management systems

Heat exchangers play a crucial role in maintaining the efficiency of semiconductor manufacturing processes. In many semiconductor manufacturing steps, high temperatures are generated, which can negatively affect equipment performance and product quality. Effective thermal management is essential for ensuring that equipment operates within its specified temperature range, preventing overheating and ensuring the longevity of the components.

Traditional methods for fabricating heat exchangers often result in bulky and inefficient designs, but AM allows for the creation of more compact and efficient systems. By enabling the production of lattice structures and intricate internal channels, AM improves the heat transfer capabilities of these systems while also reducing their size and weight. Lattice structures, for example, offer a high surface area-to-volume ratio, which enhances heat dissipation while minimising material use.

"Next-generation heat exchangers have to be developed to support advanced SCE capable of meeting increasing demands for chips," Ye noted.

Fluid delivery systems

Fluid manifolds and channels are key components in gas and liquid control systems within SCE. These systems are used to transport gases and liquids to various parts of the equipment, ensuring that processes like Chemical Vapour Deposition (CVD) and plasma etching are carried out with precision. Traditionally, these parts are produced via machining and drilling, leading to bulky designs with significant pressure loss.

AM allows for optimised fluid paths and reduced pressure drops, resulting in more efficient, compact, and lightweight fluid systems. The ability to design fluid channels with smooth transitions and curved paths, rather than the right-angle bends common in traditional designs, reduces turbulence and improves flow efficiency. This is particularly important in applications such as modular gas delivery systems, where efficiency and customisation are critical. Additionally, AM designs enable the creation of more complex,

"Traditional wafer chucks are typically machined from metal blocks, a process that can be both time-consuming and wasteful. By contrast, AM allows for the creation of wafer chucks with conformal cooling channels, which enable more efficient heat dissipation, improve the overall performance and reduce wafer deformation."

compact structures, providing significant footprint savings. This is particularly important in clean rooms, where every square foot saved can lead to substantial long-term cost benefits.

Fluid delivery systems enabled by AM can help reduce the size and weight of these components while improving their performance, leading to more efficient semiconductor manufacturing.

Precision flexure stages

Flexure stages, which provide precise movement control for components in semiconductor manufacturing, have also benefitted from AM. In processes such as lithography, where precise alignment of masks and wafers is essential for creating integrated circuits, flexure stages are used to position components with sub-micron accuracy. AM enables the creation of complex flexure designs with integrated joints and monolithic structures, features not achievable via the traditionally used subtractive manufacturing methods.

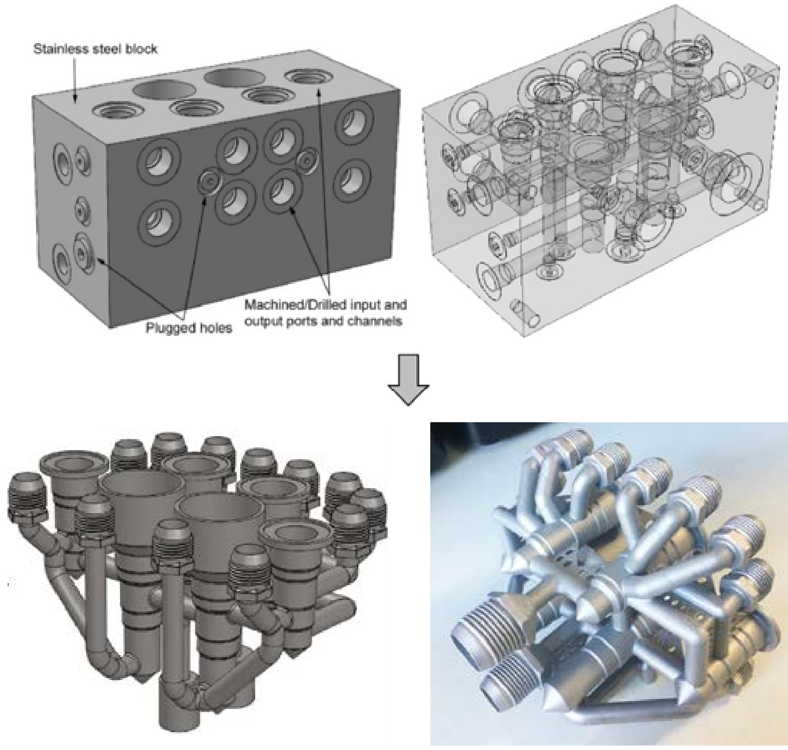

Fig. 5 Fluid manifold manufactured in AlSi10Mg with 91% weight reduction in the optimised design (above) compared to the original manifold block (top) (Image reproduced with permission from Diegel et al. (2020), DOI:10.1016/j.addma.2020.101446)

Challenges and opportunities

While the benefits of adopting AM in semiconductor manufacturing are clear, several challenges remain that need to be addressed before AM can be fully integrated into SCE production.

"AM enables the creation of complex flexure designs with integrated joints and monolithic structures, features not achievable via the traditionally used subtractive manufacturing methods."

Material selection

The range of materials suitable for AM remains somewhat limited, particularly for high-performance components. For example, copper, which is widely used in semiconductor equipment due to its thermal and electrical conductivity, presents challenges in AM processing because of its low energy absorption.

Additionally, commonly used AM alloys may contain elements that negatively interact with process gases, complicating deposition processes. Developing new materials specifically designed for use in semiconductor equipment will be crucial in overcoming this challenge.

Process optimisation

Achieving the high levels of precision required in semiconductor manufacturing often demands post-processing techniques, such as surface finishing and machining, to enhance the quality of additively manufactured parts. Further research into optimising AM processes and reducing defects like porosity will be essential for improving part reliability.

Quality Control

The high variability in the surface finish, porosity, and mechanical properties of AM parts can affect the repeatability of material deposition processes. Although the semiconductor industry may not be as heavily regulated as others, it emphasises 'copy-exact' standards, meaning part-to-part repeatability is crucial throughout the AM and subsequent post-process chain.

Fig. 6 A PBF-LB fluid manifold (Courtesy 3D Systems)

Additionally, the qualification and certification of AM components to ensure that they meet design requirements present significant barriers. SCE must meet extremely tight tolerances and high-performance criteria, often under harsh operating conditions. This makes the qualification process for AM components particularly challenging, as they must demonstrate consistent quality, thermal and mechanical resilience, and long-term repeatability under high temperatures and continuous use. AM process modelling and simulation will play a vital role in optimising designs and build parameters to minimise distortion and ensure consistent part-to-part repeatability. In addition, advanced quality control methods, including real-time monitoring, high-throughput non-destructive evaluation techniques, and machine learning-based inspection, are being developed to ensure that AM parts meet industry standards.

"...the qualification and certification of AM components to ensure that they meet design requirements present significant barriers. SCE must meet extremely tight tolerances and high-performance criteria, often under harsh operating conditions. This makes the qualification process for AM components particularly challenging..."

Collaboration is key

For AM to reach its full potential in the semiconductor sector – including the production of SCE – this collaboration must be more structured and involve mechanisms like public-private partnerships. These partnerships should bring together diverse stakeholders from across the innovation ecosystem, including government funding agencies, academia, small startups, and large industry players. By pooling resources and expertise, these partnerships can tackle the technical and regulatory challenges that have slowed the adoption of AM in semiconductor capital equipment production.

"AM technologies have made significant strides in heavily regulated industries such as medical and aerospace," stated Dr Ahmed El

Desouky. "However, adoption in the semiconductor industry is still in its early stages due to questions around chemical stability and cleanliness. While we are currently able to address many of these questions, we are barely scratching the surface. Collaboration between manufacturers and academia will unlock numerous opportunities for the manufacturing of complex assemblies, ultimately improving productivity and cost of ownership."

Dr Elwany continued, "Public-private partnerships are important when we want to de-risk the adoption of advanced technologies like AM, especially in its application to complex industries such as semiconductor manufacturing. Success stories can be seen in the Manufacturing USA institutes, where government, industry, and academia collaborate to accelerate manufacturing innovation. We need similar efforts specifically geared toward the use of AM for the production of semiconductor capital equipment."

Outlook and conclusion

AM represents a significant opportunity for the semiconductor industry to overcome current challenges and future-proof its production processes. By leveraging AM, semiconductor manufacturers can enhance the design, performance, and efficiency of their capital equipment while strengthening the resilience of the global supply chain.

While there are barriers to overcome that are currently halting the widespread adoption of AM in the semiconductor industry, further research from public-private partnerships can position Additive Manufacturing technology as a critical tool in strengthening the semiconductor supply chain.

As Elwany concluded, "AM holds the potential to help the US reclaim its position as a global leader in semiconductor manufacturing and strengthen its domestic supply chain, with direct impacts on the nation's economic prosperity and national security."

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Can Additive Manufacturing lower the carbon footprint of parts for the energy and maritime industries?

Additive Manufacturing is seen by the energy and maritime industries as having the potential to optimise supply chains and reduce the cost of spare parts through the use of 'digital' warehouses. The technology is used for both 'like-for-like' spare parts that were originally designed for machining, casting or forging, as well as new parts that have been optimised for AM. Here, Stian Saltnes Gurrik and Selin Erkisi Arici (DNV), and Onno Ponfoort and Mathijs van Poll (Berenschot), report on the latest findings of a Joint Industry Project that aims to understand the viability of such an approach in relation to a part's carbon footprint.

Since 2018, DNV and Berenschot have hosted a Joint Industry Project (JIP) entitled the ProGRAM JIP. In the three phases thus far, ProGRAM established and improved guidelines and industry standards for the application of additively manufactured metal components in the energy and maritime industries. By doing this, the ProGRAM JIP aims to lower the barriers of adoption for Additive Manufacturing in these industries.

Over the completed phases, consortia from over twenty companies from the whole supply chain have developed and formed the bases for publishing and revising the DNV standard DNV-ST-B203. In 2022, the JIP established technical requirements for the qualification of processes and production of parts using five different metal AM technologies, and parts made using combinations of conventional manufacturing and AM or repair techniques with AM.

In its latest phase (ProGRAM JIP 3) – begun in May 2022 – the project embarked on a journey to develop guidelines for qualification of part families, guidelines for selecting AM parts in new and existing application areas, and a standardised method to estimate and report on the environmental impact of Additive Manufacturing to allow users to quantify the sustainability benefits of AM compared with conventional manufacturing. As well as these guidelines, in 2024 the project delivered further suggested improvements to DNV-ST-B203 for producing high-quality spare parts for the energy and maritime industries.

This article presents some aspects of the latest phase of the JIP, with a specific focus on how Additive Manufacturing may affect sustainability in

Fig. 1 The ProGRAM JIP aims to lower the barriers to the adoption of Additive Manufacturing in the energy and maritime industries

DED-arc (wire) **WATERJET IMPELLER**	PBF-LB & Hybrid AM **CLOSED IMPELLER**	DED-arc (wire) **CASING HANGER**
Owner: Kongsberg Maritime **Production partner:** Guaranteed	**Owner:** Sulzer **Production partners:** Sulzer, Layerwise, Nikon SLM solutions	**Owner:** Technip FMC **Production partners:** Technip FMC, Guaranteed
		
The impeller is a component in a very efficient waterjet pump that offers high vessel speed and superior manoeuvrability. The diameter is 1,700 mm, the height is 600 mm and the part weighs 1,220 kg. Conventionally, the impeller is made in cast steel. **Reasons for selecting AM:** • Reduce lead time • Customisation without the need to produce a variety of casting moulds • Improve mechanical properties and cavitation erosion resistance • Reduce CO_2e emissions and improve energy footprint **Main results:** • Reduced lead time, cost savings • Enhanced repair possibilities • Positive sustainability benefits	The closed pump impeller is used for pumping fluids at high pressure. The diameter is 300 mm, the height is 83 mm and the part weighs 10 kg. Conventionally, it is made by casting in stainless steel and various other alloys. **Reasons for selecting AM:** • Faster lead time • Better material quality and integrity • Better performance and efficiency **Main results:** • Expected efficiency improvements due to better surface quality and geometry of 0.5 - 2%. • Mixed sustainability results	A casing hanger is a downhole component. It is used to suspend runs of casing within the well and transfer the loads into the wellhead. The part has a length of 700 mm and a diameter of 500 mm. This part weighs 317 kg. **Reasons for selecting AM:** • Good example of the part family concept • Short lead times required • AM preferred over expensive stocking programmes • Wasteful conventional manufacturing **Main results:** • Delivered input for part family guidance documentation. • Positive sustainability results

Table 1 (part 1) Overview of core teams and results

the industry. Whilst it is often argued that AM is more sustainable than other manufacturing methods because it may reduce material waste in production and may support production close to the location of use, thus reducing transportation or allowing production in a place with a more sustainable energy mix, is this always the case? How impactful are these benefits, and are there other key factors that affect the carbon footprint of the produced part?

About the ProGRAM JIP 3: set-up and overall results

The ProGRAM JIPs are supported by a consortium of participating companies representing the whole supply chain, including energy companies, contractors and equipment manufacturers, AM service bureaux, AM machine makers and other industry suppliers. Partners in ProGRAM JIP 3 were: 3D Systems, BMT aerospace, Cetim-Matcor, Effee Induction, Equinor, Eureka Pumps, F3nice, Guaranteed, IMMENSA, Imphytek, Kongsberg-Ferrotech, Kongsberg Maritime, Layerwise, Nikon SLM Solutions, National Manufacturing Institute Scotland, OneSubsea, Aker Solutions, Pelagus 3D, Petronas, Siemens Energy, Sulzer, TechnipFMC, Vallourec, Zeiss. DNV acted as programme manager, supported by Berenschot.

PBF-EB TX SEAL	PBF-LB BEARING HOUSING	PBF-LB ONLINE LEAK SEALING CLAMPS
Owner: OneSubsea (formerly Aker Solutions) **Production partners:** BMT Aerospace, NMIS	**Owner:** Eureka Pumps **Production partners:** 3DSystems	**Owner:** Petronas **Production partners:** IOSV, EOS
		
Metal to metal sealing element forms a barrier for well fluids, hydraulic fluids and chemicals. Conventionally seals are milled. The parts made vary from 1.5" ID to 14" ID with weights ranging from 1.1 kg (1.5"), 3 kg (4.5") to 11 kg (14"). **Reasons for selecting AM:** • Shorten production lead time • Less raw material to stock • Improve quality over conventionally forged parts • Large part family; sizes from 1-14" **Main results:** • AM requires less machining and produces considerably less waste • AM enables more ductile parts with improved elongation at break • An initial guideline to determine and handle part families in a more practical manner was based on finding is this case	This housing holds the axial force of line-shaft pumps. A main functionality topic is the cooling of the bearing. The part shown above is a novel design with cooling fins. This part is approximately 350 mm wide and 220 mm high with a weight of 70 kg. **Reasons for selecting AM:** • Novel design, integrating three parts into one • Improved cooling efficiency • Shorter lead time **Main results:** • Design simplification from twenty-five parts to one AM component • Original cooling circuit made from an expensive titanium alloy requiring active cooling with seawater eliminated by AM design with passive cooling (radiator structure) • -13 kg weight improves handling	The online leak sealing clamps is an emergency part to contain leaks at oil and gas production facilities. The clamp allows for continuation of operations and production. The additively manufactured part was 229 x 163 mm with a weight of 4.5 kg. **Reasons for selecting AM:** • Lightweighting the part (thinner shell and lattice design) • Faster production rate • Freedom of design **Main results:** • Approximately 57% weight reduction from 10.64 kg to 4.5 kg • Overall Total Production Time of 122 hours • Pressure tested up to 67 bar • Sealing compound injected into the groove up to 90 bar

Table 1 (part 2) Overview of core teams and results

The JIP set out to create input to a new version of the standard DNV-ST–B203 through practical demonstration and industry alignment. Here, the focus was on the aspects of AM that can be a driver for sustainability in the industry.

As in phase one and two, phase three was organised around a series of real-life use cases where the companies manufactured parts according to the latest version of DNV ST-B203. By doing this, we can verify the quality, completeness and practicality of improvements before incorporating them into a revision of DNV-ST-B203.

An overview of the parts and their owners is given in Table 1, showing the technologies involved and the initial reason for selecting AM to manufacture the parts.

Guidance to determine part families

One of the critical challenges in adopting Additive Manufacturing in the industry is the cost and effort associated with quality assurance and control of parts. Reducing this cost remains a goal for the ProGRAM JIP.

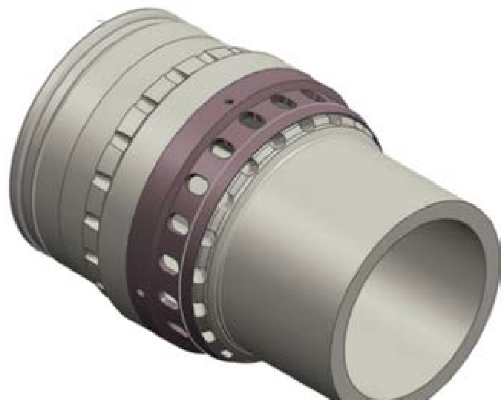
Regardless of the manufacturing method, quality assurance is essential for any part. However, when AM

What are part families?

The TechnipFMC casing hanger, featured in Table 1 (part 1) and shown below, is representative of numerous tubular components used in oil and gas applications. Casing hangers themselves are supplied in a range of diameters and lengths, but fundamentally perform the same function. As such, this component was an ideal candidate to assess from a part family perspective.

Long lead times associated with the procurement of conventional raw material are often detrimental to project deliveries. This means that manufacturers hold stock of raw material that is large enough to produce a range of different sized components (for example solid round bar or open die forgings). This ties up cash reserves; introduces several challenges and costs associated with storage and maintenance; and generates excessive amounts of waste when the material comes to being used – particularly when components towards the smaller end of the spectrum are required.

As AM offers a method of manufacturing near-net shape components for each individual size, the material use may be significantly reduced with a reduced and predictable lead time. In this project, the JIP consortium analysed the possibilities of assessing one AM produced 'raw' part for the qualification of multiple final sizes.



is employed for producing different parts in relatively small quantities which only differ slightly from one another, it appears to be leading to unnecessary time, material, and energy use for part qualifications and material testing as each part is being qualified as a unique and standalone entity.

To address this, the JIP proposes adding provisions related to the definition of 'part families' for qualification purposes. By doing so, the industry can reduce time and costs as well as emissions and minimise the impact of qualification efforts while enhancing predictability in part orders and deliveries. By providing clear definitions of part families, the JIP aims to pave the way for a more environmentally conscious and economically efficient future.

In the planned updates of the DNV-ST-B203 standard, a number of application topics and recommendations are indicated that need to be assessed when defining part families. The main categories of topics are:

- Generic and functional aspects such as geometry, application, part classification performance and acceptance criteria (AMC 1, 2 or 3, depending on the criticality of the part)
- Design aspects such as critical sections, wall thickness, coping with stresses, and special features
- Production strategy, including the main orientation and placement, deposition strategy, support structures and internal structures, and thick-thin transitions

When correctly implemented, the creation of a part family has the potential to significantly lower the threshold for using AM whilst enhancing the sustainability of the energy and maritime industries. Moreover, increased trust in the quality and timely delivery of additively manufactured parts may allow asset operators and suppliers to reduce their stockpiles of unused parts, fostering a more efficient supply chain.

Realistic sustainability benefits of AM

Public opinion, traditional line of thought

It is claimed that Additive Manufacturing reduces the environmental impact of manufacturing compared to conventional production. AM can lower CO_2 emissions by reducing waste, as well as by minimising the volume of material required through optimisation in the design phase. It is also often noted that the energy consumption of AM can be lower than that of conventional methods, especially when considering the entire lifecycle of the product. Additionally, AM often requires fewer production steps, which can lead to lower overall energy use. Lastly, AM allows for more design and production flexibility, which results in more efficient energy use during the use phase and more space-efficient packing during transport. During its research, the group used all production cases to verify these hypotheses.

Calculation model

AMPOWER developed and maintains an 'Additive Manufacturing Sustainability Calculator.' In JIP3 we used this calculator to assess the carbon footprint of the different parts. This tool enables the user to calculate the environmental impacts of production by AM versus conventional production techniques.

The calculation tool includes different phases of the production: material extraction, feedstock production and waste recycling, manufacturing and finishing; transportation emissions are not included in the model. For each process step, the calculator contains a detailed process model, including all input parameters, conversion factors and output parameters. The Additive Manufacturing Sustainability Calculator then calculates carbon emissions generated by production activities and upstream activities to deliver a total carbon footprint value per selected functional unit. The AMPOWER model allows for case-specific inputs where and when known, but offers generic technology, material and geography-related parameters in case detailed information is missing. A group made up of JIP members was established to verify the parameters and assumptions in the calculator in view of the parts manufactured and analysed.

Combining the available knowledge about the specific case – such as available CO_2 declarations for feedstock, part size, production locations and energy consumption measurements – with general default assumptions provided by the AMPOWER calculation tool, a practical, realistic and complete assessment was established. The group agreed to report for all cases on the basis of 'kg CO_2 per kg part' to present comparable information.

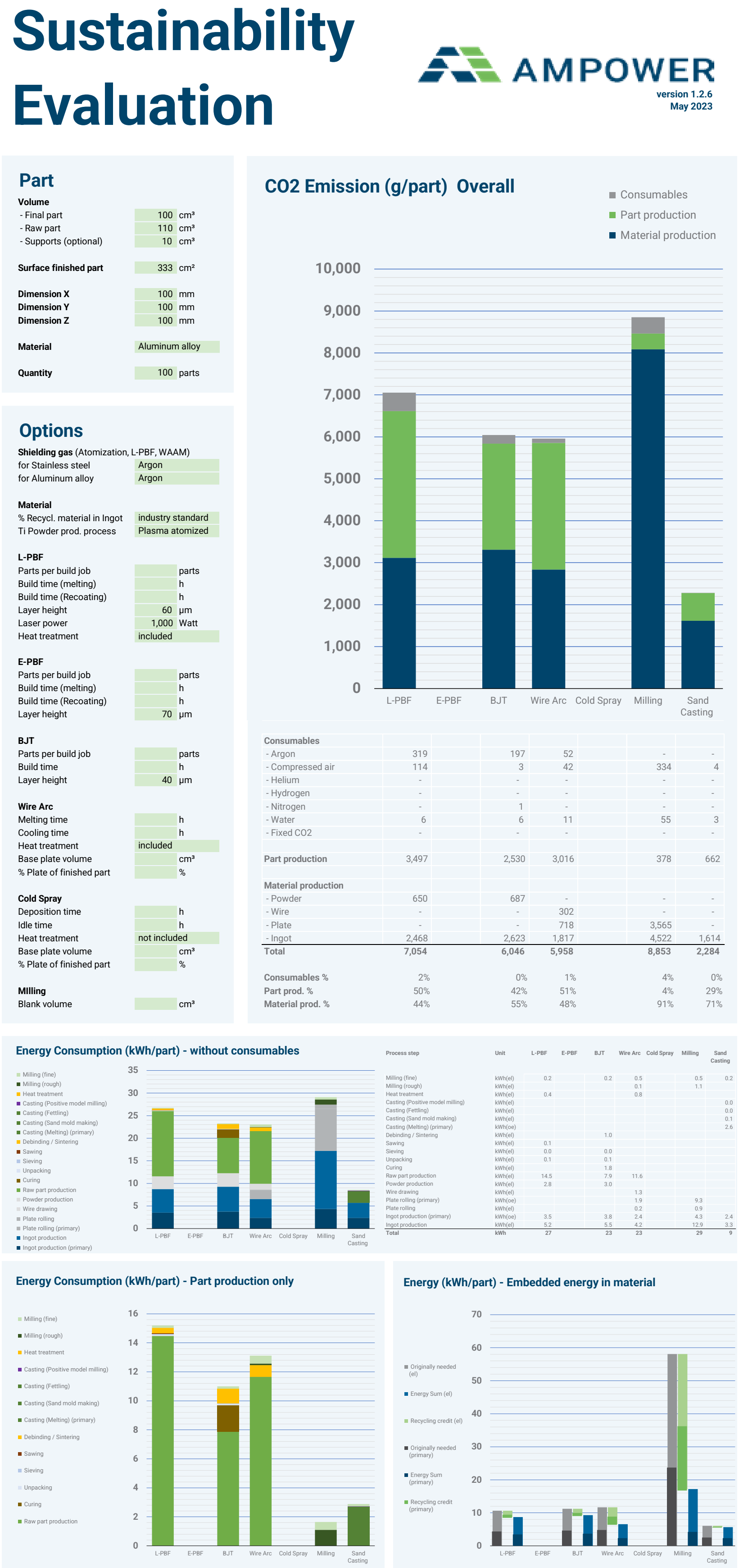


Fig. 2 Dashboard for sustainability calculations using the 'Additive Manufacturing Sustainability Calculator' developed and maintained by AMPOWER

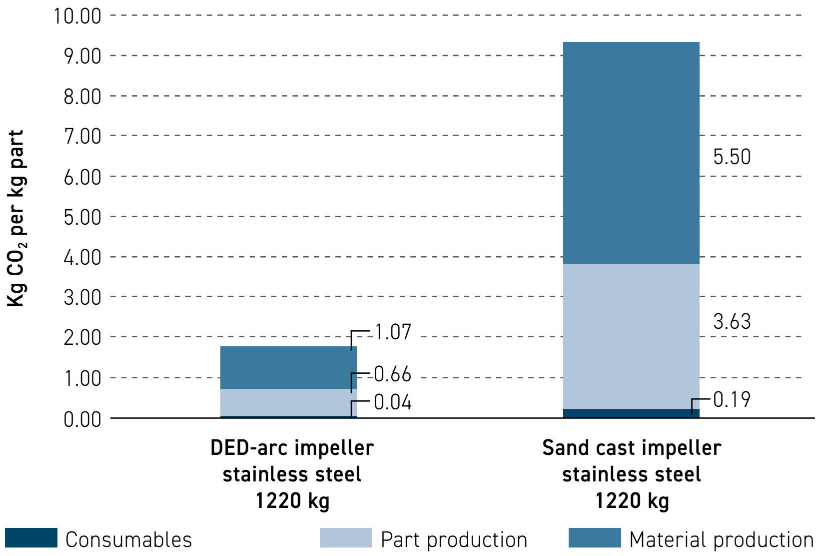


Fig. 3 A comparison of the DED vs sand cast water jet impeller

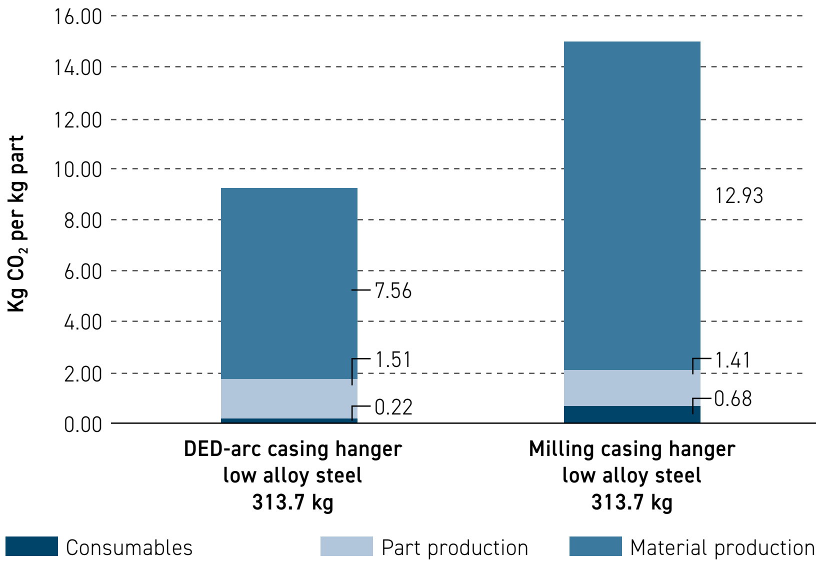


Fig. 4 A comparison of the DED vs sand cast casing hanger

Assessment results of parts produced by wire-based DED

Kongsberg Maritime waterjet impeller
Kongsberg Maritime provided an example of a waterjet impeller conventionally produced by sand casting in Delhi, India. In the JIP project, an alternative production route was executed by additively manufacturing the part at Guaranteed in Ghent, Belgium. The Wire Arc DED production of the waterjet impeller showed approximately 80% reduction in CO_2 emissions compared to conventional production (Fig. 3). Further analysis of the results suggests that the different energy mixes in the countries of production was a major driver for the amount of CO_2 produced. The CO_2 emission per KWh in Belgium is 165 g CO_2, whilst the emission in India is 713 g CO_2.

Had sand casting been carried out in Belgium instead of India, the CO_2 emission related to the energy used for sandcasting would decrease by approximately 50%. The additional 30% CO_2 reduction can, therefore, be attributed directly to the use of Additive Manufacturing itself versus the conventional sandcasting production method.

TechnipFMC casing hanger
By comparing the conventional forging and AM manufacturing routes, an assessment was done using the calculation model. This showed that the carbon footprint can be reduced by approximately 40% for the AM casing hanger versus conventional forging, mainly due to the reduction of CO_2 emissions linked to material production (Fig. 4). The assessment was based on a European conventional manufacturing route (and associated energy mix) while AM emissions were validated using actual data captured during the Additive Manufacturing process, which took place in Scotland.

Near-net shape AM leads to a higher 'buy-to-fly ratio': when using AM only a small percentage of the material is wasted compared to conventional production. In addition to this, bulk production for the entry material for conventional production leads to higher CO_2 emissions than the wire production used for the DED process.

The study of these two components show that the energy consumption for the material used is a main driver of the sustainability differences between AM and conventional manufacturing. The ability to produce nearer to the point of need allows part producers to select production locations in countries with cleaner energy mixes, resulting in a lower footprint of the part. Moreover, localised production can also reduce logistic emissions.

Assessment results of powder bed produced parts

Sulzer closed pump impeller
The closed pump impeller produced by Laser Beam Powder Bed Fusion (PBF-LB) shows three times the carbon emissions compared to casting (Fig. 5). All aspects of the PBF-LB

process deliver a higher footprint: material production, part production and the consumables used.

This calculation of PBF-LB was made without taking into account techniques which would reduce support materials and improve productivity (higher layer thickness, multiple parts in a built, etc.). It is believed that with these techniques implemented, the environmental impact of the AM impeller could be improved.

One Subsea TX seal

Two versions of the TX seal, produced by Electron Beam Powder Bed Fusion (PBF-EB) were assessed: a version with a 1.5 inch (3.81 cm) diameter seal and another with a 4.5 inch (11.43 cm) diameter seal (Fig. 6).

The case showed that Additive Manufacturing resulted in higher CO_2 emissions during production. For the 1.5 inch seal, the emissions were 131% compared to milling. For the 4.5 inch seal, emissions were 128% compared to milling. Higher CO_2 emissions for AM are observed in all three aspects of production: material production, part production and the consumables.

Despite AM production consuming only half of the material of milling, this did not impact the final emissions. This is caused by the high recycling credit assigned to the part from a 90% recycling rate assumption. If this credit is excluded from the calculation, AM production has 20% less emissions than the milling manufacturing process.

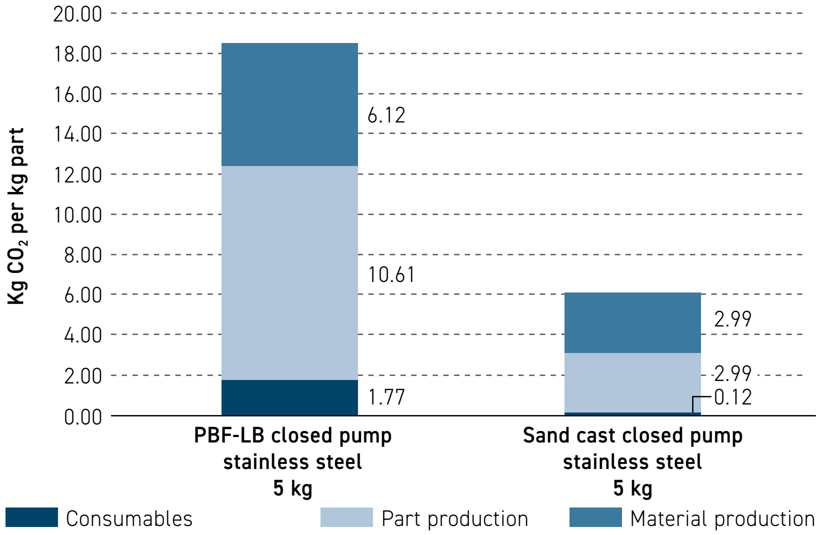


Fig. 5 A comparison of the PBF-LB vs sand cast closed pump impeller

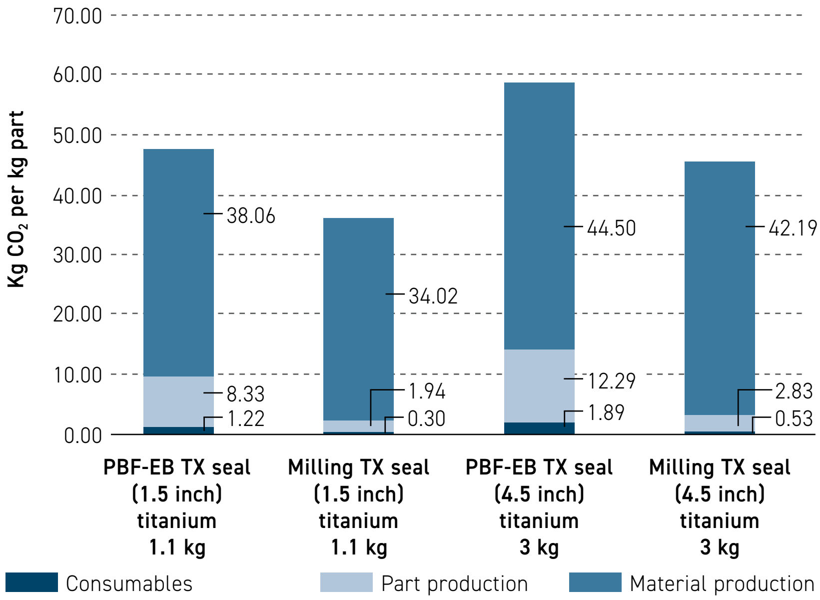


Fig. 6 A comparison of the PBF-EB vs milled TX seal

Hybrid production

The Sulzer closed pump impeller was also produced by a hybrid Directed Energy Deposition (DED) method with in-process machining capability. This is an AM technique whereby metal powder is fed into a melt pool created by a laser. After a small segment is deposited using DED, it is milled to required dimensions before the next segment is deposited.

Due to the nature of the hybrid DED process, the impeller made by this method has very high surface quality in the internal flow channels as well as a high geometric accuracy. When comparing a centrifugal pump built with such an impeller with a conventional one, an efficiency gain of up to +2% could be realised, depending on the pump type and application.

For this impeller's use case scenario, an energy mix of the EU, a twenty-year lifetime and an efficiency improvement of +1% was assumed. During the production process, the calculated CO_2eq of the hybrid process was also estimated to be about 3x that of the conventional casting process. After a runtime of only fifteen days, the higher CO_2 footprint during production is already compensated by the energy savings during use. Thus, the hybrid DED manufacturing method could be highly beneficial for the lifetime CO_2 footprint.

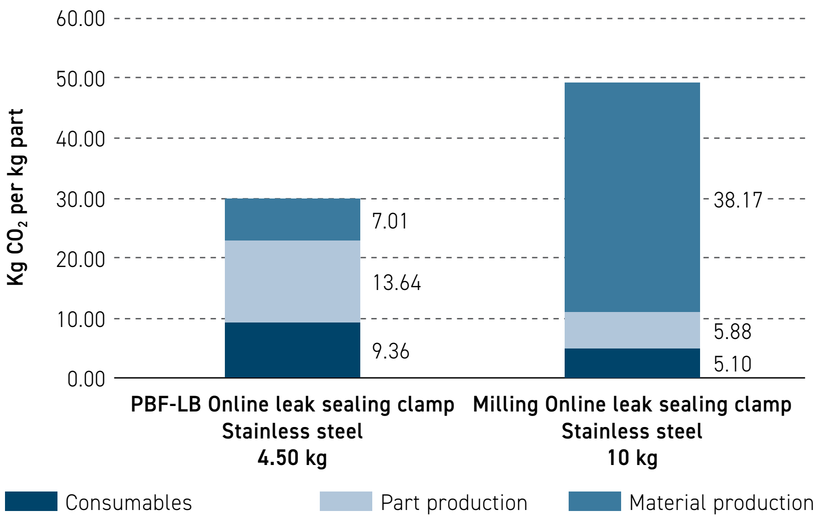


Fig. 7 A comparison of the PBF-LB vs milled sealing clamp

Petronas online leak sealing clamps

A pair of online leak sealing clamps designed for 7.62 cm pipe containing 60 bar internal pressure was produced by AM (PBF-LB) in Singapore and compared to the conventional equivalent produced by milling from a block of steel in Malaysia. The clamps were optimised for weight reduction through an AM design process (thickness reductions, complex structures). The part orientation for manufacturing (vertical vs horizontal) allowed lower volumes of support and lattice structures. This also impacted the final part quality (less distortion).

This reduced the total weight of the part by 57% (4.5 kg vs 10.64 kg), resulting in a clamp that is easier to assemble and has a lower impact on the piping structures to be sealed. Producing the part with PBF-LB decreased CO_2 emissions to approximately 61% compared to conventional manufacturing, with local emission factors of the energy mix in Singapore and Malaysia taken into account (Fig. 7). Thus, it was the optimised part design and build planning which resulted in lower emissions, primarily due to less material use.

Contrary to the previous powder bed Additive Manufacturing cases, a decrease in CO_2 emissions was realised in this instance when using AM. To a large extent, this is the result of the weight reduction achieved in the design.

The carbon emissions from part production with Powder Bed Fusion were seen to depend on the specific part, its design, and application. Compared to the conventional production method, AM may lead to higher emissions during the production phase. However, in many cases, higher emissions during production may be compensated by benefits from, for example, an optimised design or functional benefits.

This means that a case-by-case analysis is required to assess the benefit of using AM as a sustainability measure. For a complete picture, the use case of the part also needs to be taken into account to assess the full life cycle of the part. When functional benefits can be realised via AM, this can lead to considerably lower carbon emissions over the lifetime of the part, for example by lightweighting the design, the lower lifetime energy use of the part will compensate for any higher energy use during production.

> *"When functional benefits can be realised via AM, this can lead to considerably lower carbon emissions over the lifetime of the part, for example by lightweighting the design, the lower lifetime energy use of the part can compensate for higher energy use during production."*

Carbon footprint results: what did we learn from the parts produced?

During ProGRAM JIP 3, the consortium analysed five use cases to investigate the environmental impact of AM compared to conventional production methods including sand casting, forging and/or machining. Based on these use cases, we can conclude that AM does not always reduce the environmental impact of manufacturing compared to conventional (Fig. 8). Rather, based on JIP 3, the following can be concluded:

The impact of energy mix

The energy mix used for manufacturing has a significant impact on production emissions. AM often allows for local and on-demand production of parts in areas with local sources of renewable energy. Most conventional technologies

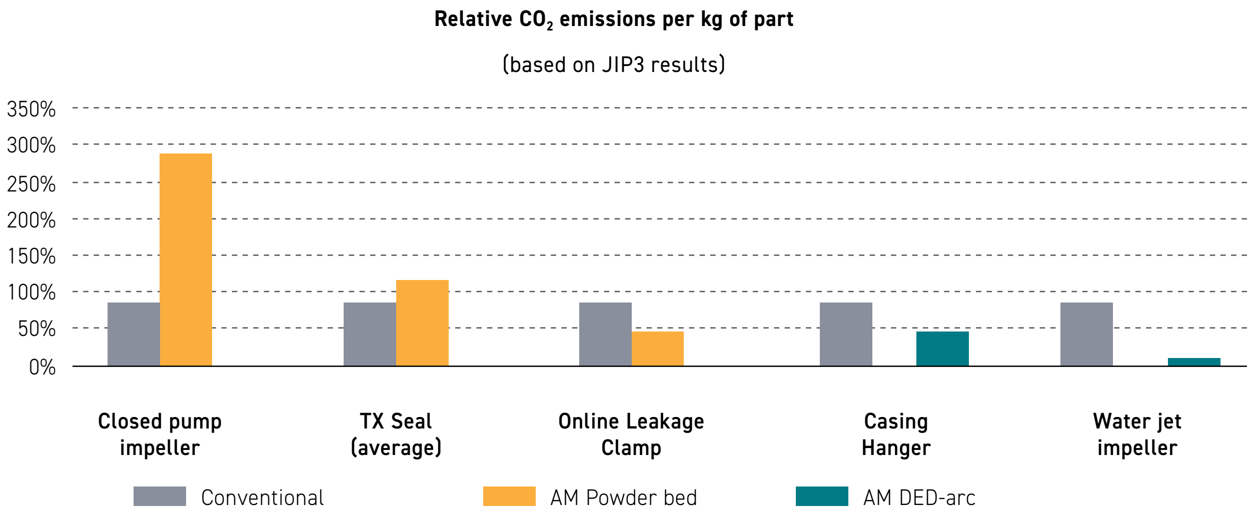


Fig. 8 Relative CO_2 emissions per kg of part for AM versus conventional production methods based on the results of this study

require large and energy-intensive production facilities. As such, AM more easily supports production in countries with a cleaner energy mix and production closer to the point of use that limits transportation and can reduce logistics emissions.

Like-for-like vs a redesigned part
When using Powder Bed Fusion AM technologies (PBF-LB and PBF-EB) for 'like-for-like' manufacturing of conventionally cast parts, increased emissions during the production phase were observed. However, the extra effort of doing a part re-design to optimise the part for AM production or improve the functionality of the part should be considered. This may offer a net benefit to the sustainability of production or performance during the lifetime.

Does part size have an impact? The emissions for the manufacturing of the larger TX seal using PBF-EB were closer to the emissions for the conventional forging and milling process than the emissions of the smaller TX Seal. Based on one case, a conclusion cannot be drawn on part size and relative emissions. But this is a topic for further analysis, especially when the PBF-EB production of part families (similar parts with various sizes) is considered.

"...AM more easily supports production in countries with a cleaner energy mix and production closer to the point of use which limits transportation and can reduce logistics emissions."

The perfomance of DED
In the example cases in this JIP, Directed Energy Deposition reduced CO_2 emissions by considerable amounts: a 40-80 % reduction compared to conventional production methods was observed. This was mainly achieved by the reduction of material use (less waste using near-net shape production) and the associated lower energy consumption during production.

Material waste and recycling
The impact of reducing material waste is partially compensated by material recycling. Therefore, a potential reduction in material usage during AM production does not necessarily translate into proportional carbon emission reduction.

In addition to the points listed above, the ProGRAM JIP investigated parts for repair or remanufacturing in phases two and three. We found that parts can be repaired or remanufactured with acceptable quality and that, in addition to the economic benefits, AM for repair or remanufacturing offers substantial sustainability benefits. We observed CO_2 savings of up to 80% compared to the production of new parts with conventional technologies. Hybrid production set-ups (ones that combine simple stock geometries made by conventional manufacturing with the complex features made by AM) also showed sustainability benefits.

Other aspects should also be factored in when looking at the energy consumption and CO_2 footprint of Additive Manufacturing. The possibility of

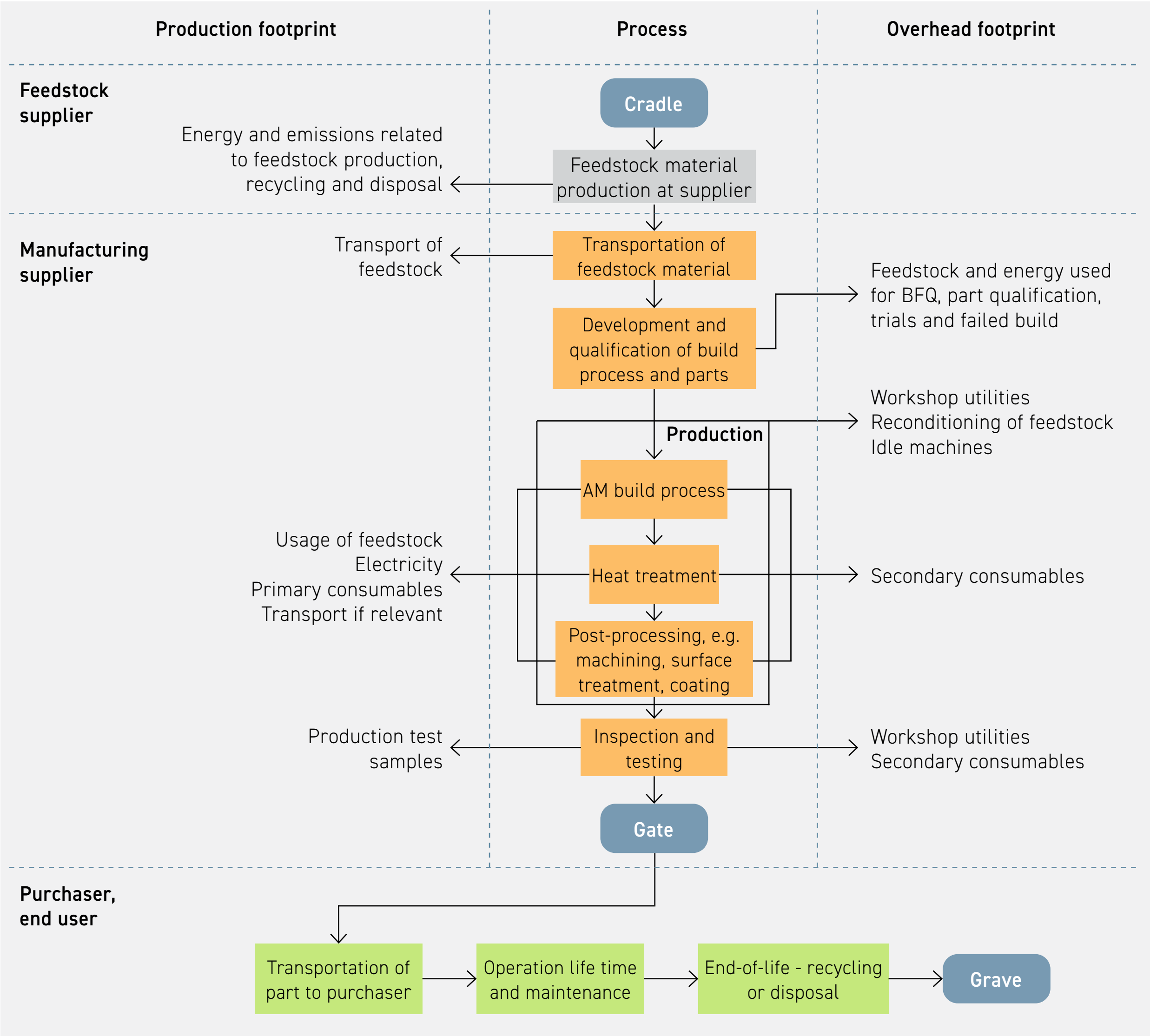


Fig. 9 Outline of the framework defined in the JIP guideline aiming to standardise calculation and reporting of CO_2 emissions for AM

digital warehousing supported by AM can lower the total number of parts produced and the impact of transportation. The use of recycled material can also lower the material production element of the footprint versus the use of virgin material.

Guideline for sustainability assessment of AM

In addition to the part family guidelines, DNV also intends to add a carbon footprint guideline for additively manufactured parts. The guideline defines terms and methodology for calculating and reporting of carbon footprint based on use of energy, materials and consumables, for raw material production, part production and transport.

When evaluating the environmental impact of AM parts, the analysis shall consider the whole lifetime of the part, including the operational phase and end-of-life scenarios. The sustainability guideline provides manufacturers and end-users the means for transparent comparison of the environmental footprint of AM parts with conventional manufacturing methods to quantify possible benefits of choosing AM. The guideline will align to relevant standards for life cycle analysis (i.e. ISO 14040, ISO 14044) and supports the communication and reporting on the environmental footprint with the following:

- Framework and reporting formats for the calculation of the production footprint of a build job
- A qualification format for energy consumption of machines or process steps; examples of aspects with potential sustainability benefits for case-by-case evaluation of process steps like the pre-production, use phases and end-of-life of the part

Conclusions

Over the past two years, the ProGRAM JIP 3 has improved industry standard DNV-ST-B203 with new provisions related to design, production, repair and manufacturing of parts using Additive Manufacturing. Based on the results of six pilot cases relevant to the energy and maritime industries, the JIP investigated real production cases. This also provided a more nuanced view on the sustainability impact of AM.

The addition of guidelines in DNV-ST-B203 for the definition of part families and for the calculation of and reporting on CO_2 production footprint will further support the uptake of AM as a valid and often (but not always) more sustainable technology for the production of parts for the energy and maritime industries.

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Acknowledgements

The authors would like to thank the joint industry project partners for their contributions and cooperation throughout the project period. Their insights and contributions to this article were invaluable.

Future participation

If you are involved in AM for the energy and maritime industries, you may wish to participate in an upcoming Joint Industry Project. If so, please reach out to the authors.




Inspect Additive Manufacturing, stop monitoring: Phase3D's unit-based, in-process inspection solution for powder bed AM

AM is at a pivotal stage, evolving from a prototyping tool to a scalable manufacturing solution. This transition necessitates real-time, process-specific inspection to ensure consistent part quality. Phase3D is meeting this need with real-time inspection solutions specifically for powder-bed processes. Its technology enables manufacturers to inspect each layer during production, enhancing product development, optimising parameters, and improving process control for end-use production. Here, Niall O'Dowd and Noah Mostow dive into the specific applications of the company's Fringe Inspection technology.

Since its inception, Additive Manufacturing has grown from a rapid prototyping tool to include a group of industry-oriented manufacturing technologies for critical applications. Opportunities across the AM industry have continued to evolve with the widespread adoption of Laser Beam Powder Bed Fusion (PBF-LB), from its original commercialisation in the 1990s to today, with machines having larger build areas and ever-expanding numbers of lasers that can build hundreds of parts at a time.

The AM industry will reach a plateau, however, if we continue to rely on expensive post-inspection techniques to certify parts or visual cameras to validate that the process is under control. Many AM applications require high confidence in safety, including aerospace engine parts, rocket nozzles, medical devices, and human implants. Despite the enormous progress in AM, process inspection methodologies have not progressed at such a rapid pace.

Through AM's evolution, users desiring part quality assurance required extensive post-inspection – or 'ex-situ' inspection. This can include computed tomography (CT), X-ray inspection, CMM geometric inspection, mechanical testing, and much more.

A continued problem, and a barrier to adoption in the commercial aviation industry, is quality inspection and safety – especially as larger

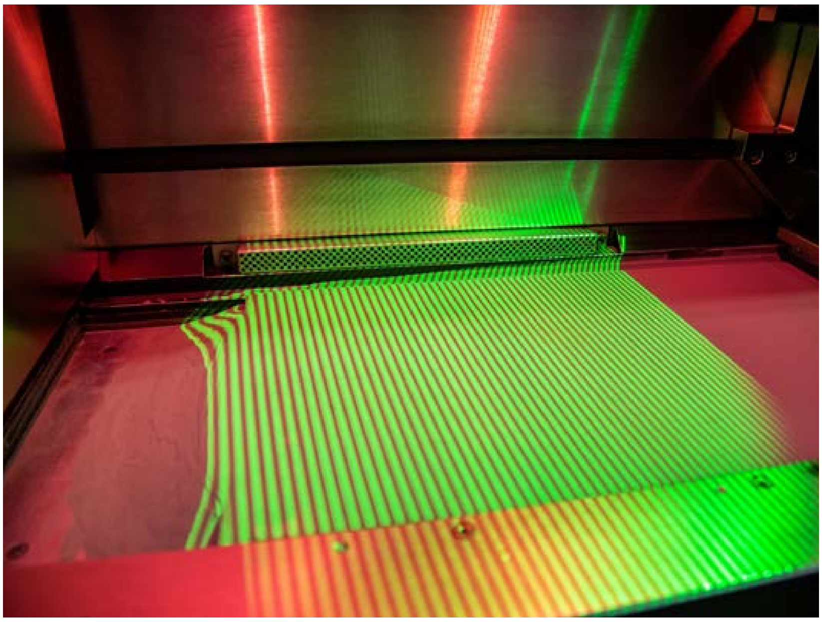

Fig. 1 Phase3D's Fringe Inspection product enables the real-time inspection of each layer of a powder bed process during production (Courtesy Phase3D)

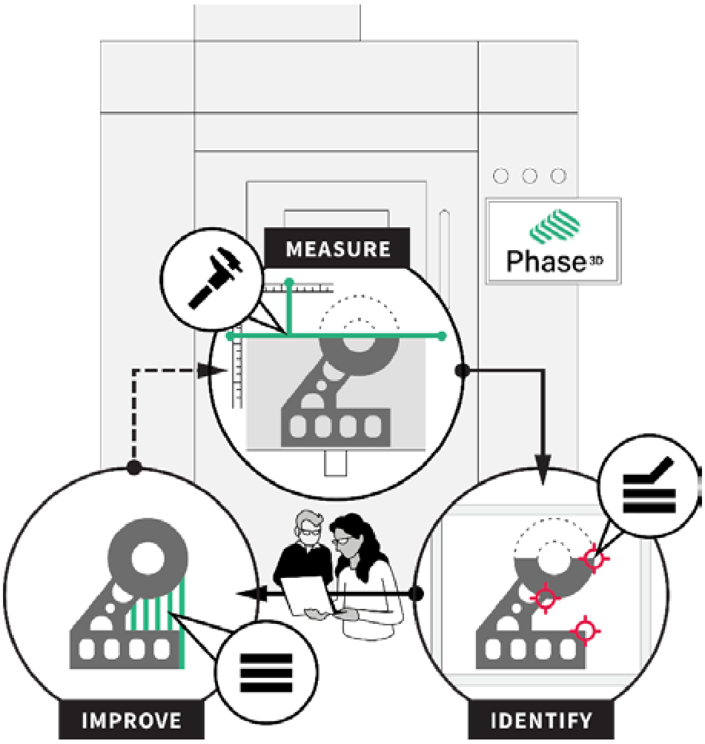

Fig. 2 Fringe Inspection measures the AM process, identifies anomalies, and helps users improve their process (Courtesy Phase3D)

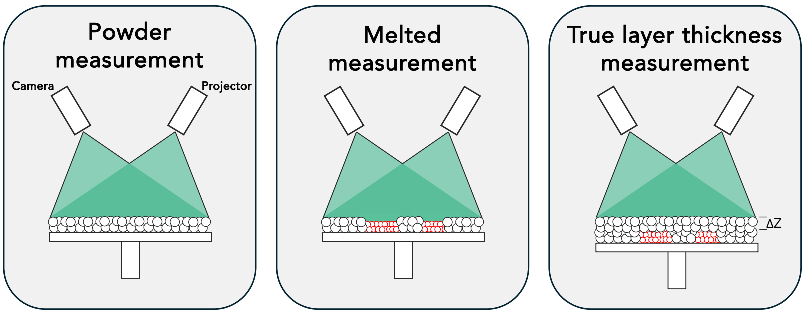

Fig. 3 Fringe Inspection patented structured light inspection process takes three measurements per layer, as shown above (Courtesy Phase3D)

"Currently, the aerospace industry can expect over 50% of part cost to come from post-processing and ex-situ inspection. This approach is neither economical nor scalable for a technology that seeks to become a standard manufacturing solution."

parts become impossible to inspect using CT scanning. Currently, the aerospace industry can expect over 50% of part cost to come from post-processing and ex-situ inspection. This approach is neither economical nor scalable for a technology that seeks to become a standard manufacturing solution.

Historically, the PBF-LB process has been monitored using optical images, long-wave and short-wave infrared (IR) cameras, and photodiodes. These solutions all use relative, uncalibrated, and subjective data, which are not unit-based. While each technology has its benefits, it also has limitations when seeking process control or achieving 'born-certified' parts, which require a repeatable, calibrated measurement. Phase 3D considers these to be monitoring technologies.

If data gathered during the process cannot be related to objective, unit-based measurements, the technology is not a manufacturing inspection methodology. For example, quality assurance for geometric tolerances does not involve an engineer taking an image of the part; instead, they use callipers, CMM machines, or go/no-go gauges to verify if the part meets specifications. For CNC, users know how many seconds the tool has been spinning or cutting and make informed decisions based on data recorded from the process. AM has been missing the same unit-based in-process inspection requirements, which has impeded its widespread adoption in many quality-critical applications.

That is why we are on a mission to provide trusted inspection technology: to advance the AM industry. In contrast to others in this sector, we offer customers a unit-based, objective, calibrated, and repeatable inspection technology that supports AM from new technology development to process control, with a clear pathway toward achieving real-time certification and qualification.

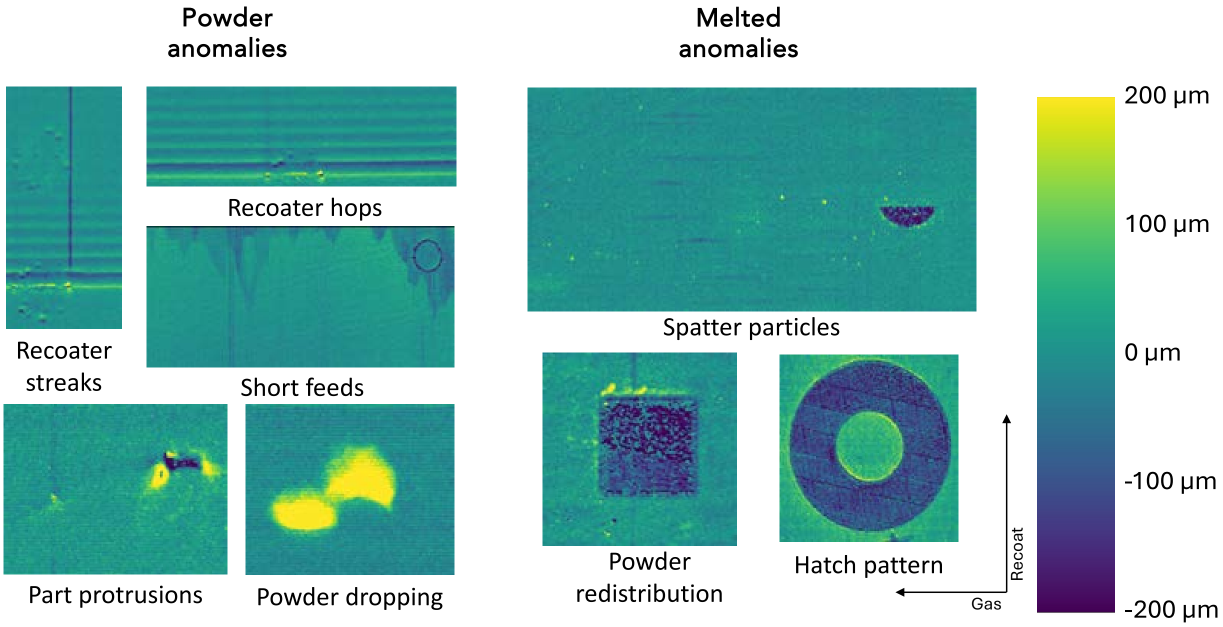

Fig. 4 Objective inspection data, collected by Fringe Inspection, from all major build anomalies in PBF-LB (Courtesy Phase3D)

About Fringe Inspection

Fringe Inspection is a hardware and software product that uses structured light inspection to measure the Additive Manufacturing process and identify anomalies (Fig. 2). These anomalies can be correlated to critical part flaws so users can improve their build quality and repeatability. Fringe Inspection works by projecting patterns of light onto the part during the build and using a camera to capture variations in light intensity, allowing for the measurement of the 3D profile of every layer in the AM process, capturing three measurements per layer (Fig. 3). As of autumn 2024, the patented [1] solution is available for PBF-LB, Binder Jetting, and Cold Spray AM. This article will primarily focus on PBF-LB applications.

The result or output of the three scans as shown in Fig. 3 is a point cloud, or 3D profile, of:

1. The uniformity of the powder spread across the build area
2. The uniformity of the melted part area
3. The amount of powder spread across the build area, including previously melted areas

"Fringe Inspection is a hardware and software product that uses structured light inspection to measure the Additive Manufacturing process and identify anomalies. These anomalies can be correlated to critical part flaws so users can improve their build quality and repeatability."

By analysing these three measurements, Fringe Inspection automatically identifies and reports powder layer anomalies such as short feeds, hops, streaks, part protrusions or powder dropping (Fig. 4). Melted anomalies such as powder redistribution, spatter, or hatch pattern variations can also be detected. Users of Fringe Inspection include NASA, the US Air Force, NIST, and several major aerospace OEMs, who utilise it to detect anomalies and gain objective inspection-level insights into their build quality.

Fringe Operator and Fringe Qualification

To make the measurement and anomaly detection data useful on the shop floor, the Fringe Inspection system includes visualisation and quality assurance tools: Fringe Operator and Fringe Qualification, respectively. Fringe Operator includes anomaly detection and deep-

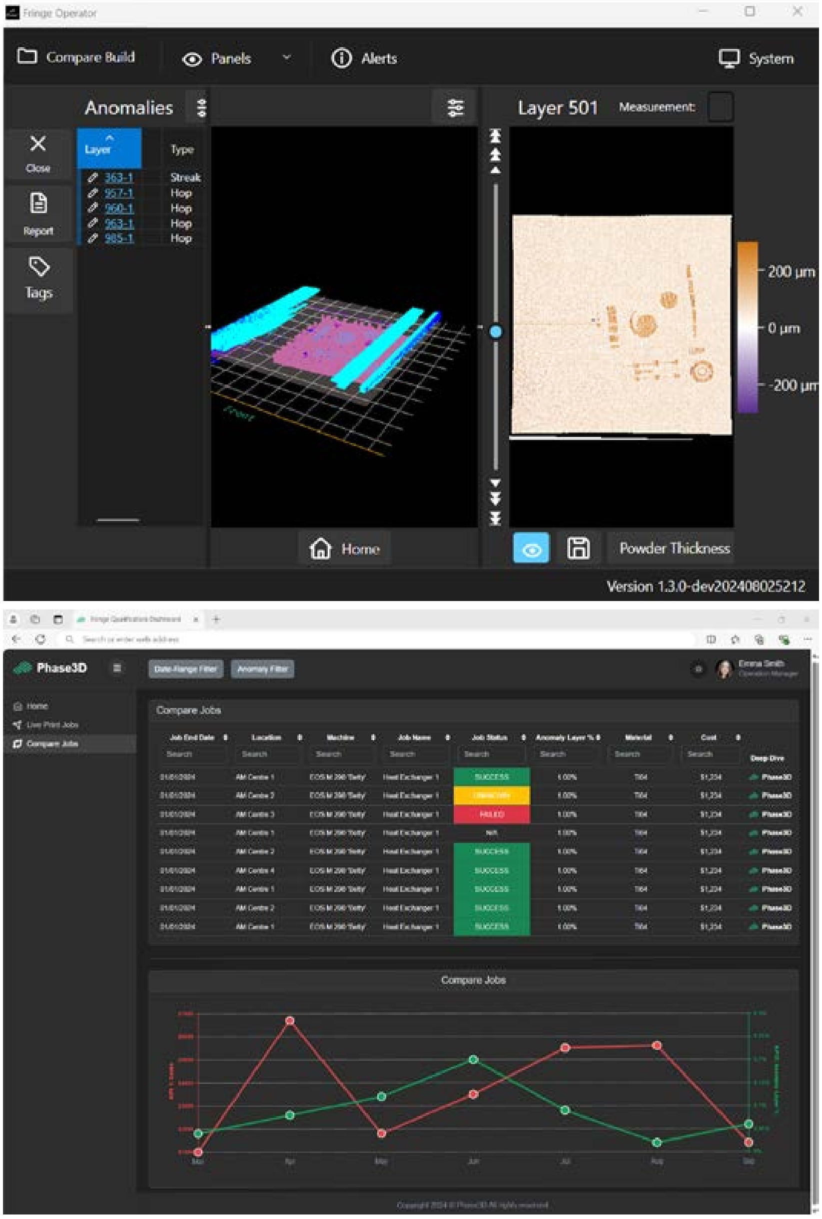

Fig. 5 Fringe Inspection includes a visualisation and data inspection tool, Fringe Operator, as shown on the top, and Fringe Qualification, as shown above, a qualification and control solution that provides users with oversight of their operation (Courtesy Phase3D)

> ***"...a designer may want to use as few support structures as possible or design thinner-walled structures supporting thicker features. However, both can lead to thermal deformation of the part during the build process, causing the part to warp and protrude above the powder surface..."***

dive analytics features so users can understand the build performance as a whole or by every layer's features down to the micron level. Fringe Qualification works alongside Fringe Operator to provide high-level details of build quality across customers' fleet of AM machines. It provides users with an executive-level build report as well as a dashboard to oversee all the builds on site and allow for comparison and process control (Fig. 5).

End-use customers use Fringe Inspection from early-stage development to final production, including product development, parameter development, and process control. Each application supports users in reducing project lead time, increasing machine utilisation, and ensuring build quality.

Product development with Fringe Inspection

Companies use Additive Manufacturing in order to develop new products. The technology may be used to replace already existing parts with a new metal AM part, to create entirely new parts, or to bridge the manufacturing timeline while tooling is being produced. The opportunities are endless, but getting a part to build correctly on a first, second, or even third try can be a challenge as designers and engineers push the boundaries of what is possible.

For example, a designer may want to use as few support structures as possible or design thinner-walled structures supporting thicker features. However, both can lead to thermal deformation of the part during the build process, causing the part to warp and protrude above the powder surface, impacting the recoater blade and parts or geometries downstream. Even though these design features reduce post-processing or enhance part performance, they can cause serious problems during the build.

With Fringe Inspection, parts warping during the process and protruding from the build surface are easily identified. Users can easily

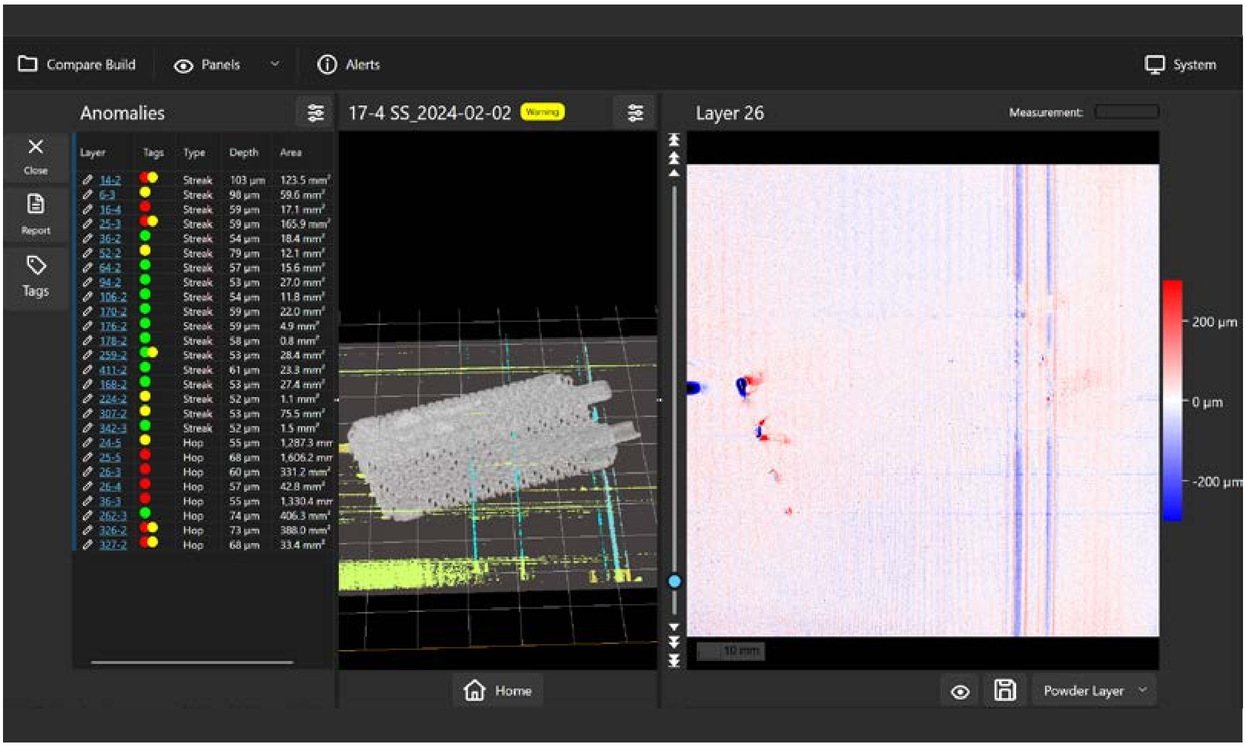

Fig. 6 Fringe Operator identifies part protrusions and powder hops in real-time (Courtesy Phase3D)

run a root-cause analysis of design problems during the first build of a part, drastically expediting the design process. Historically, root cause analysis of part failures included many unclear steps, but the software allows users to see the problems in real-time and make changes faster. For parts that self-repair during the build, Fringe Inspection is critical to understand variation and abnormalities of internal features (Fig. 6).

Even after a successful build, quality systems must be established to ensure that future builds will be of the same quality. Fringe Inspection provides customers that are developing new products with an objective inspection technology that identifies when and where a part has failed, enabling them to control the process from the first build to thousands after.

Fringe Inspection for parameter development

Every company has its proprietary build parameters for Additive Manufacturing. Even though machine manufacturers supply standard parameters for many materials, end users are looking to push the bounds of what the machines can do while getting the best performance from the parts. This means many AM users are investing tens to hundreds of thousands of dollars to develop the parameters for the parts and geometries they want to manufacture.

Developing optimal parameter sets can include extensive part testing, including testing density cubes, serial sectioning, or other mechanical testing. The problem is that many parts that are produced during the parameter development process experience extensive build anomalies. These historically are not identified, and the root cause analysis of defective parts is invalid due to a lack of in-situ inspection data.

With Fringe Inspection, customers measure the build in real-time and identify anomalies that impact the part's performance. By cancelling the poor-performing parts, customers are saving time and money by not putting these parts through ex-situ inspection.

Even more importantly, during this critical phase of development, customers are able to understand the root cause of part or geometry failures, which may not be impacted

"Even after a successful build, quality systems must be established to ensure that future builds will be of the same quality."

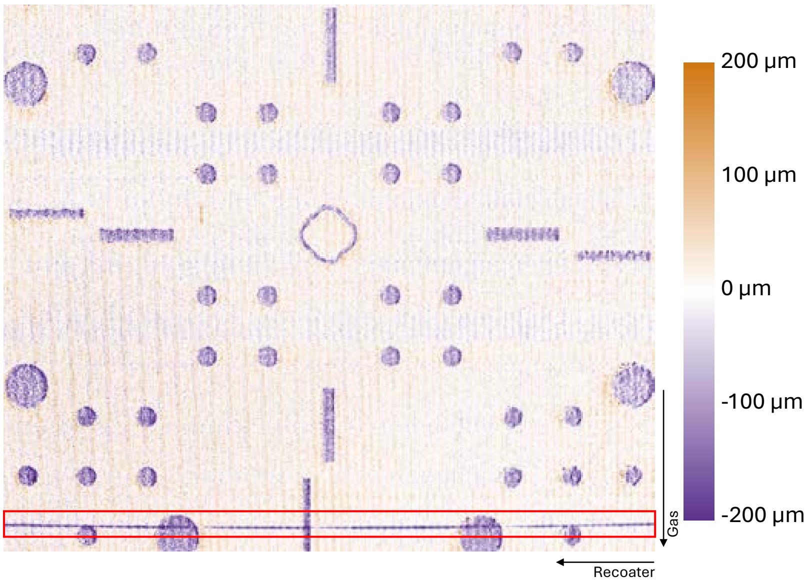

Fig. 7 Recoater streak, outlined in red, during a parameter development build that caused porosity in the parts which wasn't noticed by the machine operator (Courtesy Phase3D)

> *"Since the Fringe Inspection software provides unit-based measurements for the entire build area, users can identify what anomalies cause build or part failures and control if or when to stop the build using objective process inspection data."*

by the parameters themselves. In the build shown in Fig. 7, a recoater streak was persistent during the entire build, repeating on every layer. Further analysis showed the recoater itself was damaged, rather than the parameters causing the issue. Not surprisingly, after CT scanning the parts impacted by the recoater streak, a higher level of porosity was identified in that region (Fig. 7).

Without Fringe Inspection, users would be unaware of the recoater defect, as the streak was not visible in the visual images, meaning that these parameter sets would have failed during post-inspection, even though the results do not accurately reflect the performance of the parameters.

By measuring the entire build process – including true layer thickness measurements – users can now quantify how much powder was spread across the entire layer. As the AM industry seeks to build parts faster, thicker layers become extremely valuable. The technology can also be used to test thicker layers and understand their impact on a part's performance as well as the impact of thick layers on different geometries. In the future, instead of multiple builds to finalise new parameters for different materials or performance requirements, users will be able to gather all the data necessary to qualify a parameter set in one build.

Fringe Inspection for process control

One of the most exciting opportunities with objective in-situ inspection for PBF-LB is being able to control the process and certify the build in real-time. Since the Fringe Inspection software provides unit-based measurements for the entire build area, users can identify what anomalies cause build or part failures and control if or when to stop the build using objective process inspection data. This is a quantum shift in AM, as all previous inspection techniques used subjective inputs, which required years of understanding and are not usable in machine-to-machine comparison.

With Fringe Inspection, customers such as the US Air Force and NASA have been able to identify which anomalies cause porosity in their parts. In studies with these two organisations, a representative challenge build was designed to test the relationship between Fringe Inspection data and CT-detected porosity, a key requirement in their specifications. At the US Air Force, a build was run on an EOS M290 machine using Ti-64, and at NASA, a build was on a Colibrium Additive M2 machine using GrCop-42. The builds were measured using the Fringe Inspection system, which automatically detected anomalies such as powder streaks and hops caused by recoater-part interaction. The parts were CT-scanned to identify porosity in the final part.

Within these builds, an anomaly generator, which is a realistic part with challenging overhangs, was included to generate recoater hops and streaks that impact parts

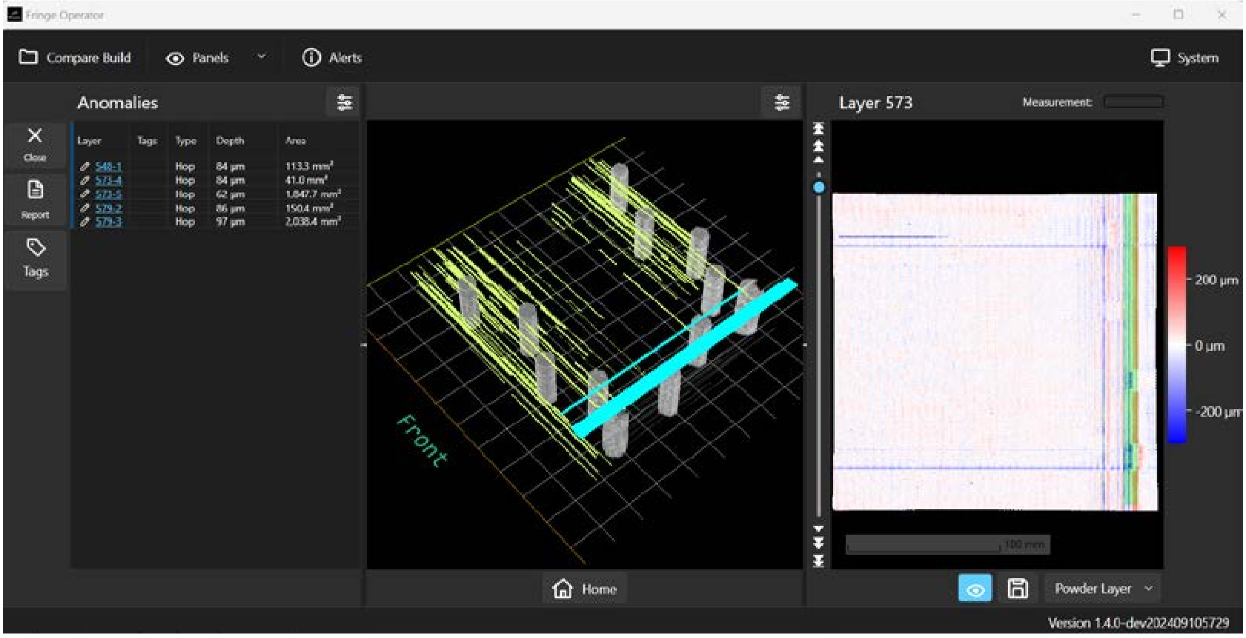

Fig. 8 Fringe Operator visualises the build in real time, automatically detects anomalies that impact the part, and ranks anomalies by area and absolute height (Courtesy Phase3D)

downstream. The anomalies were detected automatically, visualised in Fringe Operator, and ranked by area and absolute height, as seen in Fig. 8.

A porosity indication table for ground truth analysis was generated using CT scans. Both studies found a high correlation between heightmap-identified anomalies and CT-detected defects. The data showed:

- For GrCop-42 and Ti-64, 83% and 81% of test specimen defects identified were correlated to layers with Fringe Inspection identified anomalies, respectively
- For both materials, 100% of Fringe Research identified anomalies ≥50 µm depressions correlated to defects detected by CT.

Additional CT-detected defects were identified in the study; however, this study only focused on correlating automatically detected anomalies by Fringe Inspection, specifically hops and streaks. Table 1 detail porosity to defect correlation for Ti-64.

From the builds, the Fringe Inspection heightmaps were used to automatically identify many powder anomalies which correlate to pores. Many of these anomalies were not

Layer	Anomaly Magnitude (µm)	Defect on CT?	Equivalent Diameter of CT defect (mm)	Projected XY Area (mm²)	Volume (mm³)
123	36	No	N/A	N/A	N/A
262	42	No	N/A	N/A	N/A
273	40	No	N/A	N/A	N/A
278	75	Yes	0.0625	0.0025	0.0001
304	62	Yes	0.0306	0.0007	0.00004
336	49	Yes	0.0963	0.0121	0.0005
358	100	Yes	0.0397	0.0014	0.00008
413	48	Yes	0.0243	0.0004	0.00002
471	51	Yes	0.0263	0.0008	0.00005
723	63	Yes	0.0866	0.0071	0.0003
748	72	Yes	0.0437	0.0017	0.0001
1054	66	Yes	0.0652	0.0034	0.0001
1093	114	Yes	0.0497	0.0025	0.0001
1106	171	Yes	0.069	0.0044	0.0002
1119	194	Yes	0.0629	0.0037	0.0001
1144	88	Yes	0.0526	0.0019	0.0001

Table 1 Table details anomalies detected by Fringe Research and correlating CT-detected defects for Ti-64 on an EOS M290 (Courtesy Phase3D)

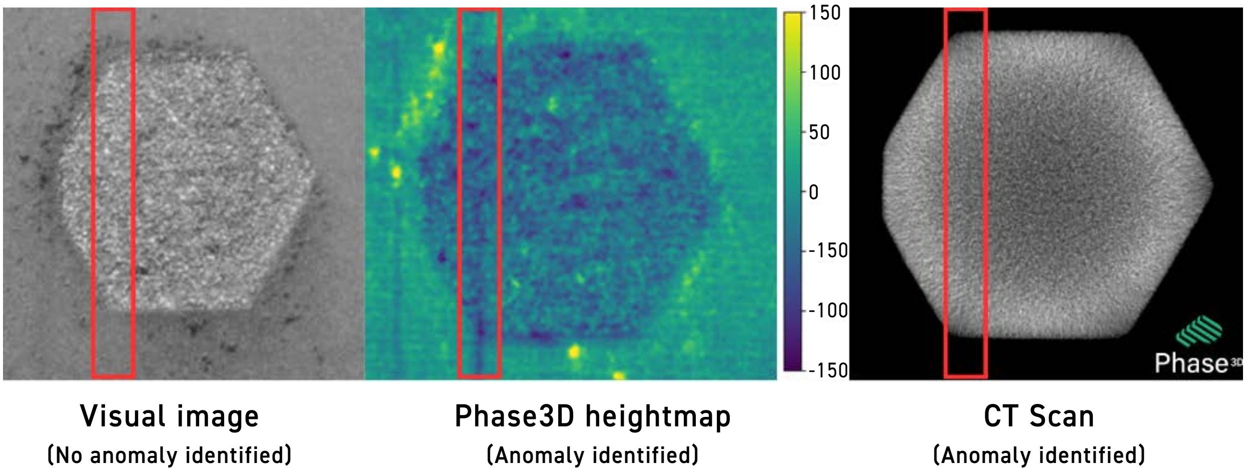

Fig. 9 The heightmap from Fringe Inspection (centre) easily identifies and measures the magnitude of the recoater streak that is correlated to the porosity identified in the CT scan (right). The data was recorded at NASA Marshall Space Flight Center, on a Colibrium M2, processing GrCop-42. No anomaly is detected in this location in the visual image (left) (Courtesy Phase3D)

"With technologies like Fringe Inspection being commercially available and used in a wide range of applications, users are beginning to push the bounds on what can be additively manufactured with a validated quality guarantee."

identifiable using visual images. In Fig. 9, the heightmap easily identifies the recoater streak in the centre image, which correlates to the cross-sectional CT data collected at the same height index, on the right. However, no anomaly can be detected in the visual spectrum shown on the left. This is a major risk with using optical images alone to certify builds. The visual image relies solely on shadows, which can and will be missed pending the system setup.

By identifying anomalies that cause defects in the parts, users of Fringe Inspection can control their process and get closer to certifying their builds in real time. For example, Fringe Inspection quantifies the number of anomalies correlated to defects that occur in a cubic area and can identify if and when a specified threshold is exceeded, a quality especially useful for aerospace companies using the standards established in NASA Technical Standards 6033 (NASA-STD-6033) 'Additive Manufacturing Requirements for Equipment and Facility Control'. Using the measurements from the build, questions are removed on whether the process is in control or not, or if the build should be cancelled.

Using this process, users of Fringe Inspection can create 'go/no-go' criteria for their builds to know whether manufacturing should proceed. In the example layer in Fig. 10, the criteria are set so any measured area less than 50 µm is green, considered 'good to go', while any area that is measured greater than 50 µm is labelled red, meaning 'no-go' or problem detected. This is an easy way for customers to identify when the process is out of control and stop the build. This feature alone is significant for the AM industry by putting control into technicians' hands with regards to when to fail a build.

The future of AM inspection

AM is still in its infancy in many respects, especially when it comes to real-time inspection of the process. With technologies such as Fringe Inspection, users are beginning to push the bounds on what can be additively manufactured with a validated quality guarantee. Beyond what has been outlined above, users are beginning to experiment with closed-loop control, possible with the real-time data captured by Fringe Inspection. Fringe Inspection can detect short feeds in the build process and, with the collaboration of AM machine manufacturers, a signal can be sent to the machine to spread more powder. In the future, more advanced solutions can be developed to deposit precisely the right amount of powder for each layer and ensure that it is applied correctly.

For users who seek to optimise laser paths in real-time, or ablate anomalies such as spatter particles that fall on or near the edge of the part, more advanced closed-loop controls are not far behind. These types of advancements will take time to develop and see real-world applications in industrial settings, but they are no longer impossible.

Beyond closed-loop control, exciting quality inspection for machine manufacturers and end users include IQ, OQ, PQ (Installation Qualification, Operational Qualification, and Performance Qualification) using Fringe Inspection. This technology can help first-build qualification and provide detailed analysis on whether the machine has been calibrated properly and verify that the recoater or build height actuators have not been damaged in transit. For operators, Fringe Inspection can quantify their first layer height or bed levelling. Finally, and arguably most importantly, Fringe Inspection provides the data, so every build is quantified and compared against true qualification metrics. This should be performed for every build to keep users informed about what is happening in their manufacturing facilities.

The future of AM requires inspection technologies. Anyone manufacturing using metal PBF, Binder Jetting, or Cold Spray Additive Manufacturing should investigate how inspection can help their process and stop relying on monitoring alone.

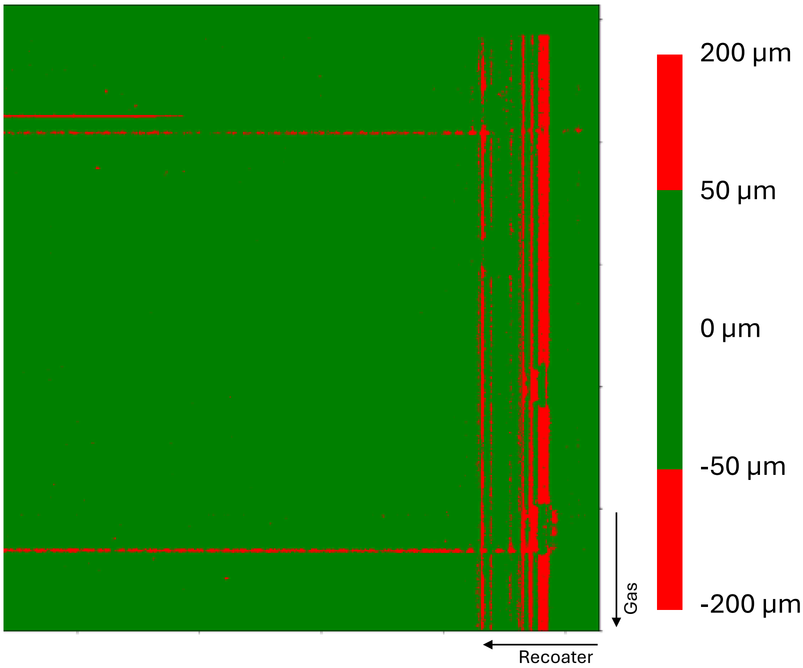

Fig. 10 Fringe Inspection layer separated so any value between +/- 50 µm is green and within bounds. Any area outside those bounds is red, denoting out of specification (Courtesy Phase3D)

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[1] Patent WO2023059618A1, US11865613B2

Industry events

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www.manufacturingexposcotland.com

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www.amsi.org.in/conference

AM Summit 2024
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www.amsummit.dk

International Conference on Advanced Manufacturing (ASTM ICAM 2024)
October 28–November 1, Atlanta, GA, USA
www.amcoe.org/event/icam2024/

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www.americamakes.us/events/trxunivaz/

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www.spacetechexpo-europe.com

Formnext
November 19–22, Frankfurt, Germany
www.formnext.com

FPM 42nd Hagen Symposium
November 28–29, Hagen, Germany
www.hagener-symposium.de

Aerospace & Defense Manufacturing & R&D Summit
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www.dec24.aerospacedefensesummit.com

AMTECH Expo
December 11–12, Bengaluru, India
www.amtechexpo.in

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www.additivemanufacturingstrategies.com

Military Additive Manufacturing Summit 2025
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www.militaryam.com

International Conference on Injection Molding of Metals, Ceramics, and Carbides (MIM 2025)
February 24–26, Costa Mesa, CA, USA
www.mim2025.org

5th International Conference on Electron Beam Additive Manufacturing (EBAM 2025)
February 26–28, Erlangen, Germany
ebam.fau.de

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March 10–12, Shanghai, China
www.amatex.cn

Fraunhofer Direct Digital Manufacturing Conference (DDMC 2025)
March 12–13, Berlin, Germany
www.ddmc-fraunhofer.de

AM Forum Berlin 2025
March 17–18, Berlin, Germany
www.am-forum.de

AMUG 2025
March 30–April 3, Chicago, IL, USA
www.amug.com

The 14th International Conference on Hot Isostatic Pressing (HIP 2025)
April 6–10, Aachen, Germany
www.hip2025.com

RAPID + TCT 2025
April 8–10, Detroit, MI, USA
www.rapid3devent.com

Formnext Chicago 2025
April 8–10, Chicago, IL, USA
www.formnextchicago.com

AMC Additive Manufacturing Conference
April 28–30, Antalya, Türkiye
www.amctr.org

WAAmathon 2025 (Wire Arc Additive Manufacturing)
May 21, Berlin, Germany
www.linkedin.com/showcase/waamathon/

Space Tech Expo USA 2025
June 3–4, Long Beach, CA, USA
www.spacetechexpo.com

3D Print Congress & Exhibition Lyon
June 3–5, Lyon, France
www.3dprint-exhibition-lyon.com

TCT 3Sixty 2025
June 4–5, Birmingham, UK
www.tct3sixty.com

Powdermet 2025 / AMPM 2025
June 15–18, Phoenix, AZ, USA
www.powdermet2025.org | www.ampm2025.org

Euro PM2025 Congress & Exhibition
September 14–17, Glasgow, Scotland
www.europm2025.com

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September 14–17, Glasgow, Scotland
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- Notification of Abstract Acceptance: January 19, 2025
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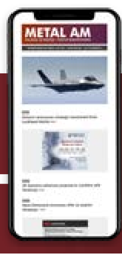

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