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THE MAGAZINE FOR THE METAL ADDITIVE MANUFACTURING INDUSTRY

METAL AM

in this issue

KENNAMETAL: AM HARDMETALS & STEELS

GENERAL ATOMICS AERONAUTICAL

PERSPECTIVES ON THE GROWTH OF AM

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METAL ADDITIVE MANUFACTURING

Staying focused on the mission

It's been a busy news season, with the Stratasys/Desktop Metal/Nano Dimension/3D Systems saga playing out across news channels and social media. Many opinions have been shared, along with vast streams of commentary.

Whilst consolidation in the industry is a necessary part of AM's journey to maturity, the manoeuvring playing out has limited interest outside of our AM bubble. This fAMily drama of sibling rivalry naturally fascinates, but, beyond the borders, AM's potential customers are more concerned about whether the industry can meet their needs.

We are currently in a place where we can take comfort from many high-profile successes – typically high-value, low-volume applications – but, really, we need to try and mix those words up a bit. 'Low-value, high-volume' may be switching things a little too far, but, at some point, that also has to become part of our destination, using, for example, metal Binder Jetting technology.

We all know what needs to be collectively achieved: vastly improved end-to-end automation, faster build speeds and improved machine stability are a good starting point. But education and awareness remain critical: until more components are designed for specific AM processes, and optimised for automated post-processing, the industry will be restricted to its comfort zone of 'high-value, low-volume' for industries such as aerospace and medical.

As this issue highlights, progress is being made and successes are being celebrated, but sometimes stopping and figuring out where we are will set us in the right direction and on a faster path to our destination.

Nick Williams
Managing Director

Cover image
A Binder Jetting machine at Kennametal producing a bed of components and test coupons (Courtesy Kennametal)


NO CASTING
VIOLATORS SUBJECT TO
OVERSEAS MANUFACTURING
AND ASSOCIATED PROBLEMS.

Contents

Kennametal is a particularly interesting company when it comes to the adoption of Additive Manufacturing. It is a dynamic global producer of tooling and industrial materials with sales of $2 billion in 2022, yet its roots are very much in 'old school' sinter-based PM processes. It is, therefore, no surprise that the company was an early adopter of AM, leveraging its materials and sintering expertise, as well as its broad customer base, to develop a leading position in the AM of hardmetals and steels.

Bernard North, who fortuitously happens to be a past VP Industrial Technology at Kennametal, visited the company's AM operation and reports for *Metal AM* magazine. >>>

General Atomics Aeronautical Systems, Inc. (GA-ASI) is the world leader in the design and manufacture of Unmanned Aircraft Systems (UAS). The company is no stranger to AM, with its Additive Design and Manufacturing Center of Excellence being integral to the qualification of more than 300 AM flight components and the installation of more than 10,000 AM parts on its aircraft.

Now, it is working to identify and partner with some of the most innovative players in the industry in order to further leverage the capabilities of the technology. Divergent Technologies, the company behind Czinger Vehicles, is one such company. Jeff Kerns reports for *Metal AM* magazine. >>>

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165 Metal AM on an industrial scale: GKN Additive draws on decades of sintering expertise to commercialise Binder Jetting

Binder Jetting's position as an accepted mass production technology for precision metal components is on the near horizon. The coming success will, however, rely as much on expertise in the sintering process as it does on expertise in jetting binder onto a powder bed to make 'green' parts.

This article reports on how GKN Powder Metallurgy's Additive Manufacturing division, GKN Additive, has leveraged decades of sintering expertise in high-capacity continuous furnaces, combined with its application development expertise, to deliver the series production of special filters by Binder Jetting for Schneider Electric. >>>

173 International Conference on Electron Beam Additive Manufacturing: Highlights from EBAM 2023

Since the first conference on electron beam Additive Manufacturing in Nuremberg in 2016, the EBAM conference series has been the central meeting point for industry and academia to exchange knowledge on this dynamic area of AM. After the event was forced to go virtual in 2020 due to COVID-19, attendees were finally able to meet face-to-face again in Erlangen, March 22-24.

Marie Franke-Jurisch and Dr Matthias Markl report on recent developments in materials, process, and machine technology, all of which serve to demonstrate that electron beam-based technologies are once again firmly established in the metal Additive Manufacturing world. >>>

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Our advertisers' index serves as a convenient guide to suppliers of AM machines, materials, part manufacturing services, software and associated production equipment.

In the digital edition of *Metal AM* magazine, available at www.metal-am.com, simply click on a company name to view its advert, or on the weblink to go directly to its website. >>>


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Industry news

Stratasys and Desktop Metal merger, 3D Systems and Nano Dimension bids

Over the last few months there has been much news around Stratasys, its planned merger with Desktop Metal and bids from both 3D Systems and Nano Dimension. As we go to press, the eventual outcome of these proposals is to be decided, but this is the situation today.

Desktop Metal and Stratasys

In May, Stratasys Ltd and Desktop Metal, Inc, announced a definitive agreement whereby the companies would combine in an all-stock transaction valued at approximately $1.8 billion. Together, the merger would create an Additive Manufacturing company delivering industrial metal, polymer, sand and ceramic solutions from design to mass production.

Under the terms of the agreement, which was said to have been unanimously approved by the Boards of Directors of both companies, Desktop Metal stockholders would receive 0.123 ordinary shares of Stratasys for each share of Desktop Metal Class A common stock. This represents a value of approximately $1.88 per share of Desktop Metal Class A common stock based on the closing price of a Stratasys ordinary share of $15.26 on May 23, 2023.

Following the closing of the transaction, which it was stated is expected to occur in the fourth quarter of 2023, existing Stratasys shareholders would own approximately 59% of the combined company, and legacy Desktop Metal stockholders will own approximately 41% of the combined company, in each case, on a fully-diluted basis.

The transaction establishes an Additive Manufacturing company that is expected to be one of the largest companies in the industry, targeting $1.1 billion in 2025 revenue.

It was announced that once the deal had completed, Dr Zeif would lead the combined company as Chief Executive Officer together with Ric Fulop as Chairman of the Board.

This transaction would also bring together complementary IP portfolios with more than 3,400 patents and pending patent applications. In addition, the combined company would have one of the largest R&D and engineering teams in the industry, with over 800 scientists and engineers focused on driving innovation across a differentiated materials library.

Nano Dimension's offer for Stratasys

In March we reported that Nano Dimension had made an initial bid to acquire Stratasys, having already obtained 14.1% of the company's shares. Although Stratasys advised its shareholders to reject this bid, Nano Dimension increased its offer on June 27, seeking to purchase an additional 31.9% up to 36.9% of the company.

Nano Dimension's new offer was $20.05 per share in cash, and was said to deliver a certain, near-term premium and all-cash value to Stratasys shareholders.

This offer is still open, however in as statement from Stratasys issued in response, its Board was said have unanimously determined that the revised partial tender offer substantially undervalued the company and is not in the best interests of Stratasys shareholders. The Stratasys Board urged shareholders not to tender into Nano's revised partial offer.

3D Systems bids for Stratasys

Shortly after the Stratasys and Desktop Metal merger announcement, Stratasys received a buyout proposal from 3D Systems. The offer was a cash and stock merger that would convert each Stratasys share into $7.50 in cash and 1.2507 newly issued shares of 3D Systems common stock. The combination would result in Stratasys shareholders owning 40% of the combined company and receiving approximately $540 million in cash.

In a later statement issued by Stratasys, rejecting this deal, the offer was said to not constitute a superior proposal and did not provide a basis upon which to enter into discussions. However, on the same day that Nano Dimension increased its bid, 3D Systems also enhanced its proposal. The new offer would still combine the two companies in a cash and stock transaction, converting each Stratasys ordinary share into $7.50 in cash and 1.3223 newly issued shares of 3D Systems common stock. Under the terms of the revised offer, the combination would result in Stratasys shareholders owning approximately 41% of the combined company and receiving approximately $540 million in cash.

This latest offer was also rejected shortly after, with the Stratasys Board of Directors said to unanimously determines the revised proposal from 3D Systems did not constitute a superior proposal to its agreement with Desktop Metal.

www.3dsystems.com
www.desktopmetal.com
www.nano-di.com
www.stratasys.com

GKN Aerospace commissions 'world's largest' DED Additive Manufacturing cell

GKN Aerospace has announced the commissioning of what is reported to be the world's largest known laser-based Directed Energy Deposition Additive Manufacturing (DED-LB) production cell. As part of its new Global Technology Center in Texas, USA, the new installation will enable the production of titanium components up to 5.6 x 2.5 m in size.

GKN Aerospace has commissioned the world's largest known laser-based DED production cell (Courtesy GKN Aerospace)

Known as Cell 3, the new plant will enable the Additive Manufacturing of safety critical air and space structures, as well as defence and civil platform parts replacement, from more sustainable and efficient methods. Using titanium wire feedstock, the Cell 3 will feature a 20 kW laser, up to ten axes of motion and a large-area inert environment of around 330 m^3.

Shawn Black, the company's president of defence, stated, "Cell 3 will create opportunities to deliver a whole new level of additively manufactured titanium components to sizes needed for safety-critical air and space structures. We are very excited to bring this new equipment to our current line of product development LMD-w [wire-based DED-LB] cells in the US. This will accelerate the introduction of our technology into production while helping to support the US supply chain and reducing reliance on foreign-sourced materials."

"LMD-w is a game-changer and a more sustainable alternative for production in a wide range of civil and defence structures," he continued. "The method has shown its proficiencies in producing components faster and with significantly reduced lead times. We also look forward to expanding this technology's role in sustainability and efficiencies through additional collaborations with customers and universities."

GKN Aerospace currently has additively manufactured components flying on several different major platforms in the commercial, military, rotorcraft, business jet and space markets. Future developments in the company's AM workflow for large-scale aerostructures are expected to include: process improvement, modelling & simulation, non-destructive evaluation methods, in-situ monitoring and the transition of technology development into production solutions. In 2022 the company revealed a 2.5 m titanium structure produced in Cell 2.

www.gknaerospace.com

Wayland Additive closes £4.6M funding round

Wayland Additive has announced the close of a £4.6 million funding round, with backing from existing investors Longwall Ventures, Parkwalk Advisors and ACF Investors. Metrea Discovery joins the round as a new supporter of the business.

Wayland states it will use the funding to increase in-house production capability to deliver more machines and materials to customers. The investment will also go towards further hiring, in particular the recruitment of a COO, as well as supporting further R&D.

Wayland manufactures and sells its metal AM machines to end-users in areas such as the aerospace, mining, and medical industries. Customers include the UK's Royal Air Force and Exergy Solutions, Canada.

"Since our last funding round, we have formally launched our machines into the market and are already seeing considerable traction, with demand from across the globe. By providing bespoke Additive Manufacturing to our customers, we can play a pivotal role in streamlining their operations and give them the tools to unlock their potential, with high value components at the touch of a button," stated Will Richardson, Wayland's CEO. "It's great to have our existing investors continuing to support us as we grow, as well as new strategic investor Metrea. We are excited by the prospect of bringing our machines to businesses who need them around the world and this investment will supercharge that mission."

Commenting on the funding round, Tim Mills, Managing Partner at ACF Investors, stated "Wayland continues to move from strength to strength and is a leading light of Yorkshire's business community. Through its machines, Wayland is pioneering the next generation of Additive Manufacturing, opening up new applications and unlocking new materials. We are delighted to be continuing to support this ingenious team on the next stage of their growth journey."

David Denny, Partner at Longwall Ventures added, "We are delighted to continue supporting the Wayland team – their ingenuity and hard work has resulted in a great product... We also appreciate having ACF Investors as co-investors because they have been pragmatic and supportive from day one."

www.waylandadditive.com


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Airbus and Oerlikon sign €3.8 million contract for the AM of satellite components

Oerlikon AM, Pfäffikon, Switzerland, and Airbus, headquartered in Occitanie, France, have signed a €3.8 million contract for the Additive Manufacturing of complex antenna clusters used in a series of communication satellites. This announcement is said to mark an important milestone in the ten-year collaboration between the companies, which has seen the development of a number of components for space applications, several of which are already in orbit.

The aluminium antenna clusters measure approximately 400 x 400 x 400 mm and are manufactured using Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing. They are reportedly part of next-generation communication satellites that will transmit and receive communication and/or data signals in K-band frequency.

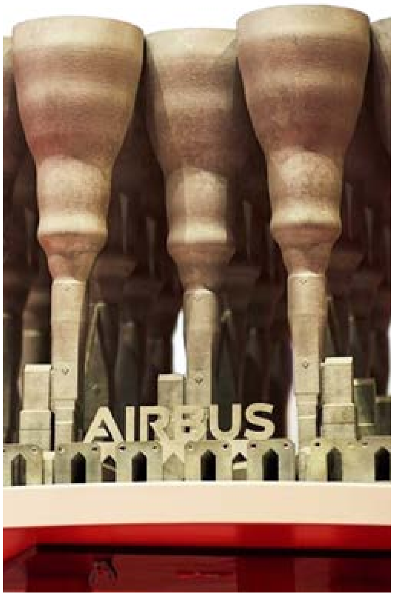
"To create a final product of excellent quality, technical cooperation and understanding each other's needs and requirements is fundamental for a well-coordinated design and manufacturing process – not only in rapid prototyping, but even more so in serial production," stated Michael Kilian, R&D Manager for Additive Manufacturing of RF Space Components, Airbus.

Additive Manufacturing has enabled benefits such as weight reduction and shortened lead times; an antenna cluster could reportedly be reduced from six months to just a few weeks compared to conventional manufacturing.

"The key success factor is the specific AM machine setup, which allows the family of geometries to be reproduced with the required accuracy and the process to be indefinitely repeated. Thus, we met the high accuracy and quality requirements of Airbus, and consequently the specified European Space Agency (ESA) standards for satellites," added Hendrik Alfter, Managing Director, Oerlikon AM. "We are pleased that the cooperation has resulted in a €3.8 million multi-year contract for the supply of antenna clusters."

In addition to aluminium Additive Manufacturing, the two parties have jointly fine-tuned post-processing as a key part of the process development. As an all-round service provider, Oerlikon AM reportedly offers Airbus Additive Manufacturing, post-processing and surface finish optimisation for radio frequency performance, precision computer numerical control milling, quality assurance, ultrasonic cleaning, assembly, and wire integration, as well as customised logistics.

www.oerlikon.com/am
www.airbus.com



Additively manufactured aluminium antenna clusters for Airbus' next-generation communication satellites are being produced at Oerlikon AM (Courtesy Oerlikon)

Sintavia announces strategic investment from Lockheed Martin

Sintavia, LLC, based in Hollywood, Florida, USA, has announced a direct investment from Lockheed Martin Corporation, headquartered in Bethesda, Maryland, USA. While the full terms were not disclosed, it is expected that the funding will support the continued development of Sintavia's proprietary thermodynamic designs and components.

Sintavia designs and additively manufactures some of the most advanced mechanical systems used in flight applications today, including multi-circuit heat exchangers, complex thermodynamic chassis, and monolithic cooling pumps.

Sintavia and Lockheed Martin have a longstanding collaboration to expand research on metal Additive Manufacturing as an alternative to traditional design and manufacturing methods. In December 2022, the companies announced a strategic partnership to explore additional AM technology areas in connection with the White House initiative AM Forward – a voluntary compact aimed at strengthening US supply chains by supporting US-based suppliers' adoption and deployment of AM.

Since 2019, Sintavia has been a component supplier to Lockheed Martin and currently maintains supply relationships across all four Lockheed Martin business areas. Components supplied by Sintavia support a number of key Lockheed Martin programmes, including the F-35 and F-22. Proceeds from the investment will be used to continue to fund additional development and testing at Sintavia.

"This investment not only cements the relationship between Lockheed Martin and Sintavia, but also demonstrates the fact that Sintavia's thermodynamic components—optimised through additive technology—are sought after by the largest and most substantial prime integrators within the aerospace & defense industry," stated Brian Neff, Sintavia's founder and CEO. "Lockheed Martin represents the very best of these, and we are honoured to have their backing as we continue to grow and expand our product line."

"Lockheed Martin's strategic investment expands our existing joint development agreement with Sintavia announced last December," added David Tatro, vice president for Operations Process Transformation at Lockheed Martin. "We look forward to strengthening our collaboration on the design and supply of additively manufactured parts across the defence industrial base."

www.sintavia.com
www.lockheedmartin.com

restor3d acquires Conformis to expand additively manufactured orthopaedics market

restor3d, Durham, North Carolina, USA, and Conformis, Billerica, Massachusetts, have entered into a definitive merger agreement under which personalised orthopaedic company restor3d will acquire all outstanding shares of common stock at Conformis at $2.27 per share in cash, which represents an approximate 96% premium to the closing price of Conformis stock as of June 22, 2023.

restor3d is a medical technology company that utilises metal Additive Manufacturing to enable the production of its bespoke orthopaedics. Conformis also focuses on personalised orthopaedic patient care and owns or exclusively in-licenses issued patents and pending patent applications that cover personalised implants and patient-specific instrumentation for all major joints.

"This combination will create a leading personalised 3D-printed medical device company," stated Kurt Jacobus, Chief Executive Officer of restor3d. "Together, we share a common belief in the power of personalisation. By leveraging the strengths in our respective portfolios around artificial-intelligence-driven implant design, digital automation, and 3D printed osseointegrative biomaterials, we see tremendous opportunity to offer clinically-differentiated and cost-effective solutions across the orthopaedic landscape, including shoulder, foot & ankle, spine, and large joints."

"After nearly twenty years of revolutionising the orthopaedic industry with personalised treatment and patient choice, this transaction is a testament to the value of our portfolio and the strength of our core technology and intellectual property," said Mark Augusti, Chief Executive Office at Conformis. "Following a diligent and thoughtful process, the board has unanimously approved this transaction, which delivers positive benefits to all of our stakeholders. We are excited to enter the next chapter for Conformis with restor3d, which allows us to continue helping patients live productive lives after knee or hip surgery and providing the surgeon community with innovative products and services."

Conformis' Board of Directors, having determined that the transaction is in the best interests of the company's stockholders, has unanimously approved the transaction. The closing of this transaction is expected by the end of Q3 2023 and is subject to approval by Conformis' stockholders and other customary closing conditions.

www.restor3d.com

www.conformis.com

Defiant3D launches Defiant200 budget metal Additive Manufacturing machine

Defiant3D, an Additive Manufacturing machine maker based in Aberdeenshire, Scotland, has launched its first metal AM machine, the Defiant200. Based upon a novel Cold Deposit and Sinter technology, the new machine is marketed as an affordable entry into metal Additive Manufacturing.

The patent-pending Cold Deposit and Sinter (CDS) process has been developed over the past five years, led by company founder Gary Cairns. At the heart of the Defiant200 is a furnace, capable of reaching 1400°C. Inside this furnace is a Z-axis build plate, onto which two powders are deposited using a print head moving in the X and Y axis a layer at a time. One of the powders is the primary metal, the other is a support powder.

Once all layers have been deposited, the Z axis retracts to the bottom of the furnace and the lid of the furnace is closed. The furnace is heated to a temperature at which the metal powder sinters together to form the object, whereas the support powder – with a melting point above that of the metal – remains as a powder. Once the furnace has cooled, the metal object can be removed from the support material and post-processed as required.

The Defiant200 is a compact, all-in-one system, measuring just 107 x 82 x 185 cm and requiring a 16A, 240V single-phase AC power supply. It has a build volume of 200 x 200 x 200 mm and can process parts in stainless steel 316L, with other materials planned to be introduced in the future. The print head deposits the powder in layers of between 100 and 300 microns.

In addition to supplying the Additive Manufacturing machine, Defiant3D also plans to offer metal powder and support powder. The company has also developed its own dedicated slicer software.

The Defiant200 is a compact, all-in-one system (Courtesy Defiant3D)

The Defiant200 is currently available for pre-order at a price of £40,000, with shipping expected to begin in the first quarter of 2024.

www.Defiant3d.com

Nikon announces global headquarters for Additive Manufacturing in US

Nikon Corporation, headquartered in Tokyo, Japan, has announced that the global headquarters for its new AM Business Unit will be located in California, USA, bringing resources and decision makers closer to the company's customers and partners. Nikon has established a new company, Nikon Advanced Manufacturing, Inc., and intends to begin operations in July 2023.

Nikon stated that SLM Solutions and Morf3D will consolidate within Nikon Advanced Manufacturing, Inc., but added that the companies will continue to separately support their own customers' programmes and requirements.

Forming Nikon Advanced Manufacturing in California marks the first time in its 100-year history that the global headquarters of a Nikon business unit is outside of Japan. Nikon states that the new company, headed by Hamid Zarringhalam as CEO and Yuichi Shibazaki as co-CEO, will bring together a highly skilled, diverse and inclusive team focused on the success of the organisation and its customers. The location is said to provide excellent proximity to customers and partners, including the aerospace, space and defence industries.

In 2019, Nikon established a specialised division to accelerate the launch of new growth businesses such as Additive Manufacturing. Since then, by leveraging synergies resulting from strategic investments including the acquisition of SLM Solutions Group AG and prior to that, Morf3D Inc., the company stated it has taken major steps towards the industrialisation of digital manufacturing.

"In recent years, Nikon has executed pivotal investments and bold acquisitions focused on building a comprehensive portfolio of technology, industry knowledge and vision," stated Hamid Zarringhalam, CEO.

Nikon Advanced Manufacturing will combine extensive Nikon experience in high-tech manufacturing with the capabilities of SLM Solutions and Morf3D. Nikon envisions providing options for holistic, industrialised and fully scalable solutions, including enabling global turnkey factory opportunities for customers at locations of their choosing.

Yuichi Shibazaki, co-CEO, explained, "Nikon DED additive, subtractive and CT scanning solutions are perfectly complemented by the industry-leading [PBF-LB] systems from SLM Solutions as well as Morf3D's strong innovation pipeline and specialised aerospace qualifications. Nikon Advanced Manufacturing will enable us to work together with our partners and customers to unlock the incredible potential of advanced manufacturing and contribute to a more sustainable society."

www.nikon.com

KBM Advanced Materials offers NASA standard GRCop-42 'RocketPowder'

KBM Advanced Materials, LLC, Fairfield, Ohio, USA, is now supplying NASA standard GRCop-42 copper alloy powder. Referred to as 'RocketPowder' by the company, the alloy is made from copper, niobium and chromium and is ideally suited for space and hypersonic applications due to its high heat transfer and increased strength when compared to pure copper.

KBM is offering a GRCop-42 copper alloy powder, originally developed for space applications by NASA (Courtesy NASA)

KBM is a distributor of metal powders across the Additive Manufacturing and advanced manufacturing industries, but reports it noted a significant challenge when sourcing GRCop-42 for its customers. As a result, KBM formed a unique technical and production partnership through which a new, stable, repeatable process was developed for this specialty alloy.

The process reportedly took over nine months to perfect, but is intended to ensure that customers will have reliable access to GRCop-42 for their own production needs. KBM said it expects to deliver multiple tons of RocketPowder per month, which will be processed, tested and packaged in Ohio. Taking this final processing step in-house, KBM said it is creating a traceable, domestic supply chain for GRCop-42.

"Our customers were continually asking for GRCop-42, to the point that we said if we can't source it, we'll find a partner and invest in developing a production process ourselves," stated Kevin Kemper, KBM CEO. "This wasn't an easy task as meeting specifications was a challenge, but we are confident we have a repeatable and reliable process, and the right production partner, to provide quality powder for the highly critical needs of our space and hypersonic customers."

The GRCop-42 alloy has reportedly been shipped to a major advanced manufacturing OEM who is currently qualifying the powder.

www.kbmadvanced.com

qualloy and AddiMap collaborate to streamline AM procurement

qualloy, a digital marketplace for metal powders, has announced that it will be partnering with AM process parameters trading platform Addimap to provide a comprehensive solution that encompasses both the sourcing of metal powders and the accessibility of validated build parameters. By linking the two marketplaces, users will be directed to the offerings of the other platform, ensuring they have access to a holistic ecosystem for their AM needs.

qualloy's digital marketplace seeks to simplify the powder market by providing a platform where sellers and buyers can connect and transact with ease. By leveraging an intelligent search algorithm, qualloy streamlines the sourcing process, enabling users to find the ideal metal powders for their specific machines and specifications from a range of certified global suppliers. This allows users to freely switch between different powder manufacturers, optimising price, delivery time, and quality, all while ensuring a transparent and efficient procurement process.

"We are thrilled to collaborate with AddiMap and combine our strengths to create a comprehensive solution for the AM industry," said Yannik Wilkens, co-founder of qualloy. "With qualloy, we have simplified the market for metal powders, enabling buyers to find the perfect match for their printers quickly. Through this partnership, we aim to further enhance the user experience by providing seamless access to AddiMap's extensive printing parameters database, empowering users to unlock the full potential of Additive Manufacturing."

AddiMap grants users access to their parameter library, allowing them to transition from digital models to physical products without the need for extensive parameter studies.

Gregor Graf, Initiator of AddiMap, emphasised the importance of cooperation and cost reduction in advancing the adoption of metal AM, stating, "Cooperation is the key to leverage the full potential of metal AM. Less costs and more materials will lead to faster industrial adoption. With AddiMap, we aim to provide users with a vast range of process parameters, enabling them to increase productivity, optimise properties, explore new materials and streamline their AM operations."

This collaboration hopes to simplify the AM industry, streamlining the procurement process for metal powders and providing users with access to a comprehensive database of build parameters.

www.qualloy.com
addimap.com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Farsoon breaks ground as construction begins for 20 acre headquarters

Farsoon Technologies, headquartered in Hunan, China, recently held a ground-breaking ceremony for its new R&D and manufacturing headquarters in Xiangjiang New District, just ten minutes from the company's current base.

This new facility covers a total area of over twenty acres, and features 140,000 m^2 of floor space. The first phase of construction is expected to be completed in 2024 and will include multiple integrated infrastructures for industrial Additive Manufacturing, including research and development, an application hub, machine manufacturing, innovation laboratory, integration facility and service centre.

"Additive Manufacturing is playing an increasingly vital role in many industries," stated Dr Xu Xiaoshu, founder & CEO of Farsoon Technologies. "Farsoon Technologies has laid out a plan for pushing true manufacturing with plastic and metal Laser Powder Bed Fusion technology. With the completion of the new headquarters, we will keep building credibility by introducing innovative industrial solutions that meet the demand of the market."

Farsoon Technologies, founded in 2009, is a global manufacturer and supplier of industrial level polymer and metal laser-based Additive Manufacturing machines. Farsoon is reported to be the leading supplier of industrial AM technology in China and has an increasing presence in the international market. The company established a North American subsidiary in 2017 and set up Farsoon Europe GmbH in 2018.

The news follows on from the company's recent growth activity, which includes expanding its global sales presence and a recent listing on the Shanghai Stock Exchange.

www.farsoon.com

Farsoon's new facility will include 140,000 m^2 of floor space (Courtesy Farsoon)

Volkswagen expands AM capacity with second MetalFAB

The Volkswagen Group, headquartered in Wolfsburg, Germany, has further strengthened its Additive Manufacturing capabilities with the acquisition of a second MetalFAB Additive Manufacturing system from Additive Industries, Eindhoven, the Netherlands.

In 2018, the company established an Additive Manufacturing centre to produce automotive components using various Additive Manufacturing technologies, including Additive Industries' MetalFAB system.

The second MetalFAB was reportedly chosen for its high level of automation, eliminating manual processes and enhancing safety. Additive Industries' service and support were also noted as crucial factors in the decision-making process.

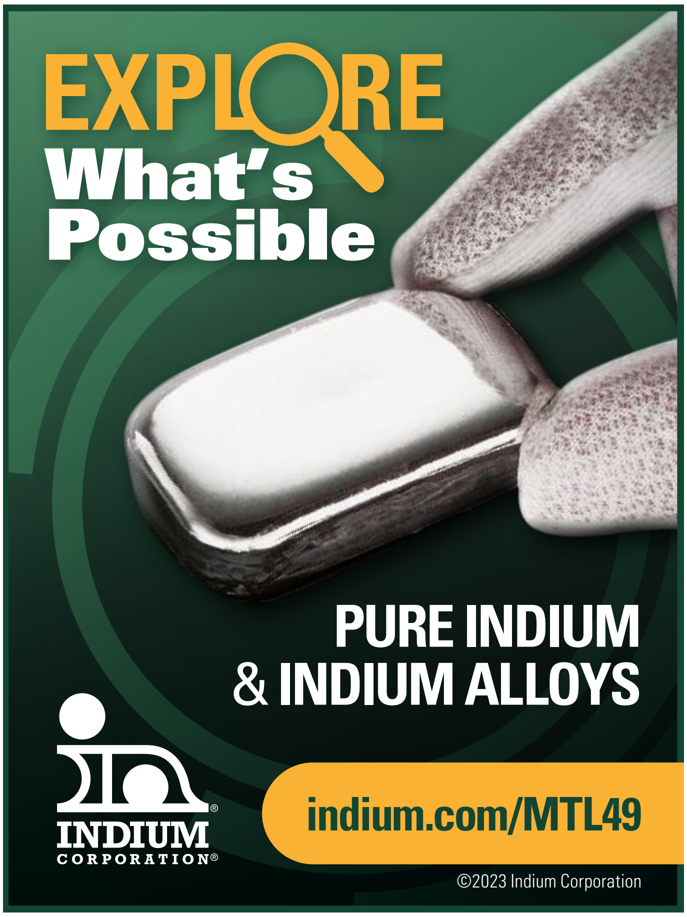
The system's modularity also allows Volkswagen to expand production capacity without major investments. Productivity features, such as full-field lasers and automated build changeovers, also enable high productivity rates and lights-out operations.

Volkswagen is also reported to have invested in parameter development and implemented the Powder Load Tool and Powder Recovery Station for efficiency and waste reduction.

Volkswagen has boosted its Additive Manufacturing capacity with a second MetalFAB system (Courtesy Additive Industries)

Mark Massey, Chief Executive Officer at Additive Industries, shared, "We as Additive Industries are pleased to be able to provide Volkswagen Group with their second MetalFAB system. We are here to help them expand their capabilities in the field of Additive Manufacturing and move towards the next step in the automotive industry."

www.volkswagen-group.com
www.additiveindustries.com



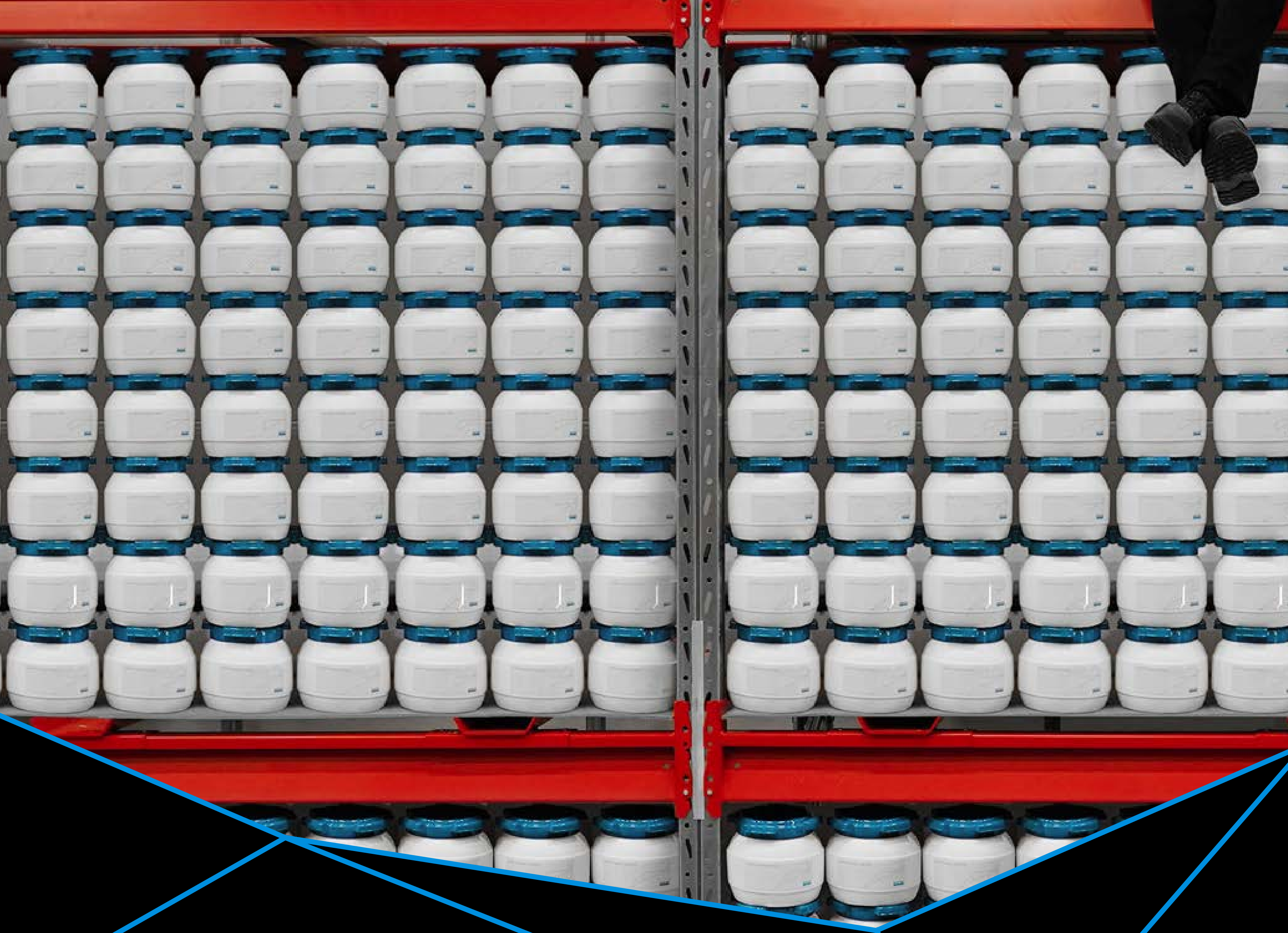
XJet to go public on Nasdaq via IPO

XJet, Rehovot, Israel, has completed preliminary filings that confirm its intention to go public on the Nasdaq stock market. According to the *The Times of Israel*, the company hopes to raise approximately $10 million from this IPO (initial public offering) through the sale of two million shares at $4-6.

"Despite market conditions, we believe going public is the best platform for us to access capital and to scale up the company as our products are ready," Yair Alcobi, XJet CEO, told *The Times of Israel*. He explained that the proceeds will be used for "scaling up, sales and marketing, and for R&D manufacturing purposes."

XJet's NanoParticle Jetting, a sinter-based Additive Manufacturing technology, is reportedly able to produce highly complex metal and ceramic parts with a fine surface finish. By using nanoparticles that are jetted in a suspension – and substantially less binder than processes such as metal Binder Jetting (BJT) – the technology is said to allow XJet to achieve superior material density at lower sintering temperatures, saving energy and resulting in less shrinkage and deformation.

www.xjet3d.com



MetalWorm introduces range of robotic Wire Arc AM machines

MetalWorm Additive Manufacturing Technologies Inc., a spin-off of Intecro Robotics Inc., based in Ankara, Türkiye, has announced two primary Additive Manufacturing systems built around its Wire Arc Directed Energy Deposition technology. Together, these two AM machines – the MetalWorm Compact System and MetalWorm Special System – provide the base for eleven computer-controlled robotic AM options.

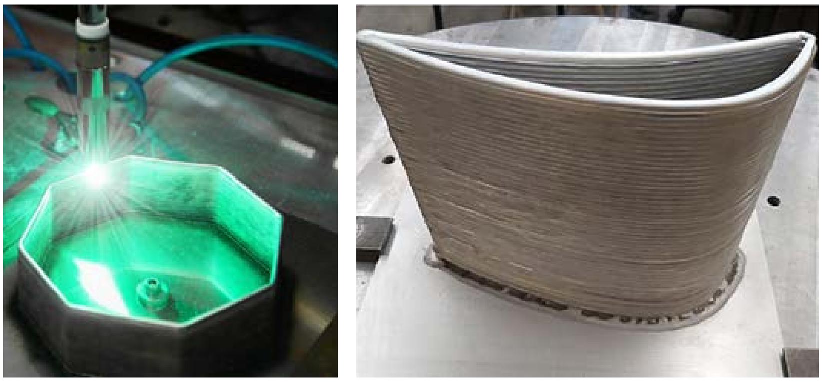
The company has also developed proprietary software that enables the generation of different toolpath strategies and robot codes for various geometries and materials. MetalWorm's process parameter library currently includes frameworks for producing steel, stainless steel, and aluminium alloys. MetalWorm is also developing parameters for additional alloys, including titanium, Inconel and armour steels.

The MetalWorm machines are customisable and include a range of monitoring and controlling options to meet the specific needs of clients, such as those using advanced digital twin technologies. The machines also feature:

- **Active Cooling Technology** that utilises a cooling table to promote heat transmission to the substrate and reduce high heat accumulation. It also allows manufacturing parts on thinner substrates, reducing substrate waste and costs. The AM process can also be accelerated by cutting down on inter-layer cooling time, increasing the deposition rate.
- **Active Heating Technology** can eliminate thermal gradients and homogenises temperature distribution, preventing cracking, residual stresses, and high distortion.
- **Vibration Technology** is intended to prevent the development of coarse and columnar grains, promoting the transition of coarse columnar grains into refined and equiaxed grains, thus improving mechanical characteristics.
- **Arc Voltage Control** allows the robot to adjust the torch's height automatically during the process based on the height difference between the torch and the component. This technology reputedly ensures a consistent and precise deposition, improving the overall quality of the final product.

The MetalWorm Compact System is marketed as a plug-and-play, user-friendly, AM machine with integrated components and technologies all designed in a single cell. The company's MetalWorm Special System is designed to provide robotic solutions for the manufacture of larger parts. MetalWorm also offers custom-designed systems for those with specific requirements.

www.metalworm.com



MetalWorm's robotic wire-arc Additive Manufacturing options are based around the Compact System and the Special System (Courtesy MetalWorm)

Markforged posts record first quarter revenues

Markforged, Watertown, Massachusetts, USA, has shared its financial report for the first quarter 2023. As of March 31, the company has reported a revenue increase of 10% to \$24.1 million, up from \$21.9 million in the first quarter of 2022.

Shai Terem, president and CEO of Markforged shared, "We have started the year strong with another record first quarter revenues and the largest pipeline in our company's history. Demand for the Digital Forge grew across all geographies in Q1, as an increasing number of manufacturers are choosing our metal and composite solutions to solve mission-critical metal applications at the point of need."

Gross profit remained stable generating \$11.6 million in both the first quarters of 2023 and 2022. Furthermore, non-GAAP gross profit was \$11.9 million in the first quarter of 2023 compared to \$11.7 million in the first quarter of 2022.

However, Markforged reported a net loss of \$19.0 million in the first quarter of 2023, compared to a net profit of \$4.2 million in the first quarter of 2022. Whereas non-GAAP net loss marked a loss of \$13.3 million in the first quarter of 2023, compared to a loss of \$14.9 million in the first quarter of 2022.

"We believe our Q1 results are a reflection of strong execution of our strategy and an early indicator of the meaningful opportunity for Markforged in the coming quarters as we remain laser focused on margin expansion and driving profitable growth," Terem concluded.

www.markforged.com

Zeda opens advanced manufacturing facility in Ohio

Zeda, Inc., Fremont, California, USA, has announced the opening of a new 7,000 m^2 facility in Cincinnati, Ohio. Providing a substantial increase from its existing 1500 m^2 site, the new facility provides a larger capacity for growth and greater capabilities to serve the demand for advanced Additive Manufacturing and nanotech solutions in the medical, space, aerospace and defence markets.

"This new facility helps Zeda offer value to our customers in multiple ways. Using a portion of the facility, we built out an end-to-end pipeline utilising high-end additive printers, and the latest CNC machines meet stringent requirements across multiple regulated industries," said Steve Rengers, Senior Vice President of Zeda.

"We also ensured the new facility provides physical space for growth. In that way, Zeda can grow with the customer. This allows us to build out processes and 'manufacturing cells' to meet specific customers' needs – which may entail higher security, proprietary materials, or unmatched efficiency to yield lower part costing," added Rengers.

Zeda has reportedly invested $20 million in new state-of-the-art capital equipment to focus on both large

Zeda has opened a new 7,000 m^2 facility in Cincinnati, Ohio (Courtesy Zeda Inc.)

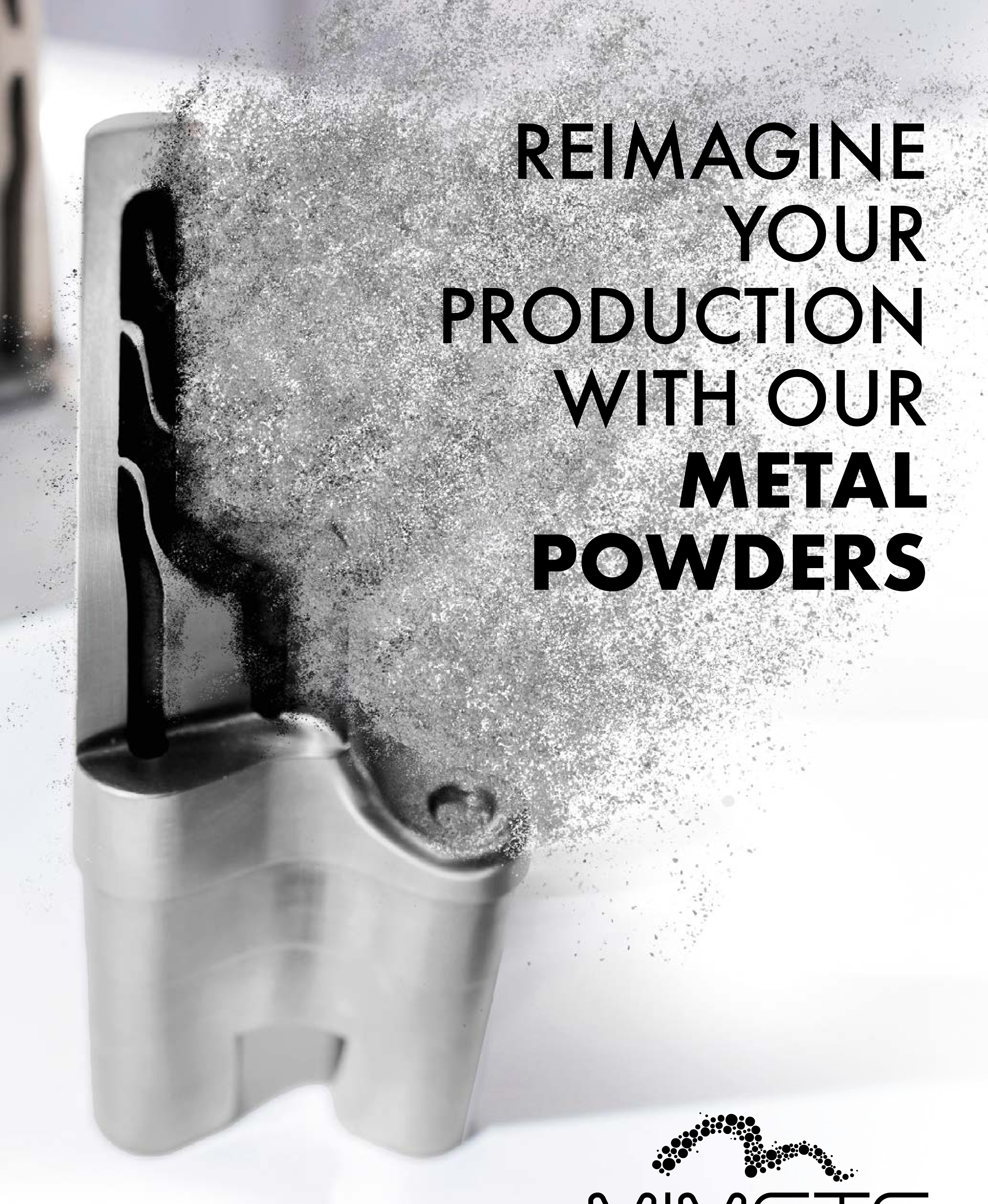
and small-format metal Additive Manufacturing and secondary processes, including CNC machining. It is also said that the facility will be AS9100 and ISO 13485 certified, meeting the demands of highly-regulated industries. The facility looks to support the vertical integration of medical cleaning, passivation, pack automation, and lights-out manufacturing with advanced technology and data collection capabilities. It will also support prototyping, advanced manufacturing technologies, and process development.

"We're excited that this facility is coming on stream," added Kishore Karkera, co-founder and COO of Zeda. "It signals that we're on a solid growth path and gives us the necessary room and utilities to expand our capacity and capabilities to meet the growing demand for localising supply chains. With the recent closure of our $52 million Series B funding round and the launch of our new facility, we're pushing forward with our vision to help our served industries and customers build things better."

The new facility will be led by Greg Morris, CTO of Zeda, who shared, "We have seen exponential growth in our Cincinnati business over the past year and expect that to continue for the foreseeable future as we expand our presence in various industries, specifically aviation, defence, energy, medical, and space. With this new world-class, state-of- the-art facility set to come online in Q3 2023, we will have the capacity and capabilities to maintain and grow our leading position in the market."

www.z8a.com

Steve Rengers, Senior Vice President of Zeda (Courtesy Zeda Inc.)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www.mimete.com

Verder acquires Formulaction to expand particle characterisation portfolio

The Verder Group, headquartered in Haan, Germany, has announced the acquisition of Formulaction SA, based in Toulouse, France. As part of the group's Scientific Division, Formulaction will be integrated into Microtrac MRB, a manufacturer of particle characterisation systems.

Formulaction develops laboratory equipment for analysing dispersion stability & shelf life, curing & drying processes and rheology. The addition of this company to the Microtrac MRB portfolio is expected to create a comprehensive suite of instrumentation for materials characterisation practitioners.

This merger adds Formulaction's Turbiscan, Curinscan, Fluidcam and Rheolaser product lines to Mictrac's own brand portfolio, including SYNC Laser Diffraction, Nanotrac Dynamic Light Scattering, Camsizer Dynamic Image Analysis and Belsorp Gas Adsorption Analysis.

"Since its creation, Formulaction has been at the forefront of technical innovation in helping scientists to directly assess key properties of their materials from early development to final product design or 'End Use Properties,'" stated Gerard Meunier, CEO of Formulaction. "The integration of the Formulaction product portfolio into Microtrac MRB opens huge opportunities for the expanded group to provide added value to customers in their pursuit of innovative product development by delivering high-quality solutions."

Microtrac MRB's and Formulaction's combined technologies will provide a comprehensive portfolio of particle and material characterisation solutions. The move is hoped to offer both companies access to new markets and opportunities in:

- Particle size and shape from 0.3 nm to 135 mm
- Surface and pore size distribution using both physi- and chemisorption
- Catalyst analysis
- Porosity and density measurements
- Dispersion stability and zeta potential analysis
- Curing and drying analysis
- Rheological properties

"We have been witnessing the development of Formulaction for years and are impressed with the technology and the agility of the team," added Andries Verder, CEO, Verder. "The addition of the people and products from Formulaction is an important building block in our drive to enable the progress for our customers in the world of particle characterisation."

www.formulaction.com
www.microtrac.com
www.verder.com

Conflux 1

Metal 3D Printing System

Powered by Metal Paste Deposition

LOW OPERATING COST

Keep low-volume part production lean and agile.

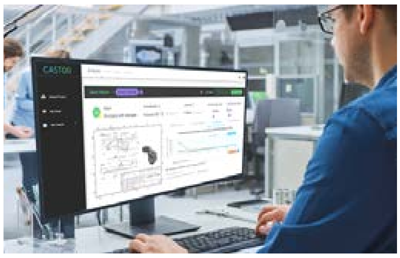
FAST TURNAROUND

Get functional parts in under 24 hours.

INSTALL ANYWHERE

Make metal parts wherever you need them.

Asahi Kasei leads investment in Castor's intelligent manufacturing optimisation software



Asahi Kasei has invested in Castor Technologies, a developer of advanced supply chain software (Courtesy Castor Technologies)

Castor Technologies Ltd, Tel Aviv, Israel, a software startup in the Additive Manufacturing industry, has secured funding from Asahi Kasei, a Japanese multinational corporation headquartered in Tokyo. In addition to Asahi Kasei's investment, existing investors such as Xerox, Spring Ventures, Evonik Venture Capital, Jeremy Coller, TAU Ventures, and Chartered Group have also contributed to the funding round.

Castor Software works to optimise manufacturing processes with its supply chain software. Using advanced proprietary algorithms, Castor automatically identifies components suitable for Additive Manufacturing, leading to a reduction in time, cost, and CO_2 emissions when compared to traditional manufacturing methods.

"We are excited to have the support of Asahi Kasei and our other investors," stated Omer Blaier, Co-Founder & CEO of Castor. "This investment will enable us to continue our efforts in developing and expanding our software solutions, which aim to assist manufacturers in optimising their production processes for greater efficiency and sustainability. We look forward to collaborating with our investors to bring our technology to a wider audience and serve more industries worldwide."

The investment marks Asahi Kasei's first venture in the Additive Manufacturing industry and was mutually celebrated with Takashi Morishita, president of CVC at Asahi Kasei, who stated, "The Asahi Kasei Group is committed to supporting a sustainable future through their investment in Castor's innovative software solutions for identifying opportunities to implement Additive Manufacturing. We see the software is a key enabler to promote Industry 4.0, which focuses on the integration of advanced technologies to increase efficiency and productivity. Castor's mission aligns with Asahi Kasei's goal the implementation of Additive Manufacturing in the industry in a more efficient and sustainable method."

www.asahi-kasei.com
www.3dcastor.com

Schaeffler showcases multi-material laser-based AM machine for metal and ceramic

Schaeffler Special Machinery, is showcasing its concept for multi-material Additive Manufacturing at automatica 2023, taking place at the Trade Fair Center Messe München, Munich, Germany, June 27- 30. The high-precision multi-material AM machine is expected to offer parts comprising of a combination of metals and ceramics, and will be available from 2024.

In its unique Additive Manufacturing process, up to three different layers of materials can be applied from integrated powder reservoirs. A recoater is used to place these different powers side by side – layer by layer – on the work platform. A laser is then used to gradually fuse the individual layers together. Multiple laser sources and scanners are said to ensure optimised processing of a wide range of materials.

Schaeffler has worked in collaboration with a partner for material application processes, and together will offer a range of services that encompasses the AM machines themselves, software and the provision of the material feedstock. Supplementary services, such as 'design to print' or machine measurement and calibration, are expected to ensure robust production of additively manufactured products.

"Our newly developed system concept for multi-material 3D printing represents a milestone in the integration of Additive Manufacturing processes into our production lines," stated Bernd Wollenick, Senior Vice President Schaeffler Special Machinery. "This solution will allow customers to use innovative material combinations, integrate new functions into components and tools, and provide a higher degree of flexibility in the design of products and tools."

www.schaeffler.de

Schaeffler Special Machinery's multi-material AM machine is expected to be available from 2024 (Courtesy Schaeffler)

Siemens Energy partners with Seurat to manufacture 59 tons of AM parts

Seurat Technologies, Wilmington, Massachusetts, USA, has announced an agreement to develop 59 tons of additively manufactured metal components for Siemens Energy turbines. Development will ramp up over a six-year-period and the initial focus will be on one part family, with the possibility of increasing volumes to include others in the future.

Seurat believes that its Area Printing technology, based on the Laser Beam Powder Bed Fusion (PBF-LB) process, will allow Additive Manufacturing to be competitive in every way (cost, scale, and quality) while leveraging 100% renewable green energy. The company stated that it anticipates mitigating as much as 100 metric tons of CO_2 by 2030 and has validated its carbon footprint forecast according to ISO 14064 standards.

"Siemens Energy is always looking for innovative technologies that can transform the future while creating a more sustainable world," stated Enrique Gonzales Zanetich, Head of Venture Building, Siemens Energy. "We're excited about our future printing high-quality parts with fantastic economies of scale to deliver cost savings. We invested in Seurat Technologies and believe that strengthening our partnership could help to accelerate decarbonisation in the industry at scale."

Siemens Energy already uses Additive Manufacturing to produce a number of parts, such as this gas turbine burner (Courtesy Siemens Energy)

James DeMuth, CEO and co-founder of Seurat added, "Seurat's partnership with Siemens Energy is a major milestone for 3D metal printing and our potential to deliver limitless scalability and cost savings. We are proud to be trusted by global leaders who are reimagining manufacturing. Volumes of this order of magnitude significantly move the needle towards greener technologies and unlocking Additive Manufacturing's full potential."

Commenting on the use of AM in the energy sector, Dr Maximilian Munsch, managing partner of strategy consultancy AMPOWER, stated, "An important driver is the energy sector. For several years now, the energy industry has efficiently utilised metal 3D printing for the production of turbine components, reaching a high level of maturity. Metal 3D printing has become a crucial enabler technology for innovation to significantly reduce the CO_2 footprint throughout the turbine's lifetime. We expect the demand for such components to grow by 26% annually."

Last autumn, Seurat announced that its pilot factory is fully subscribed and is planning on opening a full-scale production factory to accommodate customer demand. Seurat has raised $91.5 million from investors such as Capricorn's Technology Impact Fund, True Ventures, and Porsche Automobil Holding SE, and has more than 209 patents granted and pending.

www.seurat.com
www.siemens-energy.com

Farsoon Technologies lists on Shanghai Stock Exchange

Farsoon Technologies, Changsha, China, was listed on the Shanghai Stock Exchange (SSE) on April 17, following a successful IPO process.

"We especially like to give our acknowledgement to all who supported us in this process and helped to make Farsoon a strong global player in the Additive Manufacturing industry," the company stated.

Fourteen years ago, Dr Xu Xiaoshu established Farsoon in China as a laser-based Additive Manufacturing machine company, said to be motivated by his vision of enabling the industrialisation of Additive Manufacturing with truly open systems. According to the company, this vision has become reality, demonstrated by the more than 800 systems sold since the company's founding.

Growth at the company has seen its range of machines for both polymer and metal AM expand rapidly. The company established a North American subsidiary in 2017 and set up Farsoon Europe GmbH some five years ago. "Our successful business development shows the high attractiveness of open systems," the company added. "We are continuing to help our customers increasing their competitiveness in the production of metal and plastic parts."

www.farsoon-gl.com

Aubert & Duval sold to Airbus, Safran and Tikehau Capital

The acquisition of Aubert & Duval, a specialist producer of advanced material solutions including metal powders, by Airbus, Safran and Tikehau Capital has been finalised. Aubert and Duval was formerly part of the alloys branch of France's Eramet Group.

"The acquisition of Aubert & Duval will ensure the national and European sovereignty of our strategic programmes developing disruptive civil and military engines, and secure our critical parts and materials supply chain," stated Olivier Andriès, CEO, Safran. "I am confident the new team will carry through the transformation project to get this leading French industry player back on track."

Aubert & Duval is a strategic supplier of critical parts and materials to customers in the aerospace, defence, nuclear and medical industries. The company generates reported annual revenues in the region of €550 million and employs 3,700 people, mostly in France. Its experience in specialty steels and superalloys – and its more recently acquired expertise in titanium – are crucial to the aerospace, transportation, energy, defence and medical markets.

"Completion of this acquisition represents a crucial step towards the creation of a leading European player in critical parts and materials, equipped to compete globally and to support the aerospace and defence industry, thereby reducing geopolitical risks of supply," added Guillaume Faury, CEO, Airbus. "Airbus will provide its full support to Aubert & Duval as it executes its ambitious transformation plan."

Marwan Lahoud, Chairman – private equity, Tikehau Capital, stated, "The acquisition of Aubert & Duval reflects the quickening pace of transformation and consolidation in the aerospace sector. Tikehau Capital is proud to be aiding the company's recovery and the development of its industrial expertise alongside Airbus and Safran. Aubert & Duval is a strategic player vital to maintaining France's and Europe's industrial independence."

The sale marks the latest in a series of initiatives in recent years to support and strengthen France's aerospace sector, notably through the Ace Aéro Partenaires investment fund set up in 2020 and handled by alternative asset management firm Tikehau Capital with the backing of the French government, which retains a golden share in Aubert & Duval company in order to protect its strategic interests.

Bruno Durand appointed CEO of Aubert & Duval

It was also announced that Bruno Durand has now been appointed CEO of Aubert & Duval.

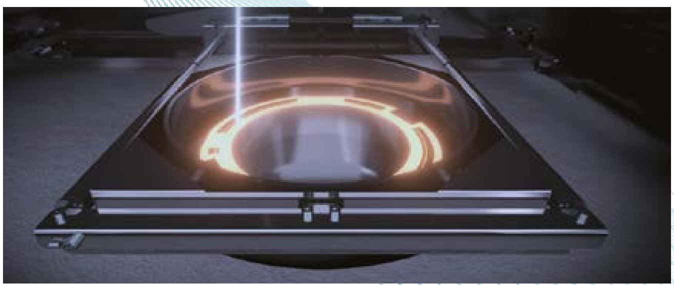
"A new chapter is beginning for Aubert & Duval, for both its staff and its customers. Our new shareholders, who are committed to a long-term vision, all share a single objective: to make Aubert & Duval the leading European supplier to the aerospace, defence and energy industries," stated Durand. "We face major challenges, in particular the challenge of decarbonising our products and developing the circular economy as we work to support the industrial sectors we supply. I understand the importance of the responsibility that has been entrusted to me, and I am looking forward to tackling these challenges alongside everyone in the company."

Durand joined Safran in 2005, where he was VP – Purchasing at Labinal (now Safran Electrical & Power) and deputy CEO. He was subsequently appointed VP – Supply Chain at Snecma (now Safran Aircraft Engines) in 2009 before joining Sagem (now Safran Electronics & Defense) in 2012 as Vice President, Industrial Operations. He was appointed VP – Industrial Operations and Supply Chain at Safran Aircraft Engines in 2014, then Safran Executive Vice President, Production, Purchasing & Performance in 2020. In May 2022, he left this post to take charge of the Aubert & Duval transformation project with Safran's CEO.

www.safrangroup.com
www.airbus.com
www.tikehau-ace.capital
www.aubertduval.com

EB-PBF

JAM-5200EBM

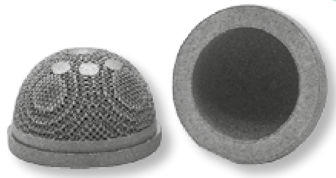


Build Cleaner, Faster, Stronger and Lighter

E-beam Metal PBF 3D Printer from JEOL

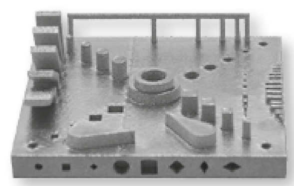
JEOL's E-beam metal powder bed fusion 3D printer optimizes series production of high quality, reproducible metal parts for aerospace, medical and energy fields. The JAM-5200EBM from JEOL delivers numerous advantages for metal 3D printing:

- Fast Build Rate with 6000W Power Electron Beam
- In-situ stress relief, removing need for post build heat treat
- Nesting parts in a single run to maximize productivity
- Support-free builds down to 15˚
- Increasing stability and accuracy with automatic electron beam correction
- Featuring helium-free manufacturing
- Eliminating smoke events with patented e-Shield
- High uptime with long-life cathode > 1500hrs
- Superior service and fast, on-site response



Nested Acetabular cup and its body (Ti64)

Vacuum chamber (Ti64)



FAT/IQ build (Ti64)

Turbine blades with stand (Ti64 & Ni-base superalloy 718)

Induction heating coil & Heat sink (Pure copper)

Discover more about the JEOL E-beam Metal AM Machine at

formnext forum AUSTIN August 28-30, 2023

www.jeolusa.com

JEOL

6K Additive to produce Z3DLab's titanium zirconium alloy powders

6K Additive, a division of 6K Inc., headquartered in North Andover, Massachusetts, USA, has announced a partnership with Z3DLab, Montmagny, Îl-de-France, France, for the production of its titanium zirconium alloys range. 6K Additive will process Z3DLab's proprietary ZTi alloys using its UniMelt technology to produce spherical, dense powders specifically for AM. The process delivers up to 100% yield, making the production of new materials more commercially viable.

Z3DLab's ZTi powders are said to improve on the ductility, wear resistance, and heat oxidation relative to Ti64. The ZTi-Med alloys range includes ZTM14N, a biocompatible titanium ternary alloy designed to maintain a good strength-ductility ratio alongside the elasticity. The elastic modulus of ZTM14N is very low at 38 GPa, reportedly matching the elastic modulus range of human bone (~5-30 GPa), making the powder well-suited for medical implants.

"Our ZTM14N material is unique for the medical implant industry and has tremendous growth opportunity in the space. However, we cannot afford to suffer the yield loss that is typical in the atomisation process during production. We will be burdening the cost unnecessarily for our customers. 6K Additive's UniMelt delivers the required high yields of highly spheroidised powder that enables us to cost-effectively deliver our material to the market. This partnership benefits not only 6K Additive and Z3DLab but also the customers we serve. I am looking forward to our next project in the aerospace sector," explained Dr Madjid Djemai, President of Z3DLab.

A key benefit of 6K's UniMelt process is the ability to use scrap, revert or used powder as feedstock, eliminating the need for virgin material extraction while simultaneously improving the quality of the final powder compared to traditional atomisation methods. Z3DLab's high-performance alloys can be reprocessed in the same way, creating a circular economy for high-value, high-performance alloys.

Francois Bonjour, European Sales Director for 6K Additive added, "Our UniMelt production scale powder manufacturing platform can process a near-infinite range of alloys thanks to its microwave plasma energy source and unparalleled controllability. It only makes sense for Z3DLab and 6K Additive to partner to bring such an innovative material to the market with the quality and cost model to make it successful commercially."

www.6kinc.com
www.z3dlab.com

DSB Technologies announces metal Binder Jetting prototyping service

DSB Technologies, a manufacturer of Powder Metallurgy components headquartered in Janesville, Wisconsin, USA, has announced the launch of its metal Binder Jetting (BJT) prototyping service. Through this service, customers will be able to leverage the speed and cost-efficiency of metal Additive Manufacturing to iterate designs more efficiently than conventional metalworking processes.

"DSB views this prototyping program as an important stride to educating the marketplace on the capabilities of the metal binder jet technology and helping grow product application opportunities," stated Paul Hauck, DSB Technologies Chief Operating Officer. "We are broadening access to DSB's experienced and knowledgeable 3D printing design and process engineers for customers seeking to prototype and iterate their metal part designs."

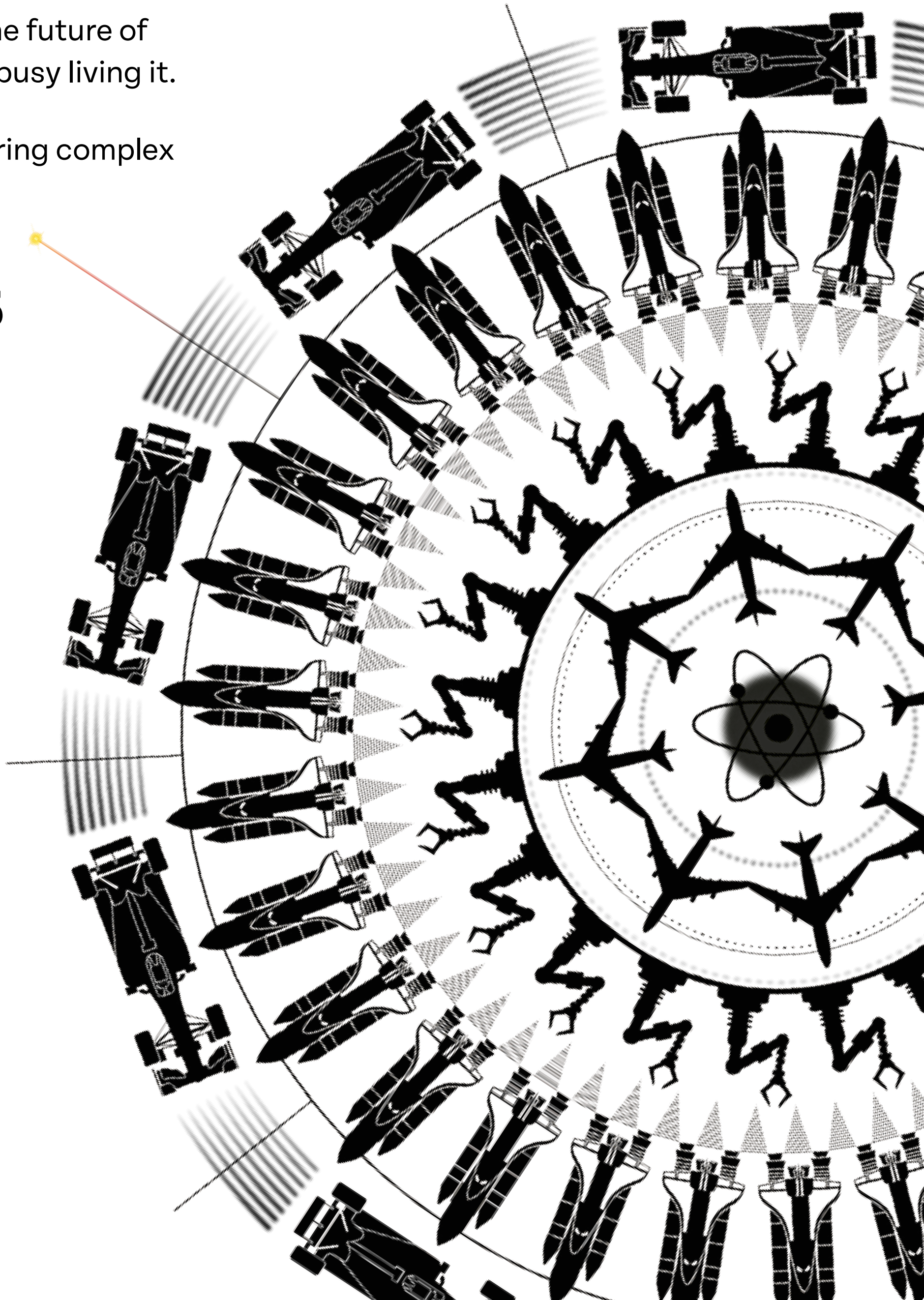
Customers can now design and produce metal Binder Jetting prototypes in two weeks or less for part sizes up to 15 cm^3 from 17-4 PH stainless steel. Prototypes of up to 5 cm^3 part size are available in four weeks or less in 316L stainless steel, M2 tool steel, and 4140 steel.

DSB Technologies has been established for over forty years and offers a wide range of metal powder-based services including press and sinter PM, Metal Injection Moulding and metal Binder Jetting. The company has extensive high temperature sintering capacity combined with its parts-making experience, and has said it remains committed to industrialising the metal Binder Jetting process for serial production as it adds this prototyping capability to its portfolio.

DSB Technologies has posted a guide to the design advantages of metal Binder Jetting on its website.

www.dsbtech.com

Part designed and produced by metal Binder Jetting (Courtesy DSB Technologies)



Formula 1 approves Aheadd CP1 aluminium for additively manufactured heat exchangers

PWR Advanced Cooling Technology will use Constellium's Aheadd CP1 aluminium powder to additively manufacture heat exchangers for F1 using Velo3D's Sapphire AM machines (Courtesy PWR Advanced Cooling Technology)

Constellium SE, headquartered in Paris, France, has announced that its Aheadd® CP1 aluminium powder has been approved for use in Formula 1 race cars. Constellium has partnered with Velo3D, Campbell, California, USA, and PWR Advanced Cooling Technology, Ormeau, Australia, to start providing efficient, compact, and lightweight additively manufactured heat exchangers for F1 cars, beginning in the 2024 season.

Aheadd CP1 is an aluminium, zirconium, iron alloy that is specially designed for Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing machines. It is thermally stable up to 300°C and reputedly provides excellent corrosion resistance, is highly isotropic, and built parts have excellent surface finish and stable microstructures.

Velo3D qualified Aheadd® CP1 for use in its Sapphire Additive Manufacturing machines and PWR will use the alloy to manufacture heat exchangers along with a variety of other high-performance components for the company's customers.

"We are proud to have our high-performance Additive Manufacturing aluminium powder approved for use on Formula 1 race cars," stated Alireza Arbab, Head of the Additive Manufacturing team at Constellium C-TEC. "Our customers can now develop a wide range of high-performance components, ranging from highly complex heat exchangers to structural parts. The benefits include previously impossible designs, cost-efficient parts, reduced machine utilisation time and better ROI."

PWR provides high-performance aluminium radiators, intercoolers, oil coolers, and other finished parts to customers in F1, NASCAR, V8 Supercars, Deutsche Tourenwagen Masters, and other motorsport categories. It also services customers in the energy, defence, and aerospace industries.

"Aheadd CP1 is a fantastic addition to our AM services and Velo3D's unparalleled print capabilities coupled with PWR's brazed fin technology creates a unique performance differentiator for our customers," added Mark Booker, PWR Technical Project Manager. "Our goal is to give our racing customers an unfair advantage on the track and we look forward to seeing these teams win using new parts manufactured by PWR."

In addition to the standard 50 μm layer thickness that all of Velo3D's AM machines use, Aheadd CP1 is also being qualified to additively manufacture parts in 100 μm layers in an effort to provide customers with a balance between finished part performance and system throughput.

"Our team is committed to listening to customers and enhancing our technology to meet their needs, so when PWR came to us with a challenge of qualifying a new alloy with a first-of-its-kind parameter set, we were thrilled to partner with them on the project," stated Dr Zachary Detweiler, Velo3D VP of Technology. "Aheadd CP1 is the first alloy qualified in our Augsburg, Germany, European Technology Center. Our American and European teams are both adept at creating scalable solutions for metal AM materials and we encourage companies who need customised material development for their applications to contact us about their specific requirements."

www.velo3d.com | www.pwr.com.au
www.constellium.com

Solar Atmospheres of California gains Airbus approval

Solar Atmospheres of California (SAC), based in Fontana, California, USA, has announced that it is now approved by Airbus for heat treating. The news follows the company's approval by Honeywell in December last year.

"Many Airbus suppliers were in need of a heat treater in the West that could process parts, plates and bars in support of increased Airbus production rates," stated Frank Trujillo, Director of Sales for Solar Atmospheres of California. "SAC is proud to be a partner on the Airbus Team!"

Using its wide range of furnaces, SAC is capable of processing small components up to loads of 22,500 kg and over 7 m in length. This approval is expected to translate into improved lead-times and greater efficiencies for Airbus suppliers that require heat treat services in the region.

www.solaratm.com

BLT expanding its metal powder production capacity

BLT is expanding its metal powder production facilities and adding further AM part production lines (Courtesy Xi'an Bright Laser Technologies)

Xi'an Bright Laser Technologies Co., Ltd. (BLT) has officially broken ground on its Phase IV facilities expansion project in Xi'an, China. This fourth phase will see the company increase its metal powder production, along with adding more Additive Manufacturing part production lines, and will result in approximately 163,200 m^2 of additional floor space.

BLT stated that Phase IV marks a new stage in the company's evolution, with a significant increase in capacity for both powder and part production. The move is said to reflect the broader adoption of AM services in aerospace and other industries both within China and abroad.

BLT's Phase I and Phase II facilities occupy about 100,000 m^2 and consist of a high-level R&D centre and six Additive Manufacturing factories. Phase III is currently under construction and covers an area of 190,000 m^2. It will focus on Design for Additive Manufacturing (DfAM), big data, intelligent equipment, unmanned factory automation and other aspects.

BLT was founded in July 2011, and today is a leading metal AM solution provider in China. The company currently employs more than 1,100 employees across sites in Schenzhen, Jiangsu, Weinan and Xi'an.

www.xa-blt.com

IperionX releases plans for largest 100% titanium powder facility by 2025

IperionX Limited, Charlotte, North Carolina, USA, has announced that it has completed the detailed engineering design for the planned Titanium Demonstration Facility (TDF), announced in September 2022, and a techno-economic assessment for the company's first Titanium Commercial Facility (TCF-1). The TCF-1 has a production capacity of 1125 metric tonnes per annum (tpa) and will be located at the Southern Virginia Technology Park in Halifax County, Virginia.

The TDF and TCF-1 will utilise Hydrogen Assisted Metallothermic Reduction (HAMR) technologies to produce titanium metal powder. Development of the TCF-1 would furnish IperionX with the largest recycled titanium metal powder production capacity globally, whilst reportedly being the only titanium production facility using 100% titanium metal scrap as a feedstock. This will also reportedly be the only such facility with zero Scope 1 & 2 emissions with the lowest carbon intensity for any commercial titanium metal powder product.

The TDF is expected to begin commissioning in Q4 2023 and be operational by Q1 2024, targeting a run rate of 125 tpa by Q3 2024. Development of the TDF remains subject to successful board approval for a final investment decision, expected in Q3 2023.

The facility is projected to initially produce approximately ~15 tpa of spherical titanium metal powder and ~110 tpa of angular titanium metal powder. IperionX then plans to install additional equipment at the facility to allow for the operational flexibility to produce 125 tpa of either 100% angular titanium metal powder or 100% spherical titanium metal powder for an incremental capital cost of $6.9 million. Cash costs for 125 tpa of spherical titanium powder production at the TDF are projected to be approximately $72/kg, before contingencies.

The larger capacity TCF-1 could be operational by Q4 2025 if items with long lead times are ordered in Q3 2024. The TCF-1 is designed to produce 1,125 tpa of angular or spherical titanium metal powder. Capital costs for this expansion would be $70 million, with $48 million needed for long lead time orders and the remaining $22 million needed during commissioning in 2025.

Assuming a conservative spherical titanium metal powder price of approximately $130/kg (vs. current estimated market pricing of approximately $200/kg), and using key operating assumptions, the TCF-1 has the potential to generate revenue of approximately $145 million and EBITDA of approximately $100 million in 2026.

www.iperionx.com

Addiblast launches MARS05 depowdering system

Addiblast, Dolenjske Toplice, Slovenia, has introduced its fully automated MARS05 depowdering machine, designed to remove powder from large, complex additively manufactured metal structures.

The machine has a workspace volume of 200 x 200 x 200 cm, and is capable of handling build plate volumes of up to 100 x 100 x 100 cm. The machine has a load capacity of 1100 kg and has an optional inert gas infusion system.

To enable precise and complete depowdering, the MARS05 features a 150 cm diameter servo-driven rotating table on a swivel arm with a frequency-regulated electro vibrator. There is also an air gun for cleaning and a large, enclosed chamber for safe operation.

Addiblast has introduced a fully automated depowdering machine for metal Additive Manufacturing (Courtesy Addiblast)

The machine also features a programmable logic controller unit which allows users to set, store and recall different depowdering operations in order to improve workflow and productivity.

www.addiblast.com

Paragon Medical opens AM facility with $16M investment

Paragon Medical, Pierceton, Indiana, USA, has opened its new Additive Manufacturing facility located on its existing Pierceton campus. The new facility is supported by an initial investment of $16 million with an anticipated additional investment of $19 million over the next five years.

Wil Boren, CEO of Paragon Medical, stated, "With the healthcare Additive Manufacturing market anticipated to be $8 billion by 2030, our investment demonstrates a continued commitment to innovation in design and manufacturing in this rapidly growing space. Our new Additive Manufacturing capability is serving our local medical device community, as well as making a global impact."

www.paragonmedical.com

Oerlikon to additively manufacture heat exchangers for Ariane 6 rocket launcher

ArianeGroup, headquartered in Issy-les-Moulineaux, near Paris, France, and Oerlikon AM, Pfäffikon, Switzerland, have signed an order worth up to €900,000 for the production of additively manufactured heat exchanger sets for the new Ariane 6 rocket launcher. The aluminium parts, to be produced by Oerlikon AM, will act as heat management devices for onboard equipment, enhancing the performance and flexibility of the new launcher.

The Ariane 6 launcher is seen as a crucial component for European space access, enabling the launch of satellites and high-tech payloads into orbit multiple times per year. It is expected to play a key role in Europe's space activities, including scientific exploration, Earth observation, telecommunications, and national security. Designed for optimised flexibility and efficiency, the Ariane 6 is intended to provide a reliable and cost-effective means of launching a wide variety of payloads into space, including satellites.

Oerlikon AM has reportedly worked very closely with the Ariane 6 technical team to ensure the heat management solution meets the most stringent technical specifications. During the development process, the team utilised key advantages of metal Additive Manufacturing, such as increased geometric freedom of design, minimal weight, and rapid lead times to ensure that the heat exchangers' new, compact design fits perfectly into the limited installation space.

Oerlikon AM will additively manufacture heat exchangers for the new Ariane 6 rocket launcher seen here under construction at the new Ariane 6 Launcher Assembly Building at Europe's Spaceport in French Guiana (Courtesy ESA-CNES-ArianeGroup-Arianespace / CSG Service Optique)

After its initial launch, Ariane 6 will reportedly take off several times per year into various orbits, including low Earth orbit, geostationary transfer orbit and sun-synchronous orbit. Thus, the heat exchanger sets were explicitly designed for serial production. Oerlikon AM is set to support ArianeGroup to meet their production requirements over the coming years, based on the forecasted demand for the rocket.

"Delivering components for Ariane 6 is an important milestone as we consolidate and expand our position as a reliable and innovative partner for serial parts in the space industry. Driving the industrialisation of class 2 and 3 space components is the prerequisite of our success. These products are already part of our product portfolio, taking us an important step further on our way to supplying the industry with flight-critical class 1 parts in very short term," stated Hendrik Alfter, Managing Director of Oerlikon AM. "We are confident in our level of expertise and maturity, and further announcements on flight critical parts for launcher applications will follow soon: We have been working in close collaboration with our customers on these applications for a long time now."

www.ariane.group

www.oerlikon.com

Masan High-Tech Materials announces record revenues in 2022, plans for future

Masan High-Tech Materials Group, headquartered in Ho Chi Minh City, Vietnam, has reported record revenues of VND 15,550 billion in 2022, an increase of 15% compared to FY2021. Tungsten trioxide revenue increased by 13%, with midstream products (tungsten carbides and powders) produced by its subsidiary HC Starck Tungsten Powders, accounting for 70% of that growth.

HC Starck Tungsten Powders now offers special tungsten powders and complementary services for Additive Manufacturing under the trademark starck2print.

"Masan High-Tech Materials had a year of challenges, overcoming market fluctuations and impacts of various factors in the region and the world," stated Craig Bradshaw, CEO. "Though tungsten revenues and tungsten scrap recycling rates were significantly higher, contributing to delivering FY2022 record revenue".

Production from tungsten scrap recycling within HC Starck increased by 13%. MHT is working to increase the proportion of its production coming from secondary sources (scrap recycling), in keeping with the company's reduce, reuse, recycle policy.

During 2022, Masan High-Tech Materials established a global innovation hub based on the company's two R&D centres in Goslar, Germany, and Thai Nguyen, Vietnam. Leveraging technological advancements of HC Starck over the past 100 years, MHT continued to invest in innovation and process improvement in order to maintain its long-term growth trajectory. The company has developed processes, solutions, and eco-friendly products to meet the global market's unmet needs, earning ninety-five new patents worldwide and fifty patents that are still in the application stage. With extensive experience and potential in the field of supplying high-tech materials, as well as on-going research to evaluate the needs of critical industries, MHT has reported that it believes tungsten is the key to the innovation future of these industries.

Masan High-Tech Materials plans to implement the first and largest tungsten recycling plant project in Vietnam servicing the Asian region. The goal is to make Vietnam the leading tungsten and critical metals recycling technology development centre in the region.

In 2023, the company intends to further focus on developing a fully-integrated circular economy model with a closed value chain that encompasses waste and scrap collection, processing, recycling of scraps, and raw material recovery. Accordingly, tungsten will be recovered from used batteries and industrial wastes, then recycled to be used as feed materials for new product development.

www.masanhightechmaterials.com

Atomising Systems celebrates thirty years and plans £1.75 M expansion

Atomising Systems Ltd. (ASL), Sheffield, South Yorkshire, UK, is celebrating its thirtieth anniversary, and investing some £1.75 million to further boost its machine development and powder production facilities.

Having begun operations with just three staff members in a small office in January 1993, the company grew to around fifteen staff and moved to a 900 m^2 factory in 2001. This was outgrown and in 2011 the company relocated to its present 3000 m^2 facility, where eighty-five are now employed. Although the company was started as a manufacturer of atomisation production systems, it moved into metal powder production as demand increased. Today, the production capacity for steels, Ni & Cu alloys, using gas atomisation, water atomisation, and ultra-high-pressure water atomisation (for MIM grades) exceeds 4,000 t/year.

In its 30th year of operation, £1.75 million is being invested in a number of expansion and quality improvement projects to remove bottlenecks. These include a third QC laboratory with ICP analytical facilities, a 5 t blender, and a major relocation and expansion of sieving and classifying equipment for special powders, largely for the AM industry.

Plans for 2023 call for a fifth melting furnace to be installed to boost gas atomising capacity and an upgrade to the packing equipment. ASL is also applying a number of innovative in-house developments to its process plant, with the objective of reducing scope 2 CO_2 emissions by over 100 t/year.

The newly-installed classification system (Courtesy Atomising Systems)

John Dunkley, the founder of the company, has now worked on atomising for fifty years and is semi-retired. He is still involved in strategic planning and technical investigations, assisting an eight-strong R&D team. Record turnover in the year ended September 30, 2022, was in excess of £13 million, boosted by rapidly increasing sales to the Additive Manufacturing industry, for both Laser Beam Powder Bed Fusion (PBF-LB) techniques and Binder Jetting (BJT). Stainless steels, especially 316L, are the major focus of activity, but many different alloys are available.

www.atomising.co.uk

Ford selects IperionX to supply titanium automotive components

IperionX Limited, Charlotte, North Carolina, USA, has announced it has agreed to a Scope of Work to supply additively manufactured titanium components to Ford Motor Company using its 100% recycled, low-carbon titanium powder. The two companies have been actively collaborating to design, test and additively manufacture a series of high-quality titanium components for future Ford Performance production vehicles.

Ford Performance is the high-performance and racing division of the Ford Motor Company, known for a range of performance cars such as the F150 Raptor, Bronco Raptor, Mustang Mach 1 and the Shelby GT500. Ford reportedly aims to be the only manufacturer competing in Formula 1; Le Mans 24 Hours with the Mustang GT3; WRC with the MSport Ford Puma Hybrid Rally1; Baja 1000 with Ranger Raptor and Bronco; and NASCAR and Supercars with the Mustang.

The Scope of Work follows a detailed programme of quality and strength testing of IperionX's low-carbon titanium metal for future Ford Performance production vehicles. Ford's Sustainability and Advanced Materials divisions reportedly undertook a range of testing procedures, verifying that IperionX's titanium surpassed the required parameters set under ASTM International standards.

The titanium components are set to undergo a comprehensive 'finishing study' to assess a range of potential surface finishes. The insights gained from this Scope of Work will reportedly guide the final design, and unit costs, for a range of low-carbon titanium components for Ford Performance production vehicles.

Ford Performance produces cars such as this Mustang GT3 competing in the Le Mans 24 Hours race (Courtesy Ford Performance)

Automotive parts made with titanium are notable for their strength-to-weight ratios, high levels of corrosion resistance, outstanding durability and – reportedly unique to IperionX's technologies – can be sustainably recycled at the end of product life.

Anastasios (Taso) Arima, CEO, IperionX stated, "Ford has a commitment to achieve carbon neutrality by 2050. We are proud to partner with Ford to accelerate the deployment of a sustainable, circular titanium supply chain for the global automotive market."

"IperionX is re-shoring a lower cost and more sustainable US titanium supply chain – shifting from a linear supply chain to a lower carbon, circular titanium supply chain – recycling titanium scrap to manufacture low carbon, high performance titanium components. We are pleased that Ford has partnered with us to improve automotive supply chains and scale our low-carbon, circular, titanium business," Arima concluded.

www.iperionx.com
www.performance.ford.com

Sandvik's metal powder shop Osprey Online is open for business

Sandvik AB, Sweden, reports that Osprey® Online, the company's metal powder online store, has now officially opened. Osprey Online will initially offer titanium powders, maraging steel, and nickel-based superalloys, as well as stainless steels such as duplex and super duplex, austenitic, martensitic, and precipitation hardening steels from stock through an on-demand platform accessible from any device.

The webshop offers a range of standardised alloy powders for Additive Manufacturing and will service Europe as a first step, with additional markets being included shortly.

The platform was launched with a special episode of the company's interactive webinar series, Additive By Sandvik: Material Matters, and offered viewers insights into its range of alloys.

Luke Harris, Sales Director at Sandvik Additive Manufacturing, stated: "It was such a great honour to take part in this webinar, and to finally unveil Osprey Online in full. Getting to interact with the audience while presenting this solution and the ways in which it can make a true difference in our customers' businesses, was so rewarding. Now we're eagerly anticipating feedback, to keep improving and remain the most customer-centric partner we can be."

Sandvik's metal powder online shop is now open (Courtesy Sandvik)

www.metalpowder.sandvik

6K Additive to supply Ni718 to Cumberland Additive in long-term deal

6K Additive, based in North Andover, Massachusetts, USA, and Cumberland Additive (CAI), headquartered in Pflugerville, Texas, USA, have announced a partnership that includes a long-term agreement (LTA) in which 6K Additive will supply CAI with Ni718 powder. The LTA also calls for expansion to supply an additional volume of nickel powder, as well as further alloys to support CAI's expanding production requirements.

"Our customer base continues to expand, and we need to ensure not only the quality of the powder but also a reliable supply chain that we can be 100% confident we can meet our manufacturing demand," stated Tim Blaisdell, Chief Strategy Officer for CAI. "We've worked with the team at 6K Additive over the past twelve months and they have consistently proven to be a reliable partner. Key to our military and defence customer requirements, 6K Additive is a domestic supplier offering sustainably sourced feedstock making this the ideal partnership."

Frank Roberts, president, 6K Additive, added, "We are excited about the partnership with Tim and the team at CAI. As our capacity and capabilities increase, we need to align ourselves with growing organisations like CAI to ensure their strategic AM customers' goals and needs are met. Securing long-term agreements allows our operation to forecast, plan, and ultimately produce powder at volumes that meet market demands. The LTA with CAI helps our operational efficiencies and builds long-term partnerships that provide mutual success."

Cumberland Additive offers series production of parts and engineering design services in both metal and polymer materials, using multiple AM technologies including both laser- and electron-beam Powder Bed Fusion (PBF-LB & PBF-EB). With locations in Pflugerville and Pittsburgh, Pennsylvania, Cumberland provides AM services to customers in major markets such as aerospace, defence, space, energy, and industrial sectors.

6K Additive is a producer of Additive Manufacturing metal powder made from sustainable sources. The company offers a full suite of powders, including nickel, titanium, copper, stainless steel, aluminium alloys, and refractory metals such as tungsten and rhenium. 6K's proprietary UniMelt® system is a microwave production-scale plasma system that features a highly uniform and precise plasma zone with zero contamination and high throughput production capabilities.

www.6kadditive.com

www.cai-3d.com

MTC Powder Solutions breaks ground on new Swedish HIP facility

MTC Powder Solutions (MTC PS), Surahammar, Sweden, has broken ground on its new 9,000 m^2 advanced production site in Hallstahamma, Sweden. The new facility will be used for the Hot Isostatic Pressing of critical components for industries such as nuclear, oil & gas, and medical.

The project, named SHIN (進), is anticipated to dramatically increase the capacity for near-net shape HIP components in Europe, with the company seeing increasing demand in existing and new industries. Since the acquisition of MTC PS by MTC in 2020, the company has made multiple investments, including the purchase of a state-of-the-art HIP unit, which will be installed in the new production site."

"We are not only investing in state-of-the-art equipment but, also in people," stated Magnus Nyström, Managing Director at MTC PS. "We will be hiring for multiple positions in the near future. So, all skilled workers are encouraged to follow us on LinkedIn and other media in order to not miss the chance to be a part of our exciting journey."

www.mtcpowdersolutions.com

EOS, Tecomet, Precision ADM and OIC partner to provide end-to-end medical device Additive Manufacturing

The partnership will offer an end-to-end solution for medical device Additive Manufacturing (Courtesy Precision ADM)

EOS, headquartered in Krailling, Germany, along with Tecomet, Inc., Woburn, Massachusetts, USA, Orthopaedic Innovation Centre (OIC) and Precision ADM, both based in Winnipeg, Manitoba, Canada, have announced a collaborative partnership offering an end-to-end solution for medical device Additive Manufacturing. The partnership reportedly includes a full range of services including front-end engineering and design services, 510k approval pathways, device and machine validation, pre-clinical testing, and commercialisation.

This new partnership seeks to offer a complete end-to-end solution to customers starting from product design and process development, to large-scale manufacturing and as well as testing, validation and FDA submission. The advantage for medical OEMs is seen as a significant reduction in product development lead-time and a reduced time to market and overall risk, while leveraging the most recent manufacturing innovations.

This collaboration looks to harness the strengths and industry knowledge of each organisation. EOS, for example, specialises in both metal and polymer AM, whereas Tecomet focuses on the precision manufacturing of medical devices and components. OIC provides accredited medical device testing and contract clinical research services to the orthopaedic industry and Precision ADM provides comprehensive engineering and AM contract services to the medical device industry. This cohesive team works to enable medical device manufacturers to compress their time-to-market.

www.eos.info | www.tecomet.com
www.orthoinno.com
www.precisionadm.com

Parker Hannifin Gas Turbine Filtration joins ETN Global Group

Parker Hannifin, Mayfield Heights, Ohio, US, has announced that its Gas Turbine Filtration division has become a member of the ETN Global organisation, a non-profit body dedicated to supporting a clean energy transition through technology development, networking, and knowledge sharing. A key objective for the organisation is to accelerate the environmental changes to energy systems through development, demonstration, and deployment of safe, secure, affordable, and dispatchable carbon-neutral energy solutions by 2030.

"With a focus on the development of new, clean combustion technology, ETN Global is supporting the development of low-carbon energy production from flexible and reliable gas turbines," stated Gerald Woodward, Parker Gas Turbine Filtration, Global Marketing Manager. "Despite the boom in renewable energy, conventional gas-fired power generation will continue to play a strategic role in the future energy system. That's why knowledge sharing is so important for tomorrow's clean energy world. We're thrilled to join the ETN association and look forward to supporting ETN and its members in furthering the role of gas turbines through the clean energy transition".

ETN Global works to bring together the entire turbo-energy value chain, featuring more than 120 members from over twenty countries. The organisation encourages and facilitates research & development, information exchange and cooperation between gas turbine manufacturers, operating companies, engineers, academics, and market leaders. ETN Working Groups include those dedicated to air filtration, exhaust systems, corrosion, and emerging areas of interest, including decentralised energy systems, Additive Manufacturing, hydrogen, and CO_2. The groups also include a gas turbine user community that aims to deliver a single independent voice that can articulate user issues and trigger an appropriate response from OEMs, ISPs, and the R&D sector. The independent user groups focus on frequently-used gas turbines within both the power generation and oil and gas sectors.

The ETN also produces policy briefings, tailor-made educational courses for the gas turbine user community, and position papers on key issues.

Christer Björkqvist, Managing Director, ETN Global, added, "Our vision for gas turbines to deliver affordable and dependable carbon-neutral energy solutions that can be implemented globally by 2050 relies on our members actively contributing to technology development. As a leading player in the gas turbine industry, Parker Hannifin has a major role in technology deployment, but also the vital research and development capabilities that can advance the global energy business. We look forward to sharing their varied and valuable contributions both within our working group research areas and more broadly across our organisation and between our members. I am very pleased to be able to welcome them aboard as members of ETN Global."

www.parker.com
www.etn.global

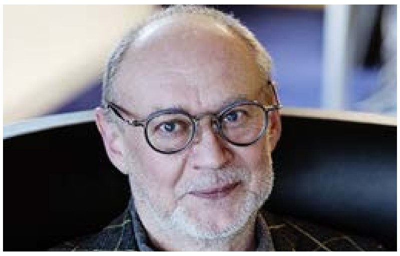
FIT brings Additive Manufacturing business together with FIT.technology

FIT Additive Manufacturing Group, Lupburg, Germany, has reorganised its operational structure, with a newly-established subsidiary FIT.technology GmbH uniting all services related to Additive Manufacturing under one roof. This will include the Additive Manufacturing of prototypes and tools as well as single part, series, and spare part manufacturing. FIT Production GmbH will continue to be active for customers in the field of medical technology.

Founded as a service provider for prototyping in 1995, FIT has since focused on the Additive Manufacturing of prototypes and tools. In 2011, following the increased importance of industrial series manufacturing, the prototyping as well as the series manufacturing businesses were spun off into the two subsidiaries FIT Prototyping GmbH and FIT Production GmbH.

Today, however, the company explains that the formerly quite distinctive businesses are converging more and more as customers' needs are changing. In response to this, a large part of the business of FIT Production GmbH has been merged into FIT Prototyping GmbH, which has hence become FIT.technology GmbH. This means customers will receive all FIT services from one company.

"We have realised that the splitting into two separate subsidiaries has led to some kind of confusion among customers," stated Carl Fruth, CEO of FIT Additive Manufacturing Group. "Just recently, our annual customer satisfaction survey revealed, again, the strong wish for unchanging contact persons at FIT, independent of what service will be provided. By merging FIT Production and FIT Prototyping into FIT.technology GmbH, there is no longer any need to ponder what subsidiary will be the most suitable to turn to. You have a manufacturing need? Just ask FIT.technology GmbH. It's one for all. This helps us to define ourselves more clearly."


Carl Fruth, CEO of FIT (Courtesy FIT Additive Manufacturing Group)

The only exception to this was said to be the Additive Manufacturing of medical devices. Since this industry is a very specific area of application for Additive Manufacturing, the expertise will remain with FIT Production GmbH, which will then focus entirely on medtech customers.

www.fit.technology

NASA launches Space Technology Research Institute for metal Additive Manufacturing

NASA has announced that it will create two new institutes to develop technology for critical areas of engineering and climate research. The new Space Technology Research Institutes (STRIs) will leverage teams led by US universities to create multidisciplinary research and technology development programmes critical to NASA's future. By bringing together science, engineering, and other disciplines from universities, industry, and non-profits, the institutes aim to impact future aerospace capabilities through investments in early-stage technology.

One of the research institutes (the Quantum Pathways Institute) will focus on quantum sensing technology in support of climate research. The other (the Institute for Model-Based Qualification & Certification of Additive Manufacturing) will work to improve understanding and help enable rapid certification of metal parts created using Additive Manufacturing techniques.

"We're thrilled to draw on the expertise of these multi-university teams to create technology for some of our most pressing needs," stated Jim Reuter, associate administrator for the agency's Space Technology Mission Directorate at NASA Headquarters in Washington. "Their work will enable next-generation science for studying our home planet and broaden the use of 3D printed metal parts for spaceflight with state-of-the-art modelling."

Each institute will receive up to $15 million over five years.

Institute for Model-Based Qualification & Certification of Additive Manufacturing

Carnegie Mellon University in Pittsburgh, Pennsylvania, will lead the Institute for Model-based Qualification & Certification of Additive Manufacturing (IMQCAM) aiming to improve computer models of additively manufactured metal parts and expand their utility in spaceflight applications. The institute will be co-led by Johns Hopkins University in Baltimore, Maryland.

Metal AM can be used for applications such as rocket engines, giving more flexibility to create new parts when designs change. The technology could also be used at a human outpost on the Moon, where bringing pre-fabricated parts would be expensive and limiting, for example. However, efficient certification and use of such parts requires high-accuracy predictions of their characteristics.

"The internal structure of this type of part is much different than what's produced by any other method," added Tony Rollett, principal investigator for the institute and US Steel professor of metallurgical engineering and materials science at Carnegie Mellon University. "The institute will focus on creating the models NASA and others in industry would need to use these parts on a daily basis."

Detailed computer models, known as digital twins, will allow engineers to understand the parts' capabilities and limitations – such as how much stress the parts can take before breaking. Such models will provide the predictability of part properties based on their processing that is key for certifying the parts for use. The institute will develop digital twins for AM parts made from spaceflight materials that are commonly used for Additive Manufacturing, as well as evaluating and modelling new materials.

Quantum Pathways Institute

The University of Texas at Austin will lead the Quantum Pathways Institute, focused on advancing quantum sensing technology for next-generation Earth science applications. Such technology would enable new understanding of our planet and the effects of climate change.

Quantum sensors use quantum physics principles to potentially collect more precise data and enable unprecedented science measurements. These sensors could be particularly useful for satellites in orbit around Earth to collect mass change data – a type of measurement that can tell scientists about how ice, oceans, and land water are moving and changing. Though the basic physics and technology for quantum sensors have been proven in concept, work is required to develop quantum sensors at the precision necessary for next-generation science's needs during spaceflight missions.

The institute will work to further advance the physics underlying quantum sensors, design how these sensors could be built for space missions and understand how mission design and systems engineering would need to adapt to accommodate this new technology.

www.nasa.gov

A NASA project called Long Life Additive Manufacturing Assembly is using Additive Manufacturing for building rocket engine component (Courtesy NASA)

Study offers insight into vibration-assisted drilling and machine hammer peening of AM parts

The Institute for Production Engineering and Photonic Technologies (IFT) at TU Wien, Austria, and research company Fotec, based in Wiener Neustadt, Austria, have confirmed through joint investigation that vibration-assisted drilling can be successfully applied to additively manufactured components to reduce cutting force by 30% compared to conventional drilling when working with martensitic steel alloys. In addition, the machine hammer peening showed effective surface smoothing and can be considered a recommended treatment for functional surfaces of additively manufactured parts.

These results were found as part of the interdisciplinary Ad-Proc-Add project where Dipl-Ing Dimitrii Nikolaev and Dipl-Ing Ismail Yavuz, under the leadership of Univ-Prof Dr Friedrich Bleicher from the IFT, investigated the energy efficiency of post-processing methods and evaluated the possibility of vibration-assisted drilling and machine hammer peening (MHP) on components produced using Additive Manufacturing.

IFT and FOTEC are investigating the effect of vibration-assisted drilling and machine hammer peening on PBF-LB parts (Courtesy IFT/Fotec)

The researchers also found that a minimum material thickness of 3.5 mm is required for freestanding surfaces of heat-treated AlSi10Mg components produced using Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing to avoid plastic deformation. When using a smaller impact head and a parameter set with more distant impacts, a thickness of 3 mm may be sufficient. However, components with wall thicknesses below 3 mm should not undergo MHP treatment due to the high risk of plastic deformation.

This study is said to provide important insights for developing more effective and energy-efficient post-processing methods for additively manufactured parts, as well as for optimising process parameters and material properties. These findings can assist system and service providers when developing new products with enhanced functionality and enable end-users to implement additive-subtractive process chains with higher productivity and increased economic and environmental efficiency.

www.ad-proc-add.eu
web.ift.tuwien.ac.at
www.fotec.at

Meteor granted US patent for 'shell' formation in Binder Jetting

Meteor Inkjet Ltd, a wholly owned subsidiary of Hybrid Software Group headquartered in Cambridge, UK, which services the industrial inkjet systems market, has been granted US Patent No. 11,625,902 for "Methods and Systems for Shell Formation in 3D Printing." The ShellPro technology utilises the greyscale of capability of inkjet to offer step-function savings in the energy and materials required to additively manufacture complex parts via Binder Jetting (BJT).

Binder jet technology often necessitates multiple structural constituents of different densities. One such structure might form a strong 'shell' around the object's surface, which is typically denser than the object's interior. Meteor's ShellPro technology utilises the multiple drop size capacity of greyscale industrial inkjet printheads to more easily create sections of higher or lower density as needed. The technology can also automatically reduce shell thickness for small features, thus improving dimensional accuracy.

"This innovation offers the potential for Additive Manufacturing print systems to use as much as 50% less binder fluid, reduce the energy needed for curing and create 3D objects faster, all without sacrificing quality," stated Ken Hillier, Meteor's Director of North America and the patent's primary inventor.

ShellPro is included as a standard feature in Meteor's Met3D software. Met3D offers users a means to convert 3D CAD files such as STL or OBJ to rasterised vector files compatible with inkjet Additive Manufacturing machines.

Clive Ayling, Meteor's Managing Director, added, "Meteor continues to undertake basic research to find and develop ways to improve the functionality, cost, quality and reliability of the industrial inkjet printing process. We are delighted that this invention has been recognised with a US patent and are confident that our ongoing investment in technological innovation will directly benefit not only our OEM customers, but also the industry."

www.meteorinkjet.com

Siemens expands AM initiatives in the US

Siemens has announced plans to expand its Additive Manufacturing initiatives in the United States in an effort to accelerate the transformation of the industry through serial Additive Manufacturing. The company is focused on supporting the domestic AM machine manufacturing community, and is working to integrate its motion control, automation hardware, digitalisation software and technology capabilities to assist machine builders.

From its Charlotte Advanced Technology Collaboration Hub (CATCH) located in Charlotte, North Carolina, Siemens intends to act as an ecosystem platform for machine builders, machine users and Additive Manufacturing design engineers alike.

"We are on the threshold of a new frontier in American industry, where the implementation of Additive Manufacturing will bring fundamental changes to the landscape, end-to-end, from product to machine to manufacturing," stated Steve Vosmik, Head of Siemens Additive Manufacturing in the United States. "Siemens is very excited to be at the forefront of this process."

"More than 100 machine builders from around the world are implementing Siemens automation solutions to industrialise their machines," added Rajas Sukthankar, vice-president, Motion Control, Siemens Industry, Inc. "Now it's time to support even more customers and accelerate their transformation from single machines to series Additive Manufacturing factories. North America is heading in this direction."

Siemens can assist Additive Manufacturing job shops as well as Tier One production facilities with end-to-end solutions, including product design software, digital twin machine simulation and virtual execution of manufacturing methods, with full data feedback into the design protocol for necessary adjustments, prior to any machine building.

"This comprehensive suite of software and motion control hardware offerings makes Siemens a viable partner at every step of the AM process," explained Vosmik.

Siemens is adding metal Binder Jetting (BJT) Additive Manufacturing to CATCH through the purchase and installation of a production machines from ExOne/Desktop Metal and a robotic machine from Meltio equipped with Siemens' SINUMERIK RunMyRobot application. This application controls the kinematic path of an industrial robot as it integrates with the CNC machine.

Siemens is also establishing an Additive Manufacturing Advisory Board of industry leaders, drawn from various industries and technical disciplines, to provide the company guidance as it works to support the fast-growing needs of the AM market.

www.siemens.com

Elementum 3D to relocate headquarters

Elementum 3D, has announced the relocation of its headquarters to a recently-constructed building in Thornton, Colorado, USA. The move is scheduled to be completed by the fourth quarter of 2023.

"Elementum 3D has had a presence in Erie, Colorado since 2014, but we are very excited to have a space purposefully built for us," stated Dr Jacob Nuechterlein, president and founder, Elementum 3D, Inc. "We are actively involving our colleagues in the transition process to develop space that streamlines workflow, builds relationships, and gives us the room we need to grow."

The consolidation of the two locations based in Erie, Colorado, under one roof in Thornton is expected to expand opportunities for the company's teams to collaborate with each other and continue to provide a nurturing environment for further team innovation and increased operating efficiencies. The new corporate headquarters includes upgraded office amenities and larger workspaces, all designed to provide the necessary infrastructure for the staff to continue to build on its current momentum and sales in the United States and International markets.

www.elementum3d.com

Redwire wins NASA contract to advance in-space Additive Manufacturing

Redwire Corporation, Jacksonville, Florida, USA, has been awarded a \$5.9 million contract from NASA to complete the design of FabLab, a new in-space multi-material AM system.

FabLab is expected to be tested onboard the International Space Station (ISS) and serve as a precursor for Artemis missions to the Moon and Mars. The system will allow NASA crews in deep space to manufacture tools and components on demand using metal, plastic and ceramics, in an effort to enable a sustainable human presence on and around the Moon, Mars, and beyond.

"FabLab is a solution for some of the key logistics challenges with sustained human deep space exploration aboard the Lunar Gateway and on the Moon and Mars," stated John Vellinger, executive vice president, Redwire. "Astronauts won't need to pack their spacecraft with every tool or part they may need millions of miles from Earth. Make it, don't take it."

In 2017, Redwire was selected to prototype FabLab through NASA's Next Space Technologies for Exploration Partnerships programme. This latest contract will see the FabLab design fully matured to space-flight-ready status. An anticipated follow-on contract will support the construction of a FabLab unit and its test aboard the ISS in low-Earth orbit (LEO).

Testing FabLab on the ISS will be an important step toward building versions for use at destinations beyond LEO, such as NASA's Gateway. With FabLab technology, crews on the Moon, Mars, and in deep space will be able to additively manufacture critical assets, such as tools, replacement parts, and circuit boards on demand.

"Having an integrated capability for on-demand manufacturing and repair of components and systems during space missions will be integral for sustainable exploration missions," added Jim Reuter, associate administrator for NASA Space Technology Mission Directorate programmes. "This is a rapidly-evolving, disruptive area in which NASA wants to continue working with industry and academia to develop these technologies through collaborative mechanisms such as this one."

Redwire's Additive Manufacturing Facility (AMF), reputedly the first permanent commercial manufacturing platform to operate in LEO, has manufactured over 200 tools, parts, and assets onboard the ISS. AMF's versatility and durability have made it a resource for government and commercial customers since its activation in 2016. Building on this experience, Redwire is continuing to develop new capabilities that will leverage in-space manufacturing for unprecedented applications to meet future space exploration goals.

www.redwirespace.com

Wohlers Report 2023 shows continued double-digit growth in Additive Manufacturing sector

Wohlers Associates, powered by ASTM International, Fort Collins, Colorado, USA, has announced the release of the *Wohlers Report 2023.* This year's report takes a deep dive into the growth of the Additive Manufacturing industry, with insights from ten industry sectors.

New content includes an examination of large-format AM applications, including aerospace and construction, as well as a look at the growing number of Additive Manufacturing standards and codes.

"The AM industry is continuing to expand into end-use production applications," stated Terry Wohlers, head of advisory services and market intelligence at Wohlers Associates, powered by ASTM International. "This trend will grow as standards are further developed and adopted. AM is delivering larger and more critical parts across multiple industry sectors."

Wohler's Report 2023 shows an overall worldwide growth in AM products and services of 18.3%, continuing a trend of double-digit AM industry revenue growth in twenty-five of the past thirty-four years.

This year's report also features intelligence from industry experts in thirty-five countries, with expanded coverage of Argentina, the Czech Republic, and Greece. Research and development activities are covered in detail, and the following new topics are initially explored in this issue:

- Recycling and the circular economy
- Point-of-care Additive Manufacturing in healthcare
- Opportunities and challenges associated with metal Binder Jetting
- Attracting a younger workforce into Additive Manufacturing
- Expanded discussion of investments and startups.

An expanded section offers insights into the future of Additive Manufacturing, including thoughts on automated production, emerging applications, workforce development, and more. Input on the report was gathered from 119 service providers, 128 manufacturers of Additive Manufacturing systems, and twenty-eight producers of third-party materials. *Wohlers Report 2023* draws on the expertise of a worldwide network of experts as well as nearly three decades of data and market intelligence, creating a thorough picture of Additive Manufacturing activity across the globe.

www.wohlersassociates.com

Markforged completes move to new headquarters


The relocation of its headquarters has allowed Markforged employees to work in a single location (Courtesy Business Wire)

Markforged has completed the transition to a new global headquarters in Waltham, Massachusetts, in a move uniting employees previously split between corporate headquarters and its research & engineering facility. The new headquarters can accommodate over 500 employees, and includes engineering labs and a product showroom.

"This move is a significant milestone for Markforged," stated Shai Terem, president and CEO of Markforged. "It will allow us to continue developing cutting-edge technology and solutions faster than ever before so that our manufacturing customers around the world can rely on us for mission critical part production right on their factory floors."

The headquarters are reported to feature a modern design and amenities intended to promote teamwork, innovation and employee well-being. The office space includes open work areas, meeting rooms, and a variety of breakout spaces for team members to collaborate. The facility is now the home of Markforged's corporate, commercial, and engineering teams, increasing interdepartmental synergy and customer service by enabling more communication between teams.

"We are thrilled to have our entire metro Boston team in one location, as this will foster a stronger sense of community and collaboration. Not only can we be more efficient but our new home gives us the room to have fun and be with each other more often," added Dorit Liberman, Chief Human Resources Officer of Markforged. "We believe that this move will enhance our ability to foster our 'One Team' culture as we continue to grow."

www.markforged.com

Outokumpu adds metal powder atomisation plant to German facility

Outokumpu, headquartered in Helsinki, Finland, is entering the metal powder sector with the construction of a new atomisation plant at its facility in Krefeld, Germany, planned for April 2023. The move is intended to further strengthen the company's sustainability strategy and circular economy efforts by using the steel scrap from local production to create metal powders suitable for Additive Manufacturing, Metal Injection Moulding (MIM), Binder Jetting (BJT) and Hot Isostatic Pressing (HIP).

"The global demand for metal powder is on the rise and we see great potential for the business in the near future," stated Thomas Anstots, President of BL Advanced materials at Outokumpu. "We have seen the growth of Additive Manufacturing industries and the potential to strengthen the position and use of stainless steel for metal powder products, and, therefore, decided to start the construction of a new designed atomisation plant. Outokumpu has an extensive expertise on the materials and will partner with interested powder customers. We are happy to start with the internal production soon, followed by external run a bit later. There is already a great interest among customers and the first projects have started."

Outokumpu's primary focus is on producing metal powders that are not yet on the market which are suited for companies that use technologies such as metal AM, MIM and HIP to produce parts for demanding applications.

"In the near future, the estimated total production capacity will be approximately 330 tons annually. Our longer-term target is to utilise the learnings and to build up our R&D know-how to support the customer journey with expertise, new material development, flexibility and customisation for various powder metallurgy technologies. In our future vision, we could be able to serve our customers in such a way that they could come to us with a problem and leave with a solution," Anstots continued.

Outokumpu sees the new atomisation plant as a large recycling unit. The company's stainless steel is said to be the single most recycled material globally, and the company's mills in Europe and in the US are among the largest material recycling facilities in the world.

Anstots concluded," We want to help our customers to reduce climate burden by means of the right material choices. I'm proud of the fact that our new atomisation plant in Krefeld will be a large recycling unit to support the circular economy further. The embodied carbon footprint of our whole production process is also reduced as the raw material is generated, and the product is produced and packaged, all in one place. This ensures to control the entire process and to significantly cut down the transportation emissions too."

Outokumpu's brand new portfolio of metal powders (which includes stainless steel and nickel alloys) has been formulated to meet the demands of modern manufacturing in terms of quality, sustainability and flexibility. Outokumpu is partnering with SMS group GmbH, headquartered in Düsseldorf, Germany, as the technology supplier. The Equipment as a Service (EaaS) contract is intended to ensure a continuous line optimisation and close collaboration in the powder business between the supplier and the producer over the next years.

www.outokumpu.com

Uniformity Labs launches low-porosity UniJet 17-4 PH stainless steel for Desktop Metal Production System

Uniformity Labs, Fremont, California, USA, has announced the availability of its ultra-low porosity 17-4 PH stainless steel powder jet UniJet™ SS17-4PH Performance for the Desktop Metal Production System. The qualified powder is reported to deliver double the green strength of existing stainless steel powders, due to its uniform powder bed layering.

UniJet 17-4 PH is also reported to result in an average of 20% less shrinkage than other stainless steel powders qualified for use on the Desktop Metal machine. These factors are said to result in better-sintered part geometric accuracy and less breakage of green and brown parts during post-build handling and depowdering, resulting in high process yield at high throughput.

"The application of Uniformity UniJet 17-4 PH stainless steel for BJT delivers mechanical and process excellence for our customers who require materials that perform to the highest standards across each step of the production process," said Adam Hopkin, Uniformity founder and CEO. "Our powders deliver superior mechanical properties, printing yield, and process stability, delivering repeatable production scale Binder Jetting."

One advantage noted by the company is the improved apparent and tapped densities of UniJet 17-4 PH, resulting in green parts with more contact points between particles and higher density (10% reduction in relative porosity) than standard Binder Jetting powders. This enables green parts with reportedly twice the magnitude of transverse rupture strength across all layer thicknesses. Such green parts, alongside the very high flowability of Uniformity powder, result in the fabrication of more complex thin-walled or heavier green parts with larger aspect ratios viable by minimising breakage during the de-powdering of large, high aspect ratio and geometrically complex parts with fine features and channels.

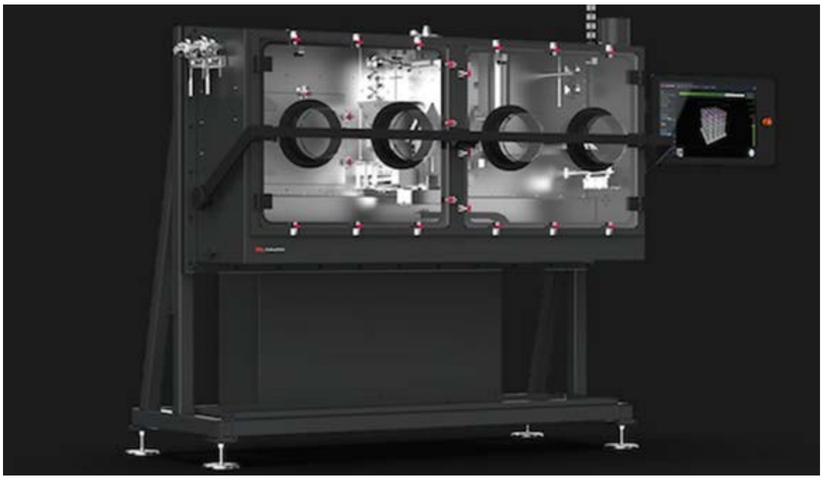
Uniformity's UniJet 17-4 PH powder on the Production System is said to have consistently achieved about 25% less shrinkage in X, 19% less shrinkage in Y, and almost 20% less shrinkage in Z axes than the standard Binder Jetting powder across all layer thicknesses. The powder repeatably delivers 99-100% final part density. UniJetTM 17-4PH powder yielded parts with, on average, three-times lower standard deviation in green density than standard binder jetting powder.

The highly-flowable powder is said to improve throughput by allowing repeatable fast layering at thicker layers. At 75 µm layer thickness and with 20% reduced shrinkage (allowing more parts fit on the bed), a net throughput benefit of approximately 25% relative to standard Binder Jetting powders for the Desktop Metal machine enables further cost reduction for parts manufacturers. At 110 µm layer thickness – still delivering improvements in green strength, uniformity of powder bed, and sintered density relative to standard inert gas atomised Binder Jetting powders printing at 65 µm layer thickness – the throughput improvement is over 80%.

"Desktop Metal is delighted to offer this highly advanced 17-4 PH stainless steel powder from Uniformity Labs for our Production System platform," added Ric Fulop, founder and CEO of Desktop Metal. "This latest addition to our material portfolio allows us to binder jet 17-4 PH stainless steel materials critical to producing complex designs. Binder Jetting powders processed with Uniformity Labs technology enables unmatched mechanical properties and can further improve the economics of printing. We look forward to continuing to collaborate with the Uniformity team."

Shri Shetty, CEO of Zeda and a partner of Uniformity Labs, stated, "This is not the first time we've partnered together to develop materials, and Uniformity's powders have a history of exhibiting superior mechanical properties and higher machine productivity, which will help us further our mission to build things better together in the medical device industry."

www.uniformitylabs.com
www.desktopmetal.com



Uniformity Labs has released a low-porosity 17-4PH stainless steel powder compatible with the Desktop Metal Production System (Courtesy Desktop Metal)

AML3D expands presence in US defence and oil & gas sector

AML3D Limited, Edinburgh, Australia, has recently highlighted its expansion within the US defence sector and updated oil & gas targets, including the scheduled delivery of a large-scale ARCEMY® machine to the US Navy; an update on its US Department of Defense (DOD) materials testing contract; an extension of the subsea pipeline fittings contract with Chevron Australia; and investment in a software suite to extend the company's IP.

"AML3D has a very clear focus on our OEM supplier strategy – scaling up our presence in the US Defence sector by supporting the US Navy submarine industrial base, in the first instance," stated Ryan Millar, CEO, AML3D. "We are making the final preparations to ship a large scale ARCEMY X-Edition 6700 system ('ARCEMY X') to Oak Ridge National Laboratory, Tennessee, USA, a key partner to the US Navy and other global Tier 1 clients."

"We have established and are working to expand the AML3D sales team based in the US, which reports to Kerrye Owen, VP of Global Sales, who has twenty-four years' experience in sales roles in the US and Australia, most recently as Senior Sales Manager with GE Digital," he continued. "We are also leveraging the unparalleled US defence network of our value-added reseller partner Phillips Corp. From a standing start, in January of this year, we have developed a robust and growing early-stage US sales pipeline and are strengthening our understanding of how to convert these pipeline opportunities into contracts like the Oak Ridge ARCEMY deal. We are in active negotiations around several additional OEM sales into the US defence sector and I look forward to updating the market on our progress in due course."

These ongoing US defence contracts are reportedly driving the expansion of AML3D's US sales, with multiple US DOD contract negotiations underway through the partnership with Phillips Corp. The combination of AML3D's existing relationships with global Tier 1 companies in the US defence, marine and aerospace sectors and Phillips' network is also reportedly expanding non-defence OEM sales opportunities that are expected to further support AML3D's US growth.

In the oil & gas sector, the company's contract with Chevron Australia has been extended to include additional piping to enable comprehensive independent testing. AML3D believes the oil and gas sector represents an opportunity to target additional, non-US defence revenues through its OEM strategy. Millar explained. "We have initiated early phase discussions with Chevron Australia on how the AML3D OEM strategy can be adapted to improve the effectiveness and resilience of their supply chains and the supply chains of their suppliers and peer companies. We are also underpinning our success in creating shareholder value through our OEM strategy by strengthening our software development team to ensure we remain the certified WAAM [Wire Arc Additive Manufacturing] technology leader."

www.aml3d.com

AMPOWER report analyses publicly listed AM companies

Management consultancy AMPOWER, based in Hamburg, Germany, has released the *AMPOWER Report Special: Investors' View 2023*. This free report follows on from the publication of the *AMPOWER Report 2023*, and examines the market growth across various segments to provide a comparison of the performance of publicly traded companies in the Additive Manufacturing sector.

The AMPOWER Report Special: Investors' View 2023 provides a comparison of the performance of publicly traded AM companies (Courtesy AMPOWER)

A detailed analysis, with more than eighty figures, tables and diagrams, describes the worldwide industrial metal Additive Manufacturing market. The data is based on primary research results with industry experts and representatives of the supply chain and user market.

The report also offers readers the chance to discover more about the state of the art and maturity level of all known Additive Manufacturing technologies, and offers a deep dive into supply chain, materials, design characteristics and cost.

"Additive Manufacturing has a high market potential but has long suffered from over-expectations and hype," stated Deniz Yigit, Director of Global Business Development – Customisation Technologies, Höganäs. "The AMPOWER team has a track record of substantial market knowledge and with the *AMPOWER Report*, the team delivers hands on market data with a proven forecast methodology based on user expectations. Höganäs, as a major global metal powder supplier for Additive Manufacturing, utilises the *AMPOWER Report* as part of their internal market assessment and strategic decisions."

A free download of the report is available via the website.

www.additive-manufacturing-report.com

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Horn optimises depowdering stage with Solukon SFM-AT350

Precision tool manufacturer Horn GmbH, headquartered in Tubingen, Germany, is reported to be using a Solukon SFM-AT350 Smart Powder Recuperation system to automate the depowdering of its additively manufactured components.

Currently, Horn uses the Solukon SFM-AT350 to depowder parts made from tool steel, stainless steel, and reactive materials like aluminium and titanium. Depending on part size, several dozen parts can be arranged on a build plate, which are then simultaneously cleaned of powder, making the cleaning process considerably faster and more efficient.

The SFM-AT350 can clean complex metal parts weighing up to 60 kg with two-axis rotation and adjustable vibration in a protected atmosphere. "The Solukon system increases safety (explosion protection) because we can also use it to depowder metal parts made of reactive materials in a protective gas atmosphere," stated Dr Konrad Bartkowiak, Production Manager for Additive Manufacturing at Horn.

Bartkowiak also shared that when it comes to depowdering, parts with interior cooling channels, lattice structures or powder residue in the support structures are the greatest challenge. The SFM-AT350, however, cleans these complex parts automatically, made possible by the Digital-Factory-Tool, a sensor and interface set used to monitor all the key data of the depowdering process, such as humidity, chamber pressure and temperature.

Michael Schäfer, Designer and System Operator in Additive Manufacturing at Horn, operating the Solukon SFM-AT350 (Courtesy Horn/Nossek)

www.solukon.de
www.horn-group.com

BLT develops deployment structure for CubeSat satellite

Xi'an Bright Laser Technologies (BLT), Xi'an, China, reports it has helped develop and Additively Manufacture the deployment structure of the Dalian 1- Lian li Satellite, a 12U CubeSat. The satellite was launched aboard the Tianzhou 6 from the Wenchang Space Launch Site in China's Hainan Province on May 10.

BLT worked alongside Dalian University of Technology to optimise the satellite's deployment structure for production by Additive Manufacturing. Through simulation analysis, the team redesigned most of the components, increasing stiffness and reducing the overall mass.

The deployment structure of Dalian 1-Lianli Satellite consists of multiple components such as the main frame and the hatch. The structure of the main frame is approximately 400 x 400 x 500 mm in size, with a minimum wall thickness of 1 mm, and requires high precision parts. BLT selected AlSi10Mg and used its BLT-S800 Laser Beam Powder Bed Fusion Additive Manufacturing machine (equipped with eight 500 W lasers) for production.

The additively manufactured parts met the required dimensional accuracy and material specifications for the satellite, enabling it to withstand the extreme high and low temperatures, function in a thermal vacuum, and resist atomic oxygen corrosion.

The CubeSat deployment structure was developed and additively manufactured by BLT (Courtesy Xi'an Bright Laser Technologies)

www.xa-blt.com/en

Bodycote announces search for Chief Executive

Bodycote plc, headquartered in Macclesfield, Cheshire, UK, has announced that Stephen Harris, Group Chief Executive, will retire from both the board and the company next year. Harris joined Bodycote in November 2008 and became Chief Executive in January 2009.

A formal process to recruit Harris' successor will be led by the board's nomination committee. A range of internal and external candidates will be considered by the company.

Daniel Dayan, Bodycote's Chair, stated, "Stephen's leadership of the group over the last fifteen years has been exceptional. We look forward to continuing to work with him as we move forward with the succession process."

www.bodycote.com

Ad-Proc-Add researchers investigate influences on wire arc AM

As part of the international Ad-Proc-Add project, a team from KU Leuven, Thomas More University, the Belgian Welding Institute npo, and Sirris, investigated the influence of various processes within the additive-subtractive manufacturing process chain on the quality of the final product. Empirical models for predicting bead geometry were created for both processes.

Wire Arc Additive Manufacturing (WAAM) is a Directed Energy Deposition (DED) Additive Manufacturing technique that uses an electric arc as a fusion source to melt filler wire and build a component layer by layer. The process enables the efficient production of medium-to-large metal parts, but after deposition, it exhibits low dimensional accuracy and surface quality, which is why further subtractive post-processing is often required.

A key aspect of the project was determining the material to be provided for machining to achieve the required dimensional and shape accuracy of the part. It was found that the WAAM process parameters significantly influence the effective wall width, the surface quality after deposition, and the minimum amount of material that needs to be removed during the post-processing step.

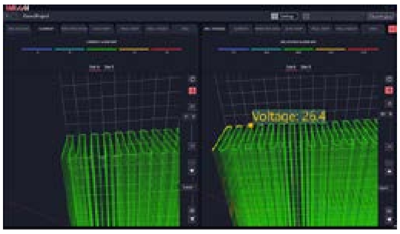
Another important finding related to the positioning, orientation, and optimal cutting parameters of the parts for post-processing. Experiments showed that the process parameters, especially speed, wire feed, and interpass temperature, had a significant influence on the characteristics of the deposited surface and the overall wall width that impact the milling process. Significant progress was said to be enabled by the development of multi-sensor platforms, which were used separately for the AM and post-processing steps, to investigate the influence of different processes on the properties of the final part. By monitoring current, voltage, gas flow rate, and temperature, the stability of the WAAM process could be evaluated, thereby eliminating various material defects and improving surface performance.

The insights gained were applied to various industrial case study parts on gas-based wire arc AM and the additive-subtractive process chain and are now said to be part of several educational courses at KU Leuven and Thomas More. These advances demonstrate the enormous potential of WAAM technology and how it can be used to improve efficiency and quality in AM.

The project's final report can be obtained by contacting Forschungskuratorium Maschinenbau (info@fkm-net.de).

www.ad-proc-add.eu
www.kuleuven.com | www.bil-ib.de
www.thomasmore.be
www.siris.be

WAAM3D releases updated operating system RoboWAAM



Split screen view enables users to compare different key process variables side-by-side (Courtesy WAAM3D)

WAAM3D, Milton Keynes, UK, has released an update of its WAAMCtrl® operating system for the company's RoboWAAM®, a multi-metre metal Additive Manufacturing machine designed for aerospace, defence, energy, and research communities.

Reportedly under development since 2015, WAAMCtrl v2 leverages the sixty sensors on board RoboWAAM to monitor and control the Wire Arc Additive Manufacturing process, a form of Directed Energy Deposition (DED), whilst recording all key process parameters on its secure server. As well as enabling operators to have a fully-controllable production process, WAAMCtrl also incorporates auditable data storage, quality logs, and interactive data navigation, to demonstrate compliance in a repeatable way.

Via its touchscreen-based graphical user interface, the operator can initiate automatic cycles for shielding atmosphere establishment, maintenance and evacuation. WAAMCtrl also provides a facility for controlling and restarting deposition programmes.

"We are very pleased to be able to offer the v2 release of our signature WAAMCtrl software," stated Jialuo Ding, Chief Technology Officer and one of the founders of WAAM3D. "WAAMCtrl serves as more than just a digital platform for collecting comprehensive process and system data for quality control purposes. It also offers a high level of process control and assists users in confidently utilising the RoboWAAM system."

The systems enable operators to see in real-time how a project is progressing, with the sensors transmitting information to WAAMCtrl tens of times per second, for monitoring and control via proprietary wire-position and interpass temperature closed-loops. Real-time colour-coding of the 3D charts also helps make sense of big deposition data, mapped over the part's real geometry.

The development of WAAMCtrl v2 has benefitted from funding from Innovate UK (part of UK Research and Innovation, driving productivity and economic growth by supporting businesses), within the HPWAAM (High Productivity Wire Arc Additive Manufacturing) project.

www.waam3d.com

Titanium Binder Jetting success following Tekna and TriTech collaboration

Tekna Holding ASA, Sherbrooke, Quebec, Canada, has announced a collaboration with TriTech Titanium Parts LLC, Detroit, Michigan, that has resulted in the successful Binder Jetting of titanium parts using a Desktop Metal P1 Additive Manufacturing machine.

"We are delighted to work with Tekna," stated Robert Swenson, CEO of TriTech Titanium Parts. "Their plasma atomised titanium powder, known for its exceptional quality, significantly enhances our capabilities in binder jet 3D printing. It enables us to offer our clients the benefits of this groundbreaking technology, reduces manufacturing lead times, and enhances performance in critical applications."

Tekna supplies TriTech with titanium powder that meets both aerospace AS9100 and medical ISO 13485 standards. Tekna's titanium powder, designed to achieve exceptional part quality and mechanical properties, is expected to enable TriTech achieve the full potential of Binder Jetting, providing clients with customised, lightweight, and high-strength titanium parts that surpass traditional manufacturing limitations.

"I want to congratulate TriTech and Desktop Metal for their leadership in achieving this historical milestone. By combining our expertise, we aim to accelerate the adoption of binder jet 3D printing and open new design possibilities for titanium components across all industries," added Luc Dionne, CEO of Tekna.

Tekna has collaborated with TriTech Titanium Parts in the successful Binder Jetting of titanium parts using a Desktop Metal P1 Additive Manufacturing machine (Courtesy Desktop Metal)

The Desktop Metal P1 Additive Manufacturing platform, using Tekna's titanium powder at the TriTech facility, can be seen in this video: https://bit.ly/3XssB3e

www.desktopmetal.com
www.tekna.com
www.tritechtitanium.com

Plansee's newest hot zones reduce energy consumption in high-temperature processes

Plansee High Performance Materials, a Plansee Group company, headquartered in Reutte, Austria, has announced its latest generation of hot zones for industrial furnaces. All versions of these new models are said to save a significant amount of energy, even at maximum performance, thus lowering both the customers' operating costs and CO_2 footprint.

The industry faces the challenge of saving energy on a large scale, explains Plansee, but this efficiency can't be at the expense of quality. The demand for high-performance, sustainable solutions becomes a complex task, however, when industrial processes require particularly large amounts of energy. This is the case for high-temperature vacuum furnaces used for heat treatment in sectors such as aviation or medical technology, where working temperatures of 1,000-1,800°C are reached.

Plansee supplies manufacturers of industrial furnaces with metallic hot zones made from molybdenum, molybdenum alloys, and tungsten, which are used in high-temperature processes and ensure that the temperature in the furnace is optimally distributed. The energy balance of these processes depends on the quality of the hot zones and if they are not optimised for the respective area of application, an unnecessary amount of heat (and, thus, energy) is lost.

Plansee's new hot zone models reportedly save up to 27% of energy compared to the previous iterations, and the lightweight design of the support frame means that the new models weigh up to 15% less.

The constructions and materials used in the heating system are said to ensure that the batch is heated optimally, and issues such as short circuits or sagging of the heating element are almost impossible. Further, the heated parts of the furnace can be efficiently cooled using gas, with nozzles placed in optimal positions determined by simulations.

Another addition is the 'FlowBox,' which enables the smooth outflow of gas at the rear of the hot zone. Together, the nozzle and FlowBox work to ensure that the batch is cooled precisely, without the unintentional formation of further cooled areas in the furnace. Another feature highlighted by Plansee is the smart mounting of the front door which adapts to the temperature changes inside the hot zone and, therefore, prevents heat from being lost.

Plansee's hot zones can be configured in advance for individual requirements via an online tool. If special individual parts made from molybdenum or tungsten are required to meet specific needs, Plansee can produce these independently via Additive Manufacturing.

www.plansee.com

ASTM International releases Additive Manufacturing in-situ monitoring technology report

ASTM International, a global standards organisation headquartered in West Conshohocken, Pennsylvania, USA, has released its *Additive Manufacturing In-Situ Technology Readiness Report*. The report is said to be a culmination of the second Speciality Workshop series, held in June 2022, which was organised by the ASTM Additive Manufacturing Center of Excellence (AM CoE) and saw sponsorship from NASA in collaboration with America Makes.

"NASA was pleased to support this important effort," notes Doug Wells, Deputy Technical Fellow with NASA. "The insights from the workshop and the detailed analysis of the AM CoE captured in this report are significant. The report is influential in guiding the agency in the development of methodologies and policies for the implementation of in-situ monitoring technologies into the qualification and certification framework of Additively Manufactured hardware. We look forward to continuing engagement with this community to bring to fruition all the promise of in-situ monitoring to revolutionise the use and acceptance of Additive Manufacturing in critical applications."

The report aims to shed light on the current challenges within the field of in-situ technology by providing an in-depth analysis of the initial landscape and the outcomes of the two-day workshop. The report identifies potential solutions and offers actionable plans for key topical areas in in-situ technology.

"The report embodies a comprehensive landscape assessment, detailed workshop analyses, targeted expert interviews, and crucial reviews by specialists, all meticulously orchestrated to create an insightful, high-value resource that the industry can tap into," says Dr Mohsen Seifi, ASTM International Vice President of Global Advanced Manufacturing Programs. "The strategic insights will also guide ASTM International and its members to bridge gaps in existing standards, and pioneer new standardisation in the field."

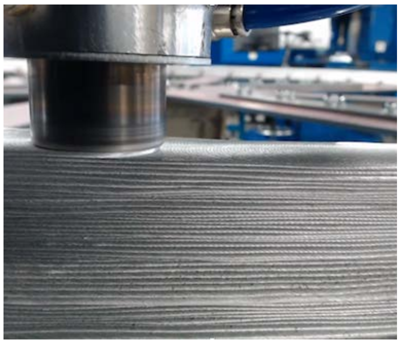
Dr Brandon Ribic, Technology Director at America Makes, adds, "The strategic guide that the team has compiled will serve as a beneficial resource for members of the AM community for years to come. The data and findings are a great example of collaboration to promote common understanding. They deliver an approach that advances our ability to leverage monitoring methods and digital data and analytics for AM qualification and certification."

www.astm.org

Mazak MegaStir named exclusive tooling supplier for MELD technology

Mazak MegaStir, Florence, Kentucky, USA, has signed an agreement which makes it the exclusive supplier for solid deposition technology from MELD Manufacturing, Christiansburg, Virginia. Mazak MegaStir will provide its hard metal expertise along with tooling specifically developed for the MELD process that also incorporates the use of friction as part of its solid deposition process.

According to Dale Fleck, General Manager of Mazak MegaStir, the company has the unique ability to provide the complex tooling with the high-strength capability necessary to commercialise MELD's solid deposition technology. The tooling is made from ultrahard materials such as PCBN and carbide and withstands the extremely high loads & forces necessary for the process.



As a solid-state process, MELD can produce parts with low residual stresses and full density with significantly lower energy requirements than more conventional fusion-based processes (Courtesy MELD)

MELD uses a patented Additive Manufacturing technology based on a process similar to friction welding used by Mazak MegaStir, and can be used for the building and repair of metal components using off-the-shelf solid-state materials or powder. The process is capable of additively manufacturing large metal parts due to the fact that it is an open-atmosphere process and is not sensitive to the operating environment or material surface condition.

As layers are deposited during the MELD process, the Mazak MegaStir tooling – operating with applied pressure and frictional load – spins and joins the layers together. The tooling mounts into deposition heads on CNC machine platforms with the ability to feed the metal material down through the centre of the head and the tooling.

From its Kentucky facility, Mazak produces over seventy models of turning centres, multi-tasking machines and vertical machining centres, including five-axis models, hybrid Additive Manufacturing processing machines and Swiss turning machines. Mazak maintains eight Technology Centres across North America to provide local hands-on applications, service and sales support to customers.

www.meldmanufacturing.com
www.mazakusa.com

HP enhances its Binder Jetting offer, adds Endeavor 3D as Metal Jet manufacturing partner

HP Inc, Palo Aleo, California, USA, has announced a raft of solutions to help customers simplify workflows and reduce costs as they move to high-volume Additive Manufacturing part production. At this years Rapid+TCT event in Chicago, USA, the company announced enhancements to its software, service and materials offerings, as well as new automation solutions.

"Companies large and small, in markets around the world, are turning to 3D printing for faster, more flexible, more personalised, and more resilient and sustainable production," said Didier Deltort, president of Personalisation & 3D Printing, HP Inc.

"It's promising to see the development of so many game-changing 3D printed applications across automotive, consumer, healthcare, and industrial, but to disrupt industries, these parts must be manufactured at scale. To help our customers scale effectively and efficiently, HP remains laser focused on delivering industrial hardware, supplies, software, and services supporting the entirety of the digital production workflow from application design to final parts production."

Expanded software & services, including sintering simulation

The HP Digital Production Suite now features expanded software products designed to help customers develop metals applications more quickly and easily, with HP 3D Digital Sintering and HP 3D Process Development software each supporting the commercial Metal Jet S100 Additive Manufacturing machine.

HP 3D Digital Sintering is an AI-enhanced simulation of the sintering process that provides feedback on the outcome of a sintered part and enables application engineers to pre-compensate part geometry to improve the dimensional accuracy of the finished product. This helps reduce time, cost, and speed of final part production by eliminating the need for a build and test approach.

The HP 3D Process Development software is said to democratise process development and give customers insight into the science of Metal Jet through access to open process parameters and build reports. The software enables users to conduct guided experimentation and optimise applications.

To help both polymers and metals customers optimise part development and scale production, HP is collaborating with other software providers to integrate Factory IT and Manufacturing Execution System (MES) solutions. The company also provides customers with access to a variety of professional and financial services through its HP Professional Services. These include support for design (DfAM), application development, and AM factory set-up.

HP is also collaborating across the post-processing ecosystem to ensure customers have access to a broad range of alternatives from providers including AM Flow, AMT, DyeMansion, and Rösler Group AM Solutions.

Workflow automation

To improve workflow automation on the AM factory floor, HP reports that it is working closely with long-standing partner Siemens on a proof-of-concept demonstration. The concept features new automation products integrated with Siemens Automation Hardware and industrial Software, for example Siemens SIMOVE for Autonomous Mobile Robots (AMR) in flexible Production Systems.

The project is active in the company's Barcelona DFactory which is a hub for HP collaboration with partners and customers on R&D, application development, and production use cases.

Endeavor 3D adds HP's Metal Jet S100 solution

HP also announced it was promoting several of its current Digital Manufacturing Network (DMN) members to its exclusive group of HP Digital Manufacturing Partners (DMP) to meet the growing demand for final parts production. More than sixty members around the world are now providing manufacturing services and enabling OEMs to build their digital supply chain.

The recently-promoted members include Athena, Endeavor 3D and The Technology House (TTH). It was announced that Endeavor 3D is expanding its HP-enabled manufacturing services in its factory in Douglasville, Georgia, adding HP's Metal Jet S100 solution to its existing fleet of HP Jet Fusion 5200 and 5420W systems.

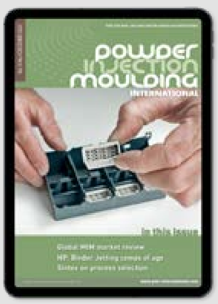
"Adding HP's Metal Jet capabilities to our manufacturing services enables us to provide more to our customers," stated Phil Arnold, CEO, Endeavor 3D. "Top-down, our expert engineering team believes that this technology will help manufacturers reshore production and we are excited to be a major player in that supply chain."

www.hp.com
www.endeavor3d.com

Discover more about HP's metal Additive Manufacturing business in the exclusive article in the December 2022 issue of *PIM International* magazine:

HP Metal Jet: Growing momentum and new applications as Binder Jetting comes of age

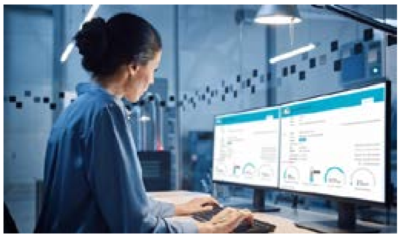
www.pim-international.com



SLM Solutions and Assembrix look to secure customers' intellectual property in Additive Manufacturing platform

SLM Solutions Group AG, Lübeck, Germany, and Assembrix, Tel Aviv, Israel, are evaluating the use of blockchain and encryption technologies, in an effort to ensure the safety and full protection of customers' intellectual property. The development builds on the successful integration of Assembrix VMS software into SLM Solutions' machines announced last year, and aims to bring this solution to industrial-scale availability.

Lior Polak, CEO of Assembrix, explained, "With the increasing demand for secure distributed manufacturing solutions, the 'Assembrix inside' integration with



Assembrix VMS allows manufacturers to remotely manage the entire Additive Manufacturing digital thread in a fully-automated and self-controlled process (Courtesy Assembrix)

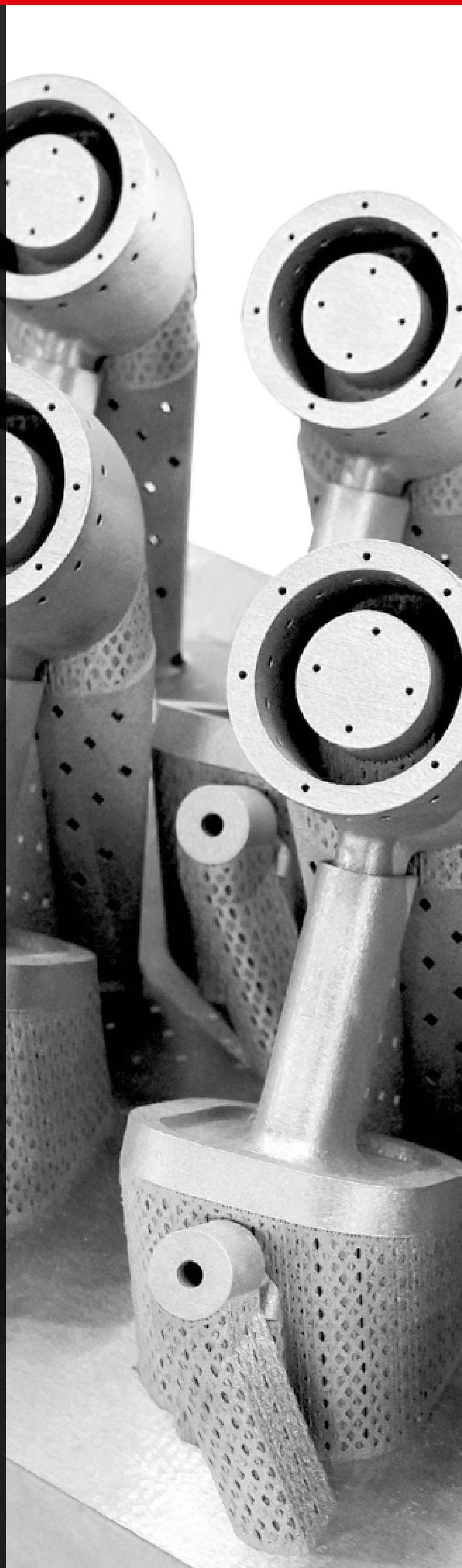
SLM Solutions sets the new standard, providing the most secure solution available. It brings substantial value to manufacturers worldwide, reducing costs and mitigating risks."

Assembrix's cloud-based Virtual Manufacturing Space platform (VMS) aims to simplify and secure the entire Additive Manufacturing process, from the initial part model to the verified physical part, enabling a simpler transition to industrialisation. Nanyang Polytechnic's Additive Manufacturing Innovation Centre is already making use of this technology, allowing users to gain hands-on experience developing solutions for the industry.

"By leveraging secure cloud-based solutions, more manufacturing companies can explore remote arrangements while upholding the highest quality control standards," stated Zaw Hlwan Moe, Manager at Nanyang Polytechnic's School of Engineering. "Technological advancements like these can significantly boost productivity in the Additive Manufacturing industry."

Nicolas Lemaire, Software Product Manager at SLM Solutions, added, "The productive partnership between SLM Solutions and Assembrix empowers customers to fully leverage secure remote printing processes, supporting their distributed manufacturing strategies. It enhances SLM Solutions' growing software and service solution portfolio, establishing itself as the leading Additive Manufacturing technology in the market."

www.slm-solutions.com
www.assembrix.com



Seco Tools finds new opportunities in metal Additive Manufacturing

Seco Tools, a leading provider of metal cutting solutions for indexable milling, solid milling, turning, holemaking, threading and tooling systems, headquartered in Fagersta, Sweden, reports that it is increasingly adopting Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing as a fundamental part of its operations.

One main strengths of this manufacturing method, noted by the company, is the possibility of making specialised customer-specific tools and solutions that would be difficult to achieve through conventional manufacturing. Above all, however, Seco anticipates that the technology will come into its own when producing tools that must be designed in a special way. This may involve complex geometries or other customisations to customer-specific needs.

Examples of such customisations include making the tools lighter, which improves the vibration-dampening properties, or provide them with better cooling possibilities.

Seco Tools is adopting Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing as a fundamental part of its operations (Courtesy Seco Tools)

"By directing the coolant to hit the cutting edge at just the right place, we can significantly extend the tool's useful life. With AM technology, coolant can be guided to locations that would otherwise have been impossible," stated Ingemar Bite, R&D Specialist at Seco Tools, who also believes that AM technology is helping to shorten lead times. "AM allows for us to produce geometries that require less manufacturing steps, which often results in shorter lead times and thereby, faster deliveries."

Additive Manufacturing is also expected to open up the possibility of repairing broken tools in the future, by removing dysfunctional components and manufacturing them anew. This could, for example, involve tool components or the reuse of different types of machine-side connections. This is a particularly a good idea in terms of the environment and sustainability. Another advantage with AM technology that Seco noted is that, overall, not as much material is used for AM manufacturing and any leftover powder can be reused.

This makes Additive Manufacturing a time- and cost-efficient method for unique production whilst still being suitable for large-scale production. Seco Tools is already additively manufacturing cooling clamps for its Jetstream tools.

"The cooling clamps have a complex form with curved cooling channels and are thus well-suited to this type of manufacture," explained Bite.

The R&D department at Seco Tools works continuously to improve the use of AM technology for the development and manufacture of new and existing products. The company is constantly looking into ways to improve its products and how to best utilise AM .

"We like to collaborate with our customers on these efforts and to conduct tests together with them," added Bite. "The materials that are currently used in AM are no different in nature than those being used in conventional manufacturing, and the technology works well with many different metals. In the future, we will add even more and superior materials, while regularly adapting our equipment and upgrading hardware and software as needed."

www.secotools.com

Freemelt granted Japanese patent for cathode technology in Electron Beam Powder Bed Fusion


A detailed view of the Freemelt ONE's electron gun (Courtesy Freemelt)

Freemelt AB, Mölndal, Sweden, has been granted a patent in Japan for solutions contained in the company's electron gun, the electron ejector used within the company's Electron Beam Powder Bed Fusion (PBF-EB) machines. The patent concerns the cathode and is reportedly the first patent in the 'Electron Gun Cathode Technology' patent family.

"Japan has the potential to become an important market in 3D printing, based on electron beam technology," stated Daniel Gidlund, Freemelt's CEO. "It is a successful industrial nation in terms of innovation and technology transformation supported by advanced solutions, including electrification of the automotive industry, which is an important market for us. Furthermore, it is a confirmation of the strong innovation ability from our team, something that has impressed on me since I took the role as CEO in the company."

The patent-protected design enables the part of the cathode that ejects electrons to retain heat through advanced thermal insulation. The diode-type source and laser-heated cathode enable consistent beam spot quality throughout the entire beam power range from 0–6 kW. The Freemelt ONE machine thus allows users to operate the electron beam at very high beam currents while still maintaining a well-focused beam spot, essential to reach high build rates and temperatures.

Ulric Ljungblad, co-founder and Chief Innovation Officer at Freemelt, added, "We have developed a solution completely focused on high productivity with high and accurate quality. One of the most important things that sets us apart from our competitors is our unique electron gun where we have full control over the manufacturing and design of our proprietary, and now patented, cathode technology."

Parallel patent applications for this invention are also pending in Europe, North America and China. The patent number in Japan is 2021-576773 and extends to 2040.

www.freemelt.com

SPEE3D installs LightSPEE3D at Hamburg university to support Additive Manufacturing development


The University of Applied Sciences Hamburg has installed a LightSPEE3D AM machine (Courtesy SPEE3D)

SPEE3D, Melbourne, Australia, has partnered with the University of Applied Sciences Hamburg (HAW), Germany, to bring its Additive Manufacturing technology to students at the institution. The University has installed a LightSPEE3D AM machine, making it the first European academic institution to utilise SPEE3D's patented metal Cold Spray technology to additively manufacture new parts.

The LightSPEE3D AM machine will be under the supervision of the Institute for Material Sciences and Joining Lab, which specialises in Additive Manufacturing of metal parts, joining and robot-based manufacturing metals, overseen by Professor Dr-Ing Shahram Sheikhi, which supports masters, PhD, and postdoctoral studies. The goal is to prove the 'form and function' of additively manufactured parts and enable adoption in local industries such as maritime and aerospace.

"The University of Applied Sciences Hamburg is a forward-thinking, innovative institution with Professor Sheikhi at the helm solving some of the world's most pressing manufacturing issues," stated David McNeill, Director of Business Development for EMEA at SPEE3D. "The opportunity to work with HAW Hamburg and support the European maritime industry represents a 'sea change' for Cold Spray printing in Europe. They can now make new parts in minutes that are more efficient and resilient than traditional supply chains allow."

SPEE3D has stated that having its LightSPEE3D machine in one of Europe's largest ports represents an exciting development. Both the university and Hamburg's maritime industries are said to believe Additive Manufacturing is one potential solution to some of the most pressing problems for the port.

"The installation of the LightSPEE3D printer pursues the innovation path of alternative manufacturing and joining technologies whereby the goal of maritime research strategy can be accomplished in the next few years," added Professor Sheikhi. "Through Additive Manufacturing, we expect a reduction of maintenance, repair, and conversion costs that can be ensured."

www.haw-hamburg.de
www.spee3d.com

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AVIMETAL AM

A World Leader In
METAL AM SOLUTION

Founded in 2015, Avimetal AM Tech Co., Ltd. is a one-stop solution provider in manufacturing metal powder, developing metal 3D machine, and offering comprehensive technical process, which has independent capability of metal alloy powder design and production, metal 3D printer development, assembly and debugging, printing parameter development and technical services. Currently Avimetal AM has owned 3 facilities,including 2 metal powder factories and 1 metal 3D equipment factory.

HIGH PERFORMANCE METAL POWDER

- Titanium/Nickel/Aluminum/Medical CoCr/Steel Alloy Powder etc.
- 9 Series,200+ alloy grades
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ADVANCED METAL 3D EQUIPMENT

- Multi-laser Selective Laser Melting Technical Roadmap
- Various Build Volume Equipment
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TECHNOLOGY SERVICE

- Customized Metal Powder Design and Production
- Optimized Structure and Printing Forming Process
- Heat Treatment and Surface Treatment

Room 301, Building 1, No.6, Rongchang East Street, Beijing Economic and Technological Development Area, China
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AddUp joins Dassault Systèmes 3DEXPERIENCE platform for digital continuity

AddUp Inc, headquartered in Cébazat, France, has joined the Dassault Systèmes 3DEXPERIENCE platform, an ecosystem offering a dedicated set of applications for Additive Manufacturing from new material characterisation, adapted design and build job preparation and simulation, to shop floor scheduling and execution monitoring. Through the single platform, users can ensure digital continuity across the entire lifecycle.

Through the collaboration, a virtual twin of AddUp's FormUp 350 AM machine has been created. Using AddUp NTwin enables 3DEXPERIENCE platform users to seamlessly produce a job file, retrieve additional build information and run simulations.

"Dassault Systèmes and AddUp have developed a virtual twin of the FormUp 350 machine in the 3DEXPERIENCE platform which enables the production file to be created interactively. Thanks to this virtual twin, Dassault Aviation is able to ensure digital continuity from design to manufacturing of the part in the 3DEXPERIENCE platform," shared Dassault Aviation.

Users can access 3DEXPERIENCE platform features and applications, while creating strategies and generating trajectories using the AddUp Trajectory Generator. To enable process accuracy, trajectories are displayed directly in the DELMIA application, before being sent to SIMULIA applications for process simulation.

At the heart of this collaboration is reported to be Aeroprint, a R&D project driven by Dassault Aviation and located in the French region of Auvergne-Rhône-Alpes. One of the expected deliverables is the establishment of a certified AM pilot line for aeronautics. Dedicated to accelerating the adoption of Additive Manufacturing by the aeronautics industry, an industrial platform at the Argonay site is being set up.

The collaboration has resulted in a virtual twin of AddUp's FormUp 350 AM machine (Courtesy AddUp Inc)

The solution is now available and can be downloaded from the AddUp community, where users can also find further information as well as ask AddUp and Dassault Systèmes' members questions.

www.addupsolutions.com
www.3ds.com

Zortrax M300 Dual now compatible with BASF Ultrafuse stainless steel

Zortrax, based in Olsztyn, Poland, has announced an update for its M300 Dual Additive Manufacturing machine that allows users to make parts out of either BASF Ultrafuse 316L or 17-4 PH stainless steel filament, as well as an upgrade for its Z-SUITE software package.

The Ultrafuse filaments, included in Zortrax's Full Metal Package, includes all necessary components to make metal parts and was first introduced by the company for its industrial AM machines last year.

Using the Ultrafuse filament results in a 'green' part comprising of 80% metallic powder and 20% polymer filler. To turn this into a fully-functional part it must undergo a two-part post-processing stage developed by BASF. In the first stage, the polymer filler is separated from the metallic powder through thermal and chemical treatment. The second stage takes place once the polymer filler is removed, with the remaining metallic part being sintered.

Zortrax has also updated its Z-SUITE software in an effort to further align with the needs of Additive Manufacturing users and the nature of the two-stage post-processing that turns 'green' parts into steel. The most important features in this area include a new gyroid infill which enables the building of metal models with 60-90% infill. This is useful in industries such as aerospace or automotive where the weight of the part has to be minimised.

Additionally, the update has reportedly improved the way that support structures are additively manufactured while building with BASF Ultrafuse Support Layer. In Z-SUITE 3.2.0 BETA, supports are separated along the Z-axis and divided down into small blocks along the XY-plane to make their removal easier after post-processing. For the same reason, support structures are also narrowed towards the bottom, thereby reducing the supports' footprint on the model. This is said to especially apply to getting rid of supports placed in small crevices or other areas in the parts that are difficult to access.

Support structures' deformation caused by shrinkage of the part is further reduced due to switching the direction of manufacturing from one layer to another. Z-SUITE 3.2.0 BETA reportedly changes the way the shrinkage plates are additively manufactured to maximise dimensional accuracy of parts that rest on such plates.

www.zortrax.com

Nuburu and GE Additive to explore advantages of blue laser use in AM

Nuburu, based in Centennial, Colorado, USA, has signed a joint technology agreement with GE Additive to explore the speed, accuracy and commercial benefits of Additive Manufacturing built around Nuburu's blue laser technology.

"As we continue to advance our proprietary blue laser technology, we have further increased both power and brightness to open up new applications," said Dr Mark Zediker, CEO and co-founder of Nuburu. "We've achieved key performance milestones that open new possibilities for significant advances in metal 3D printing. Working with GE Additive, and their expertise in metal Additive Manufacturing will allow us to rapidly optimise our innovative area printing approach. That will accelerate the further expansion of our pioneering blue laser into innovative metal 3D printing solutions which have the potential to change the landscape of military logistics, aerospace manufacturing, medical device fabrication, and beyond."

Chris Schuppe, General Manager, Engineering & Technology of GE Additive added, "As an industry leader in metal 3D printing and having been on the leading edge of qualifying parts in regulated industries, we're excited to evaluate Nuburu blue industrial laser technology and its benefits."

Nuburu's approach to Additive Manufacturing is built on the foundation of blue light absorption by metals, a fundamental physical advantage that offers high-efficiency laser-based melting for a wide range of industrially important metals. The Nuburu light engine combines the blue laser module with an optical conditioning system in an effort to optimise manufacturing performance. GE Additive will provide

Nuburu and GE Additive will explore the benefits of Additive Manufacturing built around Nuburu's blue laser technology (Courtesy Nuburu)

a Powder Bed Fusion machine and its experience in the integration and characterisation of this prototype light engine to quantify any performance improvements over existing technology.

This joint development agreement is in addition to an agreement with GE Additive to support Nuburu's previously announced AFWERX Small Business Innovation Research (SBIR) Phase II contract awarded to Nuburu in 2022.

www.nuburu.net
www.ge.com/additive

PyroGenesis signs by-the-tonne order for Ti powder for AM

PyroGenesis Canada Inc., Montreal, Quebec, Canada, has announced that it has received a signed order for 5 metric tonnes (5,000 kg) of its plasma atomised titanium metal powders for Additive Manufacturing. The down payment for this order has already been received.

"This order for 5,000 kg is the first 'by-the-tonne' commercial order received by the company for its atomised powder titanium metal powders produced using the company's NexGen plasma atomisation system," said Massimo Dattilo, VP, PyroGenesis Additive. "This represents our full entrance into the titanium metal powders marketplace."

The new client has reportedly also placed a provisional order for a further six tonnes (6,000 kg), contingent upon the client determining, at its discretion, the appropriate demand for additional powders.

The client (whose name is being withheld at its request) is reportedly an advanced materials company in the United States. However, PyroGenesis has clarified that this client is unrelated to the global aerospace OEM client for which the company continues the qualification process to become an approved supplier.

"With a goal to produce the highest quality metal powders in the Additive Manufacturing industry, PyroGenesis Additive has taken a cautious, methodical approach towards commercialisation of its powders as we designed, then readied, our new NexGen plasma atomisation process," continued Dattilo. "As mentioned in our previous releases, we started with sample batches for key customers measured in dozens of grams, then progressed to small commercial orders of 100 kg each, with the stated goal to then move up to commercial production and sales 'by-the-tonne.' This has now been achieved with this multi-tonne order."

The order will reportedly be completed at PyroGenesis' production facility in Montreal. The majority of the initial 5 tonnes of titanium metal powder order will be shipped during the second quarter of 2023, with the balance of the order set for completion before the end of the third quarter 2023.

www.pyrogenesis.com

PyroGenesis Canada Inc., has received an order for 5 metric tonnes of its plasma atomised titanium metal powders (Courtesy PyroGenesis)


VDM Metals
A company of ACERINOX
Outstanding performance
Special stainless steels, nickel and cobalt alloys produced by VDM Metals are used in many of today's key technologies for the safe and reliable handling of corrosive and high-temperature processes and procedures. In addition to exceptional materials, available as powder for additive manufacturing in a wide range of particle fractions, we offer you various first class services.
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vdm@acerinox.com
www.vdm-metals.com

ASTM announces maraging steel standard for PBF-LB AM

ASTM International, headquartered in West Conshohocken, Pennsylvania, USA, announced that its Additive Manufacturing technologies committee (F42) has developed a new standard specification for maraging steel processed by Laser Beam Powder Bed Fusion (PBF-LB). The standard, currently WK82609, will soon be published as ASTM F3607 in the *Annual Book of ASTM Standards*.

Maraging steel is a class of precipitation-hardened steel strengthened through ageing heat treatment. Its properties are useful for automotive, sporting goods, aerospace, and other industries.

This specification is intended for the use of purchasers and/or producers of additively manufactured maraging steel parts for defining the requirements and ensuring part properties. Users are advised to use this specification as a basis for obtaining parts that will meet the minimum acceptance requirements established and revised by consensus of committee members.

"Maraging steel has high strength and toughness without losing ductility, weldability, and dimensional stability," stated David Rosen, ASTM member and Principal Scientist at the Agency for Science, Technology and Research.

"If maraging steel is used to replace lower grade steels, resulting parts may be lighter and stronger, which can have positive benefits on fuel efficiency of cars and airplanes, for example."

F42 was formed in 2009 with over 150 members. The committee meets twice a year, attending two days of technical meetings; its current membership is in excess of 725, with eight technical subcommittees.

www.astm.org

Titomic launches Mobile Repair Unit for in-field repairs

Additive Manufacturing company Titomic Limited, Brisbane, Australia, has introduced its Mobile Repair Unit. Housed within a 6 m container, the unit incorporates two Cold Spray units, a D523 Cold Spray machine and a robotised integrated spray booth. The Mobile Repair Unit reportedly enables efficient in-field repair operations using a wide range of metals, including copper, aluminium, and nickel.

Initially designed for use by the military for battle damage repair, Titomic's Mobile Repair Unit has the potential to be used across various industries such as oil & gas, mining sites, and renewable energy farms. The Mobile Repair Unit's ability to operate remotely, requiring only power and compressed air to function, means that it can be powered by a generator, supporting an air compressor and the necessary power supply.

The D523, with its portable functionality, allows users to conduct remote repairs on various assets including heat exchangers, shafts, and vehicles. The integrated spray booth utilises robotic technology to enable the reliable restoration of numerous high-wear parts, including shafts, gearboxes, and other critical components.

The Cold Spray process involves propelling metal powders at high velocities onto a surface, creating a bond and restoring the original form. This Additive Manufacturing technique offers expedited and cost-effective solutions for various applications.

The Cold Spray Additive Manufacturing technology employed in the Mobile Repair Unit is said to provide a simple, effective method for repairing damaged parts.

ww.titomic.com

Excelencia-Tech Metal signs exclusive distribution agreement with Eplus3D

Excelencia-Tech Metal, headquartered in Barcelona, Spain, has been named by Eplus3D as its exclusive sales partner in Spain and Portugal for the company's Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing machines. Excelencia-Tech Metal hopes that this partnership will strengthen its position within the Spanish AM market, in which it already distributes de-powdering solutions from the German company Solukon GmbH.

"Together with Excelencia Tech Metal, we will be able to support the widespread adoption of metal Additive Manufacturing in the Iberian Market. We truly believe that with this strong and experienced industrial partner, our customers can benefit even better from local support and consultation," stated Enis Jost, Deputy General Manager of the Eplus3D German branch.

The Excelencia-Tech Metal Group holds shares and operates a service bureau called Windforce3D, this allows Excelencia Group to accelerate the market adoption of Additive Manufacturing by using its partner network to get the parts produced and post-processed.

Eplus3D recently expanded its range of metal Additive Manufacturing machines with the launch of the EP-M400, available in single, dual or quad-laser configuration (Courtesy Eplus3D)

Ronen Zioni, Excelencia-Tech Metal General Manager, shared, "We are excited by this new partnership with Eplus3D being a world class leader in metal printing for the past thirty years. The new business unit within the group will be focused on metal 3D printing and post-processing solutions such as Solukon and others to ensure we provide end-to-end solutions and maximum automation in customers' existing workflow in industrial and dental applications."

www.eplus3d.com
www.metal.excelencia-tech.com

Xometry reports stronger than expected first quarter 2023 results

Xometry, Gaithersburg, Maryland, USA, has shared its results for Q1 2023. The report included both financial and business highlights and features Xometry's recent expansion within Europe with the launch of xometry.uk, a localised marketplace for UK customers.

The company reported a total revenue for the first quarter 2023 of $105.3 million, an increase of 26% year-over-year and total gross profit for the first quarter 2023 as $39.4 million, an increase of 20% year-over-year.

"In Q1 2023, Xometry delivered stronger-than-expected 35% marketplace growth year-over-year, improved marketplace gross margin by 170 basis points quarter-over-quarter and improved operating leverage driven by our steadfast focus on our five-point strategic plan," said Randy Altschuler, Xometry's CEO. "We continue to rapidly expand our network of buyers and suppliers and enhance our products and services. We expect to continue to rapidly gain market share fuelling robust marketplace revenue growth while further tightening operating expenses to achieve Adjusted EBITDA profitability in Q4 2023."

www.xometry.com

Deutsche Bahn reaches AM milestone with 100,000 parts

German rail network operator Deutsche Bahn has reached the production milestone of 100,000 AM spare parts produced in full or in part by Additive Manufacturing and used across more than 500 applications. Deutsche Bahn began additively manufacturing parts in 2015, starting with simple spare parts like plastic coat hooks. Now, the company's spectrum of AM use cases ranges from these coat hooks to a 17 kg metal 'box backdrop' for a high-speed train. Deutsche Bahn has also begun introducing Additive Manufacturing as part of its training within plants.

Deutsche Bahn's milestone part was a gear housing for shunting locomotives. This piece of machinery was cast in an additively manufactured mould and, at a volume of almost 1 m^3 and weight of 570 kg, the housing is thus far the company's largest and heaviest part.

According to Deutsche Bahn, traditional wait times for obtaining a part like the gear housing through conventional procurement methods would be an average of ten months. Therefore, the company opted for a more efficient approach by employing Additive Manufacturing technology, significantly reducing the delivery time to just two months. The rail network operator used Binder Jetting (BJT) to manufacture the gearbox mould, which was then produced by casting.

The gearbox housing is part of Deutsche Bahn's growing digital warehouse. The database contains virtual technical drawings of spare parts. If required, these parts can then be produced quickly and easily using Additive Manufacturing. Currently, around 1,000 virtual models are stored in the digital warehouse; by 2030, Deutsche Bahn plans to have increased this to 10,000 different components.

Deutsche Bahn has shared that, as well as being a more sustainable method, this method of production saves logistics space and reduces storage costs whilst shortening delivery times and logistics chains.

Deutsche Bahn uses its own AM machines as well as a partner network for production. At the end of 2016, the railway company launched its Mobility Goes Additive network, which now consists of over 140 companies, including users, machine manufacturers, AM service providers, universities and start-ups. Various Additive Manufacturing processes are used, including Laser Beam Powder Bed Fusion (PBF-LB), Directed Energy Deposition (DED) and BJT.

www.deutschebahn.com

Deutsche Bahn's additively manufactured components range from handrails for the visually impaired to wheel set bearing covers (Courtesy Deutsche Bahn)

Adaxis joins 3MF Consortium

French-Swedish robotics software company Adaxis, headquartered in Bayonne, France, is joining the 3MF consortium as an Associate Member. The 3MF consortium is comprised of twenty-one members representing the Additive Manufacturing and 3D CAD industry. Established in 2015, its mission is to deliver a file format that adheres to key principles crucial for the Additive Manufacturing industry.

In its role within the consortium, Adaxis hopes to work with other consortium members in order to optimise the 3MF format specifically for robotic Additive Manufacturing. By collaborating and sharing insights, Adaxis aims to drive advancements in Additive Manufacturing technology, unlock new possibilities, and enhance the capabilities of robotic systems in the industry.

Emil Johansson, co-founder of Adaxis shared, "Today, the ability to create high-quality multi-axis tool paths can heavily rely on the input 3D model. A standardised and capable file format will make it easier to share and extract vital information about the 3D surfaces, optimal manufacturing sequence, and materials."

Duann Scott, Director of the 3MF Consortium added, "As Additive Manufacturing processes and applications mature, communicating design and manufacturing intent with a representation of the surface only is no longer enough to accurately or reliably produce results the machines are capable of. Adaxis brings yet another dimension to the problem with their multi-axis robot Additive Manufacturing software."

"By joining the 3MF Consortium, Adaxis will be critical in helping to shape and implement data in a standardised format to include other information such as manufacturing process, materials and more. We look forward to working with Adaxis to help their customers, and the manufacturing industry at large through open-source collaboration."

www.adaxis.eu
www.3mf.io

PTC showcases fully additively manufactured jet engine at LiveWorx 2023

PTC showcased a fully additively manufactured jet engine weighing approximately 3.6 kg and designed in its Creo CAD software (Courtesy PTC)

PTC, Boston, Massachusetts, USA, showcased a fully additively manufactured jet engine at the recent LiveWorx 2023, event in Boston, USA. PTC's micro turbojet engine, weighing approximately 3.6 kg and additively manufactured from Inconel, is a single, complete assembly, including all rotating and stationary components, and was designed in PTC's Creo CAD software.

The jet engine project was conceived by Dr Ronen Ben Horin, VP of Technology at PTC and Senior Research Fellow at Technion – Israel Institute of Technology, and Beni Cukurel, an Associate Professor of Aerospace at Technion. Designing and additively manufacturing a fully self-supported micro turbojet engine, including the 50,000 RPM turbine, that requires no assembly, is said to represent a significant breakthrough in designing for Additive Manufacturing (DfAM).

Many of the Creo advanced design capabilities were used for the jet engine assembly. The software is said to enable sophisticated lattice modelling and generative design for material and weight reduction while maintaining the same strength and performance of designs with more material and heavier weight. Beam-based lattices in Creo automatically optimise designs for AM and the software also supports self-supported formula-driven lattices that can be paired with build checks and modifiers to adjust the design for AM efficiency.

Creo is compatible with most AM equipment for build and post-processing. PTC explained that the 3D component design in Creo is critical for performing traditional machining for precise assembly. Creo also provides a variety of formats, including 3MF, for sending 3D models to the market's various AM technologies, while also allowing users to easily create associative models for machining operations.

www.ptc.com

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Researchers strengthen Inconel 718 with nanocarbides

Researchers from the Massachusetts Institute for Technology (MIT), USA, and Istanbul Technical University, Türkiye, have reported what is claimed to be a relatively simple, inexpensive way to strengthen metal powders via the addition of ceramic nanowires. The paper, 'Strengthening additively manufactured Inconel 718 through in-situ formation of nanocarbides and silicides,' was published in Volume 76 of *Additive Manufacturing*.

"There is always a significant need for the development of more capable materials for extreme environments. We believe that this method has great potential for other materials in the future," stated Ju Li, the Battelle Energy Alliance Professor in Nuclear Engineering and a professor at MIT's Department of Materials Science and Engineering (DMSE).

The team's approach begins with Inconel 718, a popular superalloy. The researchers milled commercial Inconel 718 powders with a small number of ceramic nanowires, resulting in "the homogeneous decoration of nano-ceramics on the surfaces of Inconel particles." The resultant powder was then used to create parts via Laser Beam Powder Bed Fusion (PBF-LB) AM.

The researchers reported that parts additively manufactured with their new machine-agnostic powder have significantly less porosity and fewer cracks than parts made of Inconel 718 alone. And that, in turn, leads to stronger parts that also have a number of other advantages, such as ductility and resistance to radiation and high-temperature loading.

Xu Song, an assistant professor at the Chinese University of Hong Kong, who was not involved in the work, commented, "In this paper, the authors propose a new method for printing metal matrix composites of Inconel 718 reinforced by [ceramic] nanowires. The in-situ dissolution of the ceramic that is induced by the laser melting process has enhanced the thermal resistance and strength of Inconel 718. Moreover, the in-situ reinforcements reduced the grain size and got rid of flaws. Future 3D printing of metal alloys, including modification for high-reflectivity copper and fracture suppression for superalloys, can clearly benefit from this technique."

Li stated that the work "could open a huge new space for alloy design" because the cooling rate of ultra-thin additively manufactured layers of metal alloys is much faster than the rate for bulk parts created using conventional melt-solidification processes. As a result, "many of the rules on chemical composition that apply to bulk casting don't seem to apply to this kind of 3D printing. So we have a much bigger composition space to explore for the base metal with ceramic additions."

Researchers have reported a relatively simple, inexpensive way to strengthen metal powders for AM via the addition of ceramic nanowires (Courtesy MIT)

Emre Tekoğlu, one of the lead authors of the *Additive Manufacturing* paper, added, "This composition was one of the first ones we decided on, so it was very exciting to get these results in real life. There is still a vast exploration space. We will keep exploring new Inconel composite formulations to end up with materials that could withstand more extreme environments."

Alexander O'Brien, another lead author, concluded, "The precision and scalability that comes with 3D printing has opened up a world of new possibilities for materials design. Our results here are an exciting early step in a process that will surely have a major impact on design for nuclear, aerospace, and all energy generation in the future."

www.mit.edu
www.mme.itu.edu.tr

Velo3D names Varlahanov as CTO

Velo3D, Campbell, California, USA, has announced the promotion of Alexander Varlahanov to Chief Technology Officer (CTO). Varlahanov most recently served as Vice President of Engineering, where he oversaw the company's hardware and software products.

In his new role, Varlahanov will be responsible for driving innovation of Velo3D's Additive Manufacturing technology. He will also oversee the technology team, which is responsible for process development of new alloys and techniques, as well as advanced technology development.

"In his various roles at Velo3D over the course of his career, Alex has made tremendous contributions to the company and has been pivotal in developing our innovative technology," said Benny Buller, founder and CEO of Velo3D. "These contributions have helped us quickly become one of the leaders in our category. I believe that in this new role, Alex will continue to execute on our mission of helping innovators create the next generation of technologies that change the world."

"I'm excited to take on this new role as CTO at Velo3D and I welcome the challenges that await me and my team as we work to advance our technology, deliver new products, meet the needs of our customers," added Varlahanov.

www.velo3d.com

Gemco offers mixing and drying equipment for AM powders

Mixing and drying equipment developer Gemco, Middlesex, New Jersey, USA, is offering an enhanced range of machinery designed to process engineering-grade metal, ceramic, and polymer powders for specific use in the Additive Manufacturing industry.

"Mixing and drying have a direct correlation to the performance, strength, and durability of 3D metal, ceramic, and plastic-based materials," explains Gemco's president and CEO Casey Bickhardt. "Our Additive Manufacturing mixing and drying equipment is a cost-effective and flexible alternative [for] designing and manufacturing 3D metallic, ceramic, and plastic powders for high-value components and critical applications in all the AM powder markets."

Design aspects unique to AM powders are said to include gas purging and coating, which require an internal filtering system that delivers the carrier to the powder and not to the exhaust system. Vacuum integrity is critical to eliminating contamination ingress into the product.

"While most manufacturers won't discuss leakage rates, it's critical," added Bickhardt. "Our experience as the number one mixer in the pharmaceutical industry and being trusted by the FDA has let us become the leader in blending science and technology. Our unique design facilitates the reaction, homogenising, drying, cooling, and reclamation processes all in one machine. This equipment represents the shortest processing for AM metallic, ceramic, and plastic powder mixing and drying. Reclamation allows for the reuse of expensive, unused portions of the AM powders without the need to purchase additional equipment. Waste is significantly reduced."

Gemco's mixing and drying equipment designed to process metal and ceramic powders (Courtersy Gemco)

Gemco's Additive Manufacturing mixing and drying equipment features vacuum drying that allows the process to proceed faster and at lower temperatures. It offers lot sizes ranging from 10-1800 kg with full traceability of the different batches blended. The equipment incorporates stainless steel contact parts with pharma-grade finishes to prevent lot-to-lot contamination.

www.okgemco.com

IBIS' 3D Printing in Auto Repair Task Force shares action plan

Last month at the International Bodyshop Industry Symposium (IBIS) USA 2023 trade conference, the IBIS Worldwide announced that it is launching a network called the 3D Printing in Auto Repair Task Force. IBIS Worldwide is, reportedly, the world's first provider of conferences dedicated to the collision repair industry.

The task force aims to identify opportunities for utilising Additive Manufacturing to improve the efficiency and effectiveness of automotive repair. This could include using Additive Manufacturing to create replacement parts, tools, and other components, as well as using the technology to improve the design and manufacturing of existing parts. The task force will then evaluate how additively manufactured parts can be used to assist in the collision and automotive repair sector in a safe and regulated environment by conducting extensive research into cost-effectiveness, speed of production, quality control and safety considerations.

By collaborating with Additive Manufacturing experts and manufacturers, the task force hopes to identify the best practices to achieve this goal. It will also work with industry associations and regulators to ensure that any new technologies and practices meet OEM safety and regulatory requirements. They will also take on the issue of training, working with automotive based training bodies to help upskill the industry and workforce.

Harold Sears, who has over thirty years of Additive Manufacturing experience, has been named as the Task Force lead. He has experience as a consultant and previously drove Ford's Additive Manufacturing Division for over two decades.

The 3D Printing in Auto Repair Task Force has shared the following Action Plan:

- Expand the Global Task Force – OEM, Insurance, Training Bodies and experts
- Undertake research and testing on Additive Manufacturing repair parts & performance
- Validate suitable 'OEM grade' plastic material and suppliers
- Highlight issues on non-compliant Additive Manufacturing parts suppliers in current market
- Collaborate with industry leading providers in Additive Manufacturing & related technology or supply
- Establish Additive Manufacturing parts supply pilot programmes and measure results (multi-region)
- Work with industry bodies such as IBIS to inform and update the market on developments
- Map out a regulated supply chain for 'certified' Additively Manufactured automotive repair parts
- Shape the future of the automotive repair & collision industry using Additive Manufacturing

www.3dinautorepair.com
www.ibisworldwide.com

Inmarsat selects SWISSto12's HummingSat for I-8 satellites

Inmarsat, a satellite service provider has announced that SWISSto12, a provider of additively manufactured antenna and radio frequency (RF) system products headquartered in Renens, Switzerland, will develop its new eighth-generation of spacecraft. SWISSto12 will use its HummingSat satellite platform – in conjunction with Additive Manufacturing technologies and specialised RF and payload products – to develop and manufacture the geostationary satellites, which are set to launch by 2026.

"We are delighted that Inmarsat has selected SWISSto12 as its partner for its landmark l-8 programme. It demonstrates that, with HummingSat, we have created a highly-advanced new class of small geostationary spacecraft that delivers world-leading connectivity capabilities at a fraction of the cost. Our proprietary 3D printing of Radio Frequency payload technology allows us to push the limits of existing capability and service new and existing business cases for geostationary satellite communications. This is an important step in our journey to better connect and protect every corner of the world," shared Emile de Rijk, CEO, SWISSto12.

At 1.5 m^3 in volume, the I-8's will use SWISSto12's new class of spacecraft which has a form factor up to five times smaller than conventional geostationary satellites. The three l-8 satellites will work to provide an extra layer of resilience to complement the existing constellation and Inmarsat's two I-6 generation satellites, which were launched in December 2021 and February 2023.

Each I-8 will also work to extend Inmarsat's history of launching and operating radio navigation transponders for governments and international space agencies. These transponders can enable Satellite-Based Augmentation System (SBAS) services around the world, for example, for air traffic controllers or coastguards. SBAS systems reportedly use satellite connectivity, land-based infrastructure, and software to enhance standard GPS/Galileo accuracy of 5-10 metres to 10 cm.

SWISSto12 will use Additive Manufacturing to produce Inmarsats new eighth-generation of spacecraft (Courtesy Inmarsat)

Peter Hadinger, Chief Technology Officer, Inmarsat, said, "Every single day people around the world depend on Inmarsat services. Our customers have demanding, and often safety-critical, missions that rely on our satellite technology for links that can make the difference. The I-8's will not only underpin our existing capabilities for the future, but enable ever more advanced safety innovations like SBAS that can ultimately help save more lives. We have chosen SWISSto12 because they have the ground-breaking technology that can make it a reality."

www.swissto12.com

www.inmarsat.com

SPEE3D to develop SUBSAFE submarine materials for US Navy

SPEE3D, Melbourne, Australia, has announced that the US Navy has chosen its metal Cold Spray Additive Manufacturing (CSAM) technology to develop materials as a part of a Naval Sea Systems Command (NAVSEA) project related to Expeditionary Maintenance and Sustainment that achieve Submarine Safety Program (SUBSAFE) quality standards.

SUBSAFE is a US Navy quality assurance programme designed to ensure the safety of its submarine fleet. All work done and materials used on those systems are tightly controlled to ensure the material used in their assembly and the methods of assembly, maintenance, and testing are of standard. SPEE3D was subcontracted through the Applied Research Laboratory of the Pennsylvania State University (ARL/PSU), a NAVSEA partner in cold spray technology development and transition.

The US Navy and ARL/PSU are now investigating SPEE3D's Additive Manufacturing technology to determine if it meets the rigorous engineering, quality, and safety requirements as well as rapid part production.

The partnership marks the first time a Cold Spray Additive Manufacturing technology will be investigated as a manufacturing method for SUBSAFE-compliant applications. Working together, the US Navy, ARL/PSU, and SPEE3D will develop an entirely new method to rapidly manufacture existing parts for use in critical submarine systems.

SPEE3D's capabilities reportedly have the potential to reduce the production time of submarine parts from months to hours. Its technology has reportedly been tested extensively by the US, UK, and Australian militaries. In addition, SPEE3D is platform-agnostic and can manufacture a variety of metals, including aluminium 6061, aluminium bronze, and copper.

"We are honoured to be chosen and trusted by the US Navy to participate in this ground-breaking project," said Steven Camilleri, co-founder and CTO at SPEE3D. "We have worked successfully with the US Navy in the past and understand the unique challenges they face with the need for manufacturing capabilities that are fast, reliable, and easily deployable."

www.spee3d.com

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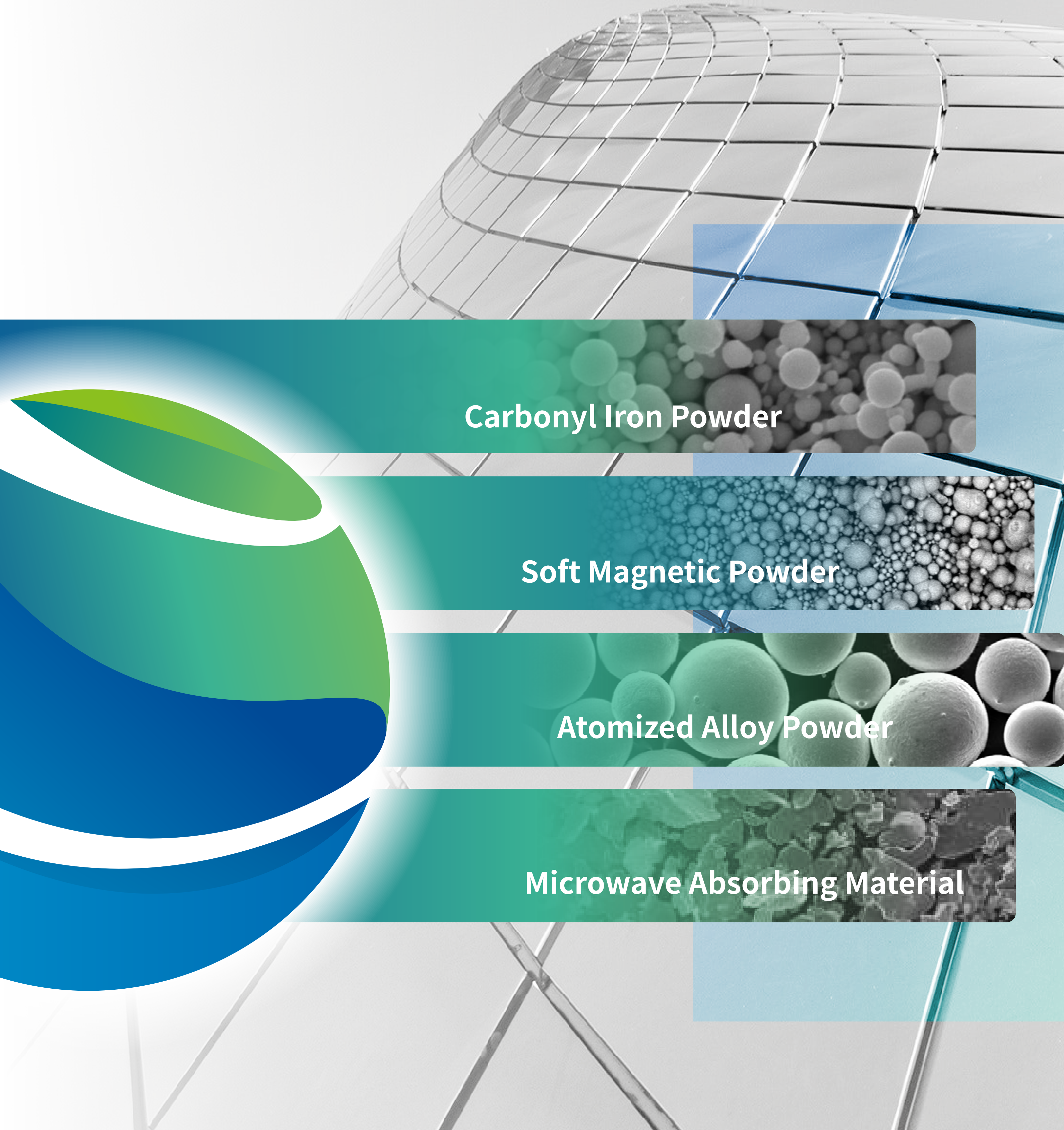

www.yueanmetal.com
oversea@yueanmetal.com

OWL achieves Aerospace Quality Management System EN9100 for HIP

OWL Additive Manufacturing GmbH, Aachen, Germany, has achieved Aerospace Quality Management System EN9100 (equivalent to AS9100) and maintained its ISO9001 status for its Hot Isostatic Pressing of metals. The company is now also certified for the encapsulation of metals, ceramics and powders.

As well as HIP services, OWL offers Additive Manufacturing services from prototypes through to serial production. It also offers FEM and topology analysis and optimisation, producing components in a wide range of metals.

OWL also offers 'shared' Hot Isostatic Pressing cycles, wherein customers can share HIP capacity to optimise costs. The company offers a range of shared cycles for base materials including titanium, aluminium, iron, cobalt and nickel.

The company was EN9100:2018 and ISO9001:2015 certified in August 2021, and works within the aerospace, motorsport, mechanical engineering and medical technology sectors. The auditing for these certifications was undertaken by TÜV SÜD.

OWL has attained Aerospace Quality Management System EN9100 certification from TÜV SÜD (Courtesy OWL)

www.owl-additive-manufacturing.com

German scientists develop XL Additive Manufacturing machine for shipbuilding

As part of the XXL3DDruck, scientists from non-profit research institute Laser Zentrum Hannover e.V. (LZH), Germany, and partners have developed a giant laser-assisted Wire Arc Additive Manufacturing (WAAM) machine, capable of producing steel components weighing several tons. The project has, thus far, produced parts of a ship gearbox housing with a mass up to three tons.

The XXL Additive Manufacturing with an installation space of 3 x 4.5 m, which is used as a prototype for research and development purposes only, is located at the marine gearbox manufacturer Reintjes in Hameln. It uses WAAM, a high-performance Additive Manufacturing process method for metals that achieves high mass throughput. The consortium can apply up to 3.2 kg of steel per hour with the machine.

The process can reduce the use of both material and energy compared to conventional manufacturing methods; traditionally, individual moulds are made for the components of marine gearbox housings. This work step is eliminated in Additive Manufacturing. Material and weight can also be saved because components can be redesigned and constructed differently – with hollow walls, for example. Laser-assisted WAAM can also implement individual, component, and customer-specific design requirements.

XXL Additive Manufacturing conserves resources during production and later during the operation of the ship, as if less material is used, the ship has to accelerate less mass and thus also requires less fuel.

A part of a ship's gearbox housing, which is currently still being manufactured, serves as an example. Through Additive Manufacturing, the project participants aim to reduce the weight of a ship gearbox housing by several tons. The long-term goal for production is to reduce manufacturing and procurement time as well as to save raw materials such as steel by reducing the amount of material used per housing.

The joint project XXL3DDruck: Energie- und ressourceneffiziente Herstellung großskaliger Produkte durch additive Fertigung am Beispiel von Schiffgetriebegehäusen was funded by the German Federal Ministry for Economic Affairs and Climate Action. The project was managed by Reintjes GmbH, whilst the LZH was responsible for the development of the process technology. Eilhauer Maschinenbau GmbH, Langenhagen, took over the plant engineering of the Additive Manufacturing machine, with Tewiss – Technik und Wissen GmbH, Garbsen, was responsible for constructing the build head and controlling the machine. The IPH – Institut für Integrierte Produktion Hannover gemeinnützige GmbH developed an inline measurement technology for process monitoring.

Supported by the Lower Saxony Ministry of Economics, Transport, Construction and Digitalization, the Laser Zentrum Hannover e.V. is dedicated to promoting applied research in the field of photonics and laser technology. Founded in 1986, almost 200 employees are now working at the LZH.

The LZH offers solutions to current and future challenges with its smart photonics. Along the process chain, natural scientists and engineers work together: from component development for specific laser systems or for quantum technologies to process developments for a wide variety of laser applications, for example for medical and agricultural technology or lightweight construction in the automotive sector. Eighteen successful spin-offs have emerged from the LZH to date.

www.lzh.de
www.reintjes-gears.de
www.eilhauer.de
www.tewiss-verlag.de
www.iph-hannover.de

Equipmake showcases Ampere-220 e-axle featuring AM electric motor

Equipmake, a developer and manufacturer of electrification products for battery-electric vehicle (BEV) drivetrains, headquartered in Snetterton, Norfolk, UK, showcased its Ampere-220 e-axle system, featuring a metal additively manufactured structure, at Battery Show Europe in Stuttgart, Germany, which took place from May 23-25, 2023.

The Ampere-220 e-axle features the Ampere electric motor, which contains a spoke rotor design which has recently also appeared in the Ariel HIPERCAR in the form of Equipmake's APM motor. The e-axle's electric motor is combined with all necessary power electronics as well as an integrated transmission system, resulting in a compact and lightweight electric drive system, ready to be integrated into a high-performance electric vehicle.

The Ampere reportedly has a peak power of 220 kW and a maximum motor speed of 30,000 rpm; the axle weighs just under 20 kg and offers a power density of 11 kW per kg. The key to its performance is said to be a combination of Equipmake's spoke design with the use of Additive Manufacturing rather than traditional manufacturing, whereby the part would be made by milling from a solid billet.

Equipmake showcased its Ampere-220 e-axle featuring an AM electric motor (Courtesy Equipmake)

The additively manufactured, thermally efficient thin-walled structure features optimised fine surface details and a multi-part assembly is replaced with a single, complex design that has inbuilt cooling, is lightweight, has low inertia and reputedly allows for greatly increased rotational speed.

www.equipmake.co.uk
www.thebatteryshow.eu

AddUp participates in $1.5M research programme to advance IN-718 AM for the United States Air Force

AddUp Inc., headquartered in Cébazat, France, has joined a $1.5M research contract entitled 'Development of Manufacturing, Heat Treatment, and Surface Finishing Guidelines to Yield Ready-to-Use IN-718 Additive Manufacturing Components' through the United States Air Force (USAF) and the Small Business Innovation Research (SBIR) programme led by REM Surface Engineering (REM).

The project is funded through a Direct to Phase II Small Business Innovation Research (SBIR) contract and aims to harness the potential of Laser Beam Powder Bed Fusion (PBF-LB) and surface finishing technologies to produce IN-718, a nickel-base superalloy, components for legacy armament systems. The endeavour looks to research the impact of various heat treatment and build parameter combinations in association with REM's surface finishing technology on a component's mechanical properties such as tensile strength and fatigue life. Both AddUp and Zeda are supporting this project, which aims to provide the USAF with a set of manufacturing guidelines that maximise the capabilities of PBF-LB to meet fleet readiness and sustainment goals.

Fatigue strength plays a critical role in ensuring the longevity and reliability of components used within the USAF. AddUp claims that the combination of fine powder and a roller recoater in its FormUp 350 machine provides a synergistic effect on surface finish improvement, leading to enhanced fatigue properties in IN-718 material. Fatigue resistance can be considerably improved by the reduction of surface irregularities, minimising defects and achieving a more uniform powder layer. This is particularly crucial in aerospace and defence applications, where fatigue performance is critical for long-term structural integrity and operational reliability.

Fatigue testing is, therefore, crucial in ensuring the reliability and integrity of IN-718 components. IN-718 fatigue specimens will be manufactured by Zeda using an AddUp FormUp 350 machine. These will then be utilised in REM's testing matrix to establish expected material properties of PBF-LB components with varying levels of surface finish and different manufacturing and heat treatment parameters. Through this collaborative effort, the project seeks to validate the fatigue strength of IN-718 AM components manufactured using AddUp's technology.

IN-718 fatigue specimens built on AddUp's FormUp 350 Laser Beam Powder Bed Fusion machine (Courtesy AddUp)

By leveraging the capabilities of PBF-LB technology and conducting rigorous fatigue testing, this project strives to enhance the performance, reliability, and cost-effectiveness of aerospace and defence components, reducing downtime and enable mission-critical operations to proceed smoothly.

www.addupsolutions.com

Kennametal: The story of the successful commercialisation of AM hardmetal and steel solutions

Kennametal is a particularly interesting company when it comes to the adoption of Additive Manufacturing. It is a dynamic global producer of tooling and industrial materials with sales of $2 billion in 2022, yet its roots are very much in 'old school' sinter-based PM processes. It is, therefore, no surprise that the company was an early adopter of AM, leveraging its materials and sintering expertise, as well as its broad customer base, to develop a leading position in the AM of hardmetals and steels. Bernard North, who fortuitously happens to be a past VP Industrial Technology at Kennametal, visited the company's AM operation and reports for *Metal AM* magazine.

It was with great interest and anticipation that this author returned to his former workplace in Latrobe, Pennsylvania to spend a few hours speaking with the leaders of Kennametal Inc.'s Additive Manufacturing programme and seeing much of its equipment and processing areas for AM development and production. Kennametal is rightly proud of its progress in this area and its experts were happy to discuss the subject in some detail.

Staff in the discussions included Jay Verellen, General Manager, Additive Manufacturing; Colin Tilzey, Director, Global Additive and Carbide Technology; Paul Prichard PhD, Research Fellow Technology, Additive Manufacturing; Zhuqing Wang PhD, Staff Engineer Technology, Additive Manufacturing; Ed Rusnica, Vice President Engineering; Jerry Dominguez, Senior Manager, New Business Development, Additive Manufacturing; and Rebecca Garrigus, Market Portfolio Manager, Additive Manufacturing.

The story of Kennametal

In 1938, Philip McKenna left the family alloy steel business to start McKenna Metals in Latrobe, Pennsylvania. The seminal invention was to presolution titanium carbide (TiC) with tungsten carbide (WC) so that steel cutting cemented carbide grades would have improved microstructures and mechanical properties. Before long the company name was changed to that of its main brand name, Kennametal, and, after a few years, it went public as Kennametal Inc.

Fig. 1 The Kennametal campus in Latrobe, Pennsylvania (Courtesy Kennametal)

Fig. 2 Kennametal Additive Manufacturing staff (Courtesy Kennametal)

Over the next eighty-five years, through both organic growth and acquisitions, the company became one of the largest in the industry, with a global presence across the metalcutting, mining and construction, and engineered wear solutions markets. As such, it has a high level of vertical integration, all the way from tungsten ore processing to finish grinding, coating, and reconditioning, and a myriad of processes in between, including all the green part making, sintering, and finishing processes typically used in the industry.

While the company is best known for its broad range of cemented carbides, its product portfolio also includes those made from alloy steels, hard CoCr and related alloys, ceramics, and superhard diamond and cubic boron nitride (CBN). While clearly technically grounded, the company's core philosophy is that of working closely with its customers to provide effective solutions to their problems.

"While the company is best known for its broad range of cemented carbides, its product portfolio also includes those made from alloy steels, hard CoCr and related alloys, ceramics, and superhard diamond and cubic boron nitride (CBN)."

A timeline of Kennametal's history in Additive Manufacturing

It was natural, given its core products and technologies, that Kennametal would keep a close watch on the development of Additive Manufacturing. Prichard described how, in the late 1990s, the company formed a working partnership with the Massachusetts Institute of Technology (MIT), Boston, Massachusetts, and Extrude Hone "just down the road" in Irwin, Pennsylvania. The respective principals were Ely Sachs (subsequently a co-founder in 2015 of Desktop Metal, which in 2021 purchased ExOne, the AM company, which was formed out of Extrude Hone), and Larry Rhoades.

At that time, the technology was judged to be "not ready for prime time", but Kennametal maintained a 'watching brief' with technology landscaping and market assessments of the various AM technologies being developed by different players.

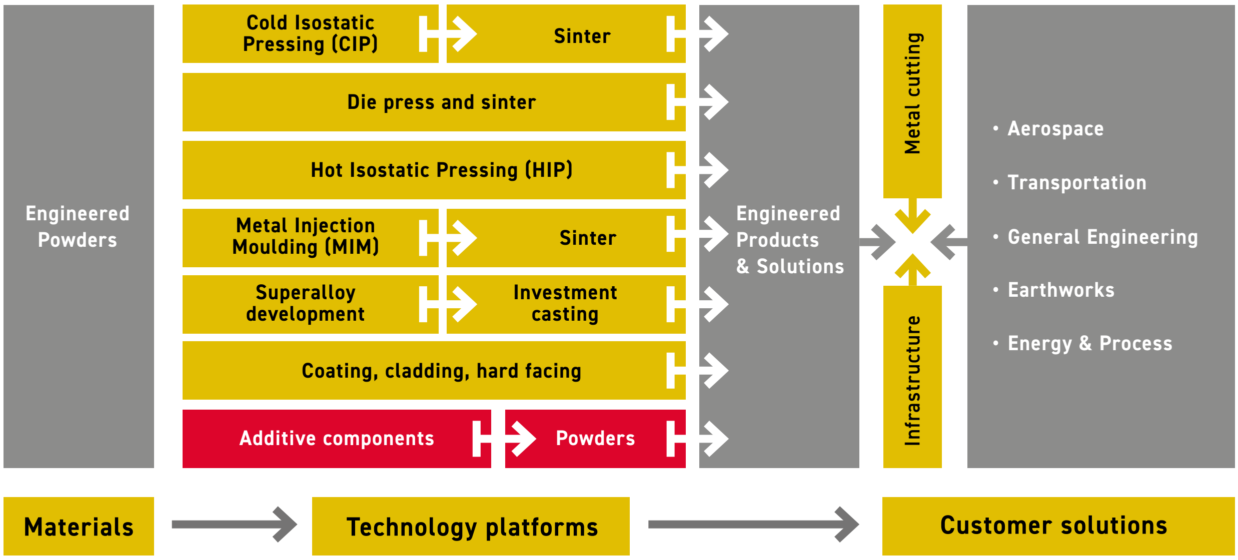

Fig. 3 Kennametal's materials and process portfolio (Courtesy Kennametal)

In 2013, driven by a new metalcutting product development for which the steel toolholders could not realistically be made any other way, Kennametal invested in Laser Beam Powder Bed Fusion (PBF-LB) technology, and subsequently fine-tuned the additive and associated processes and incorporated them into full-scale production by 2017.

By 2014, it was clear that equipment and process developments in Binder Jetting (BJT) were proceeding rapidly, and Kennametal began investing in essential equipment for its Quentin C McKenna Technology Center (Fig. 1). Additional investments continued steadily over the following years.

In 2019, a dedicated full scale production unit was set up with end-to-end solution capabilities and resources necessary to support the growing business. Kennametal officially launched solutions to its customers in an extremely tough WC-17% Co grade (KAC89-AM-K) as well as Stellite™ 6-AM-K (CoCr-based hard alloy).

In 2021, an additional, more wear- and corrosion-resistant tungsten carbide grade with 13.5% CoNiCr metal binder (KAR85-AM-K) was commercialised [1].

"It is clear that Kennametal regards AM as an integral part of its business, as exemplified by its commitment to people, capital equipment, and organisational structure, resulting in a steadily increasing range and volume of AM solutions to customers across different product applications and markets."

In May 2022, GE Additive announced that Kennametal had become a Beta Partner for its BJT technology [2], with Kennametal investing in newly available solutions to further extend its leadership position in cemented carbide Additive Manufacturing solution capabilities.

In June 2022, Prichard presented a paper at the 20th Plansee Seminar on the team's work to allow submicron WC-10%Co to be shaped by BJT and sintered to form high quality solid end mill blanks with subsequent good performance in an end mill metalcutting test [3]. Which brings us to the present day!

The business approach

It is clear that Kennametal regards AM as an integral part of its business, as exemplified by its commitment to people, capital equipment, and organisational structure, resulting in a steadily-increasing range and volume of AM solutions to customers across different product applications and markets. A diagrammatic representation of the company's operations is shown in Fig. 3.

Kennametal remains very pragmatic about AM. In Verellen's words, "AM is another innovative tool in our toolbox that we can leverage

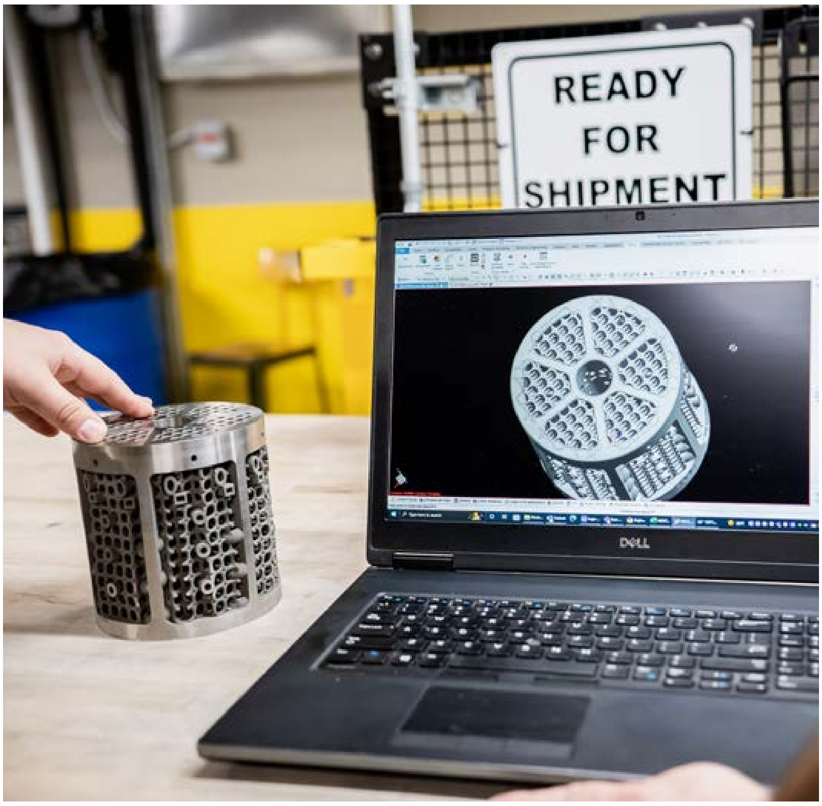

Fig. 4 Finished BJT part ready for shipment (Courtesy Kennametal)

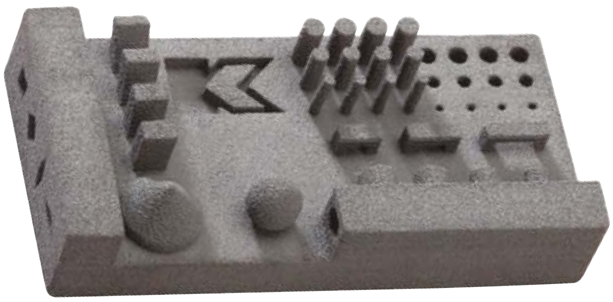

Fig. 5 A BJT test part, demonstrating fine feature capabilities in different directions (Courtesy Kennametal)

"Sometimes, customers are receive two quotes for a given component – one using AM and the other made by conventional shaping methods, as part of overall consultation to match their needs with the most appropriate solution."

to deliver complete wear solutions for our customers and transform how everyday life is built". Usually, AM is chosen for a specific part because it is the best, and often the only, way to make the component. Sometimes, however, after experience is gained, conventionally produced parts may switch to an AM route.

Conversely, some parts initially made by AM may switch to conventional shaping processes such as uniaxial pressing or isostatic pressing/green machining. Sometimes, customers receive two quotes for a given component – one using AM and the other made by conventional shaping methods, as part of overall consultation to match their needs with the most appropriate solution.

Verellen stressed Kennametal's high level of vertical integration and experience with a broad range of processing technologies, aiding both research and development and subsequent commercialisation of AM cemented carbides and Stellites. The company's experience in manufacturing advanced metal powders, and being able to tailor the relevant processes, were critical to optimisation of the BJT process in terms of success with a broader range of compositions, as well as as-sintered surface finish and fine features capability, such as holes or differently shaped protrusions and indents, and at different orientations with respect to the printing direction. Fig. 5 shows a standard test part, which enables qualitative and quantitative evaluation of such characteristics. In addition, the company's experience of sintering complex, thin-walled parts made by isostatic pressing and green machining with minimal distortion has proved invaluable with similar AM products.

Garrigus explained that customers for AM solutions are initially gained in multiple ways – in particular, existing or new customers interacting with technical field sales staff, trade show contacts, and online demand generation approaches. While the most obvious benefit for customers is

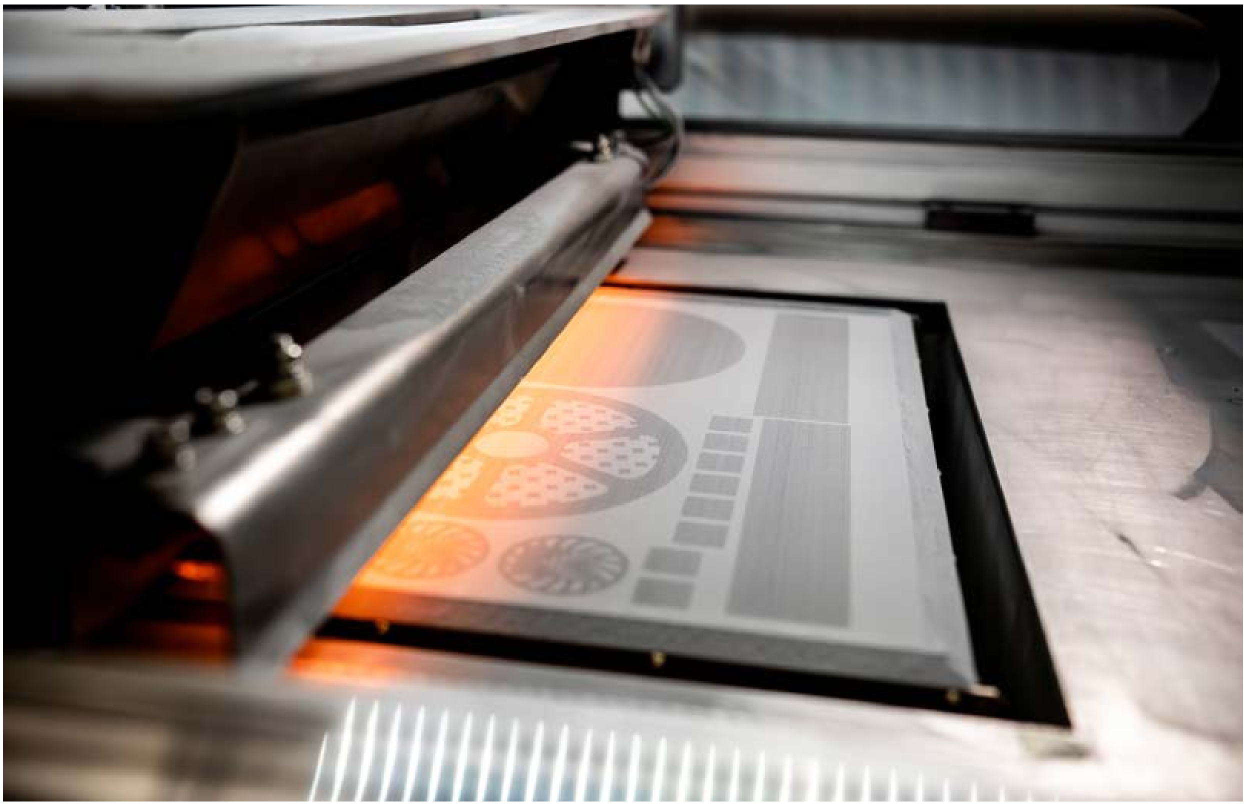

Fig. 6 A BJT machine at Kennametal producing a bed of components and test coupons (Courtesy Kennametal)

being able to get a complex geometry part made in a material with desirable properties that will solve their particular technical problems, there are other benefits of AM. In particular, the time from enquiry to product delivery is often only a few weeks – or as much as half the time that it would take if using conventional processes. This in turn has inventory reduction benefits for both the customer and Kennametal.

Verellen mentioned something very important that may not be openly discussed much in the AM community – some customers have an inherent suspicion about AM components. This is usually because they have experienced quality problems with them in the past, in particular low mechanical strength. Kennametal practices a strict phase-gate approach, which includes the rule that a material will not be offered commercially in AM form unless, or until, its AM properties match those of conventionally processed products.

"...the time from enquiry to product delivery is often only a few weeks – or as much as half the time that it would take if using conventional processes. This in turn has inventory reduction benefits for both the customer and Kennametal."

Kennametal's Additive Manufacturing component guidelines are communicated to prospective customers specific to limits and/or recommendations on physical size, tolerance, and other geometric limitations for Stellite and cemented carbide parts. However, Dominguez stressed that the guidelines are just that – actual capabilities may differ according to the specific part geometry and material. They are also subject to a detailed design review process, and, in many cases, can be improved upon with some optimisation. Fig. 6 shows the BJT process in action.

Kennametal has focused on PBF-LB for steels and on BJT for cemented carbides and Stellite alloys, partnering with multiple machine manufacturers. However, staff, aided by a global presence, network and communicate with a broad range of industry players to keep a close watch on developments, ensuring new capabilities can be identified and quickly integrated as they evolve.

Fig. 7 Stellite 6™ valve cage made by BJT (Courtesy Kennametal)

Fig. 8 A cemented carbide impeller made by BJT (Courtesy Kennametal)

Stellites™

Stellite 6-AM-K, a CoCr-based alloy, has been offered in additively manufactured customer solutions, using Binder Jetting, since 2019. Stellite 6 is not as hard or wear-resistant as most cemented carbides, but has excellent corrosion resistance, and is more wear-resistant and has better high-temperature properties than the metallic alloys, often Inconel 718 or 17-4 PH stainless steel, that it commonly replaces for specific components.

Applications continue to grow in a range of industries and component geometries, many of them in flow control applications in the oil and gas field. In some cases, customers have migrated from more conventional alloy solutions to Stellite 6 and later (dependent on the operative wear mechanisms) to a cemented carbide AM solution. Fig. 7 shows a Stellite component.

Reflecting the typical product and service offerings in this sector, Kennametal also offers AM powders to customers who have their own AM (usually PBF-LB) capabilities in Stellite 21 and F75 (CoCr), Nistelle™ 625 (NiCr), and Delcrome™ 316L and 17-4 (FeNiCr stainless steel) alloys.

Cemented carbides

Readers who are familiar with the technical literature on cemented carbides, and specific companies' public announcements, will be aware that achieving good microstructures and full density using the BJT process is aided by either a coarser grain size or a higher metal binder, usually Co, level, or a combination of the two. The basic reasons for this are that

Fig. 9 Examples of BJT cemented carbides: upper right PCD reaming bodies in the as-built and finished states, lower left nozzles used in oil and gas applications (Courtesy Kennametal)

coarser grain sizes aid in achieving higher green densities, and hence a more intimate initial contact of WC and Co particles for sintering, higher Co levels aid liquid phase sintering, and (if higher than normal sintering temperatures are used to aid densification) fine grain materials are more prone to oversintering, or discontinuous grain growth.

Kennametal's progress in AM exemplifies this trend insofar as its initial commercialisation in 2019 was of the medium/coarse grain size WC-17% Co grade KAC89-AM-K, which is well towards the very tough (K1c ~18 MPam$^{0.5}$), but not especially hard (Rockwell A ~86, HVN30 1060 kg/mm^{2}) end of the cemented carbides' grade spectrum. Nevertheless, the grade has very good thermal properties and, in many applications, superior wear and/or corrosion resistance to allow it to replace other materials used in engineered wear solution applications. It is also a good choice for the pre-form bodies (Fig. 9) used for polycrystalline diamond (PCD) brazed cutting tools; in such applications, the opportunity can also be taken to reduce material usage by hollowing out the shank end of the tool, as well as adding advanced coolant channel designs not possible with traditional manufacturing processes.

Continuing the trend, the next grade to be commercialised was the medium grain size WC-13.5% CoNiCr grade KAR85-AM-K; the grain size and composition changes raised the hardness to Rockwell A ~88.5 (HVN30 1225 kg/mm^{2}), while the toughness dropped a little to ~16 MPam$^{0.5}$. In

Fig. 10 A BJT cemented carbide commemorative coin (Courtesy Kennametal)

Fig. 11 A cemented carbide complex flow control stack produced by BJT (Courtesy Kennametal)

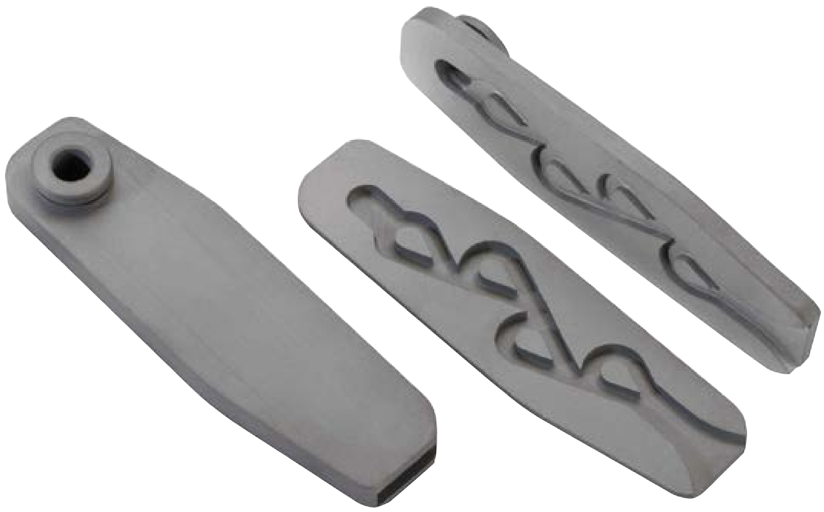

Fig. 12 A cemented carbide flow control device, showing internal coolant channels, produced by BJT (Courtesy Kennametal)

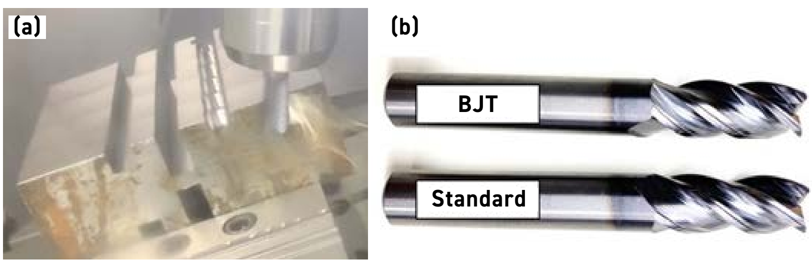

Fig. 13 Solid end milling test of BJT vs conventional 10% Co submicron grade (Courtesy Kennametal)

addition, the partial substitution of Co by Ni and Cr gives greatly improved corrosion resistance, and this product is thus an excellent fit with engineered wear solution applications, especially in the oil, gas, and chemicals industries, typified by components shown in Figs. 11 and 12.

In June 2022, Prichard presented a paper at the 20th Plansee Seminar on the team's work on process optimisation to allow submicron WC-10%Co to be shaped by BJT and sintered to form high quality solid end mill blanks which, after being processed into finished end mills, showed equivalent performance to conventionally processed materials in a very tough metalcutting test, as shown in Fig. 13. This author was fortunate to be in the Plansee Seminar audience and it is difficult to overstate the significance of this development. Grades of this type constitute the highest volume in the metalcutting field, being almost ubiquitous for solid round tools such as drills and end mills, as well as being used for some insert applications. Garrigus emphasised that such a grade also has many applications in the engineered wear solutions arena. It has already been assigned a designation: KAF82-AM-K. Its preliminary hardness is Rockwell A 91.9 (HVN30 ~ 1580 kg/mm^2) and its toughness ~13 MPam$^{0.5}$. Further process optimisation is underway and Verellen indicated testing with beta customers in the 2023/4 timeframe, followed by full commercialisation.

What's next? Hardmetal industry people will know that, while there are many exceptions to this generalisation, the biggest families of grades have either 10% or 6% (by weight) Co, in each case with the hardness/toughness (and other properties) trade-offs being achieved by grain size and fine-tuned binder metal composition variation. The former group has now been demonstrated as being viable for BJT AM, so the obvious question is: what about 6% Co grades? The Kennametal people were

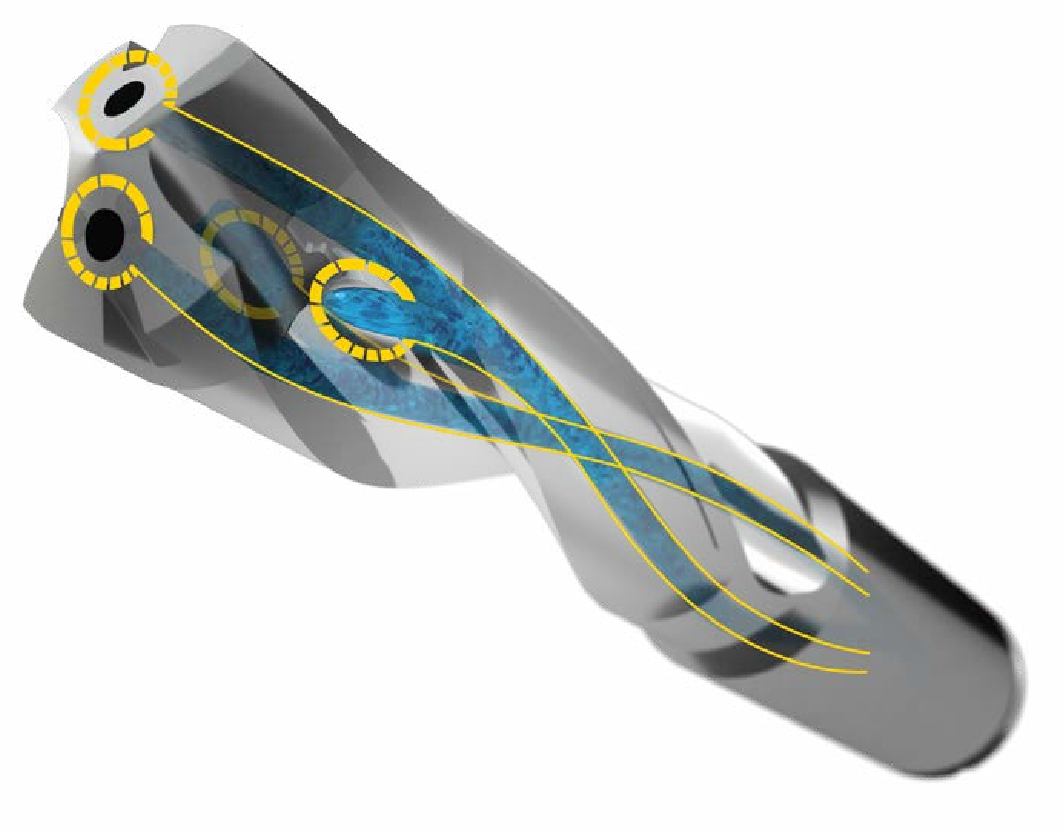

Fig. 14 A PBF-LB steel body with helical coolant channels for KenTip FS™ modular drill (Courtesy Kennametal)

understandably non-committal in answering this author's enquiry, with Prichard and Wang simply indicating that 6% Co grades are "difficult".

Reflecting Kennametal's standard business practices, cemented carbide grade powder for AM is not offered for external sale. Components are sometimes sold as pre-forms, but most commonly as fully finished products ready for incorporation into customers' applications.

Steels

Kennametal first became closely involved with AM of steels, using the PBF-LB process, in 2013, driven by the need to develop and manufacture steel toolholders for a new modular drilling system, the KenTip-FS™, as shown in Fig. 14. This required helical coolant holes passing through the toolholders' flutes in order to enable 'through the insert' cooling, which in turn reduced cutting edge temperatures and improved metal chip evacuation. The process was fully incorporated into manufacturing in 2017 and is used to make standard and customer-specific toolholders in very high volumes as required for this very broad application range, industry-leading product family. Subsequently, in 2021, this AM process was also used for the reducer sleeves for the HiPACS drilling system used to produce countersunk fastener holes in the aerospace industry.

Most recently [4, 5], Kennametal introduced customer application-specific insert toolholders, namely a stator bore tool for EV motor housings and a boring tool for

"Reflecting Kennametal's standard business practices, cemented carbide grade powder for AM is not offered for external sale. Components are sometimes sold as pre-forms, but most commonly as fully finished products ready for incorporation into customers' applications."

Fig. 15 Light-weighted PBF-LB steel cutter body with coolant channels for transmission housing boring operation (Courtesy Kennametal)

transmission housings (Fig. 15), which, to an even greater degree, utilise the unique capabilities of AM. To metalcutting industry veterans like this author, these tools look like something from a science fiction movie! However, the driving force for such designs is completely practical – Rusnica explained that the major weight reductions, for example from 30 kg down to 11.5 kg in the case of the transmission housing tool, allow easier tooling changes, as well as more rapid acceleration and deceleration in use, while combining multiple operations into one. The AM route also allows multiple channels to put coolant exactly where it is most effective.

In total, these characteristics allow major cycle time and machined part cost reductions, as well as reduced maintenance and energy use for the machine tools running the operations. The dimensional stability of the AM process is such that, when combined with some finish machining of the insert pockets and the cutting inserts' own tolerance levels, very tight machined component tolerances are achieved. For example, the transmission housing tool creates a maximum bore diameter in excess of 350 mm (~14") with an IT7 tolerance (per ISO 286-1) i.e. ~60 µm.

The design process for such tooling is very sophisticated: this example was achieved by Kennametal engineers using various advanced approaches to modelling, optimisation, and finally, confirming overall tool performance commensurate with requirements.

AISI H13 (X40CrMoV5-1, BH13, 1.2344,SKD61) steel is used for these toolholders, because of the combination of high strength (important due to much-reduced part cross-sections in some cases), deformation resistance (for long-term insert pocket integrity), and erosion resistance, the latter to resist chip wash – abrasion by fast-moving metal chips during machining operations.

The pros and cons of different AM processes

The author engaged the Kennametal development staff in a brief discussion of the respective advantages and disadvantages of different AM approaches for its materials.

For steels, it was made abundantly clear that both the sinter-based BJT process and the beam-based PBF-LB processes are practical alternatives to conventional production, and both are in use across the industry. Rusnica felt that the former approach was more suitable for high volume production, and it may also be a better fit for existing PM steel part manufacturers who already possess the requisite sintering capacity for parts made by pressing or injection moulding. For hard alloys such as Stellites, it is also clear that either approach can work, dependent somewhat on individual alloy compositions.

The most interesting discussion centred on cemented carbides. The papers presented at the 20th Plansee Seminar in 2022 [6, 7] were a good demonstration of its present capabilities. The current EPMA programme [8], summarised in [6], is aimed at further clarifying the situation. Prichard stated that BJT is the most mature and highest production process and fits the characteristics of cemented carbides best.

Its disadvantages – namely low green densities and susceptibility to subsequent oversintering, making lower Co and/or finer-grained grades more difficult to process, and de-powdering from small orifices or fine features, are steadily being overcome through equipment and process development.

The material Material Extrusion/ Fused Filament Fabrication process (MEX/FFF) is more able to process a wide range of grades, but its productivity is much lower and part surface finish is poorer. The laser PBF-LB method shows little promise of working, due to the atmospheres employed and difficulty of controlling local temperatures, leading to inhomogeneous microstructures and deleterious phases [9]; these problems are not easy to overcome. However, the Electron Beam Powder Bed Fusion (PBF-EB), with higher energy inputs and a more conducive high temperature environment (near vacuum) has found application for high Co materials [10].

In closing

This author came away from the Kennametal facility extremely impressed with the combination of technical prowess, integration into manufacturing, pragmatism, and customer focus evinced by Kennametal's AM programme. It will be fascinating to see how the efforts progress and what the timescale of further technical and commercialisation advances will be!

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General Atomics Aeronautical on metal Additive Manufacturing's place at the centre of the digital manufacturing revolution

General Atomics Aeronautical Systems, Inc. (GA-ASI) is the world leader in the design and manufacture of Unmanned Aircraft Systems (UAS). The company is no stranger to AM, with its Additive Design and Manufacturing Center of Excellence being integral to the qualification of more than 300 AM flight components and the installation of more than 10,000 AM parts on its aircraft. Now, it is working to identify and partner with some of the most innovative players in the industry in order to further leverage the capabilities of the technology. Divergent Technologies, the company behind Czinger Vehicles, is one such company. Jeff Kerns reports for *Metal AM* magazine.

General Atomics Aeronautical Systems, Inc. (GA-ASI), based in San Diego, California, is a leading developer of advanced technology solutions for government and commercial applications. Known most widely for its Predator unmanned aerial vehicles, the company is privately owned and vertically integrated, and describes itself as having "the freedom to invest in the most innovative technologies, and the resources to deliver them as products for customers around the world." It, therefore, comes as no surprise that the company has been a significant player in the Additive Manufacturing industry for a number of years with its own in-house AM capabilities.

A recent partnership caught headlines when it was announced that GA-ASI was able to move from the design phase of a new Remotely Piloted Aircraft to functional prototype hardware in less than five months using metal Additive Manufacturing. What was particularly surprising was that the partner that helped to enable this speed of development was Divergent Technologies, a small company better known for a record-breaking additively manufactured hypercar and a bold ambition to turn automotive manufacturing on its head.

What Divergent Technologies brought to the table was its Divergent Adaptive Production System (DAPS), a metal AM-based digital manufacturing solution that was able to supercharge the speed of product development and manufacturing for

Fig. 1 Skyguardian UAS and Sparrowhawk SUAS – part of a fleet of multi-mission platforms at GA-ASI (Courtesy GA-ASI)

Fig. 2 An AM inlet air duct for a small UAS platform (Courtesy GA-ASI)

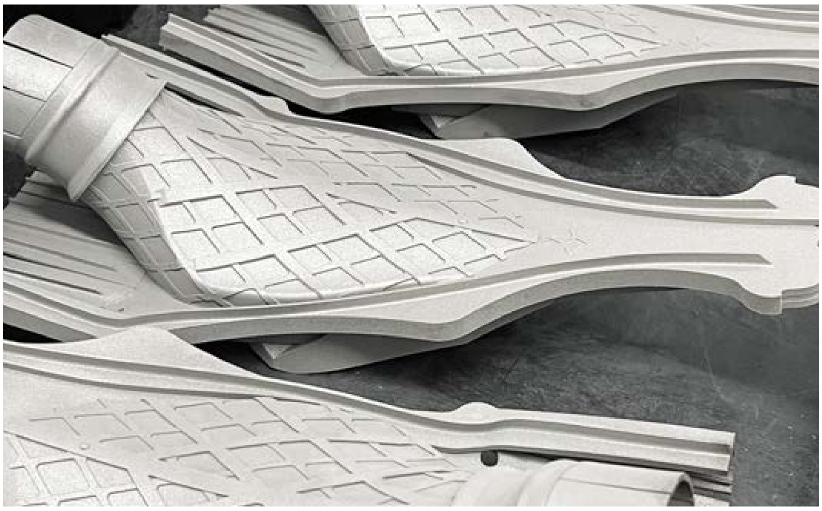

Fig. 3 PBF-LB titanium intake NACAs for the Skyguardian UAS (Courtesy GA-ASI)

"...GA-ASI is prioritising the integration of some of the most innovative companies in the metal AM community, attracting collaborators from other industries such as oil and gas, and automotive, as well as providing real opportunity to grow AM's acceptance in the wider aerospace industry and beyond."

a new generation of applications coming out of GA-ASI's Additive Design and Manufacturing Center of Excellence and its advanced engineering programme teams.

This unlikely industry collaboration not only shines a light on how metal AM can now be considered as a critical solution on the path to making digital manufacturing a reality, but also how a company such as GA-ASI, through its position as a lead systems designer and integrator, is able to identify and leverage existing expertise in the wider AM field and bring diverse parties together as expert collaborators to deliver the most complex of systems, packed with emerging technology capabilities.

As advanced manufacturing within defence requires the expertise of many partners, GA-ASI performs the role of identifying potential collaborators, qualifying their capabilities, and then integrating them into the larger cohort that is responsible for delivering the entirety of the UAS system.

This article offers insight into how GA-ASI is exploring the emerging capabilities of Divergent, its latest official partnership in the metal AM space following previously announced collaborations that include Australia's Conflux Technology for heat exchangers, and Norway's Norsk Titanium for large structural AM components.

With its leading profile in the industry, GA-ASI is prioritising the integration of some of the most innovative companies in the metal AM community, attracting collaborators from other industries such as oil and gas, and automotive, as well as providing real opportunity to grow AM's acceptance in the wider aerospace industry and beyond.

Additive Manufacturing at General Atomics

GA-ASI is by no means a newcomer to AM, having qualified hundreds of flight components produced by various processes. It is estimated that the use of AM parts on its MQ-9B

Fig. 4 Metal PBF-LB machines within the Additive Design & Manufacturing Center of Excellence at GA-ASI (Courtesy GA-ASI)

UAS platform alone has saved the company over $2 million in tooling costs and over $300,000 per aircraft in recurring cost avoidance by using approximately 240 additively manufactured parts.

It was back in 2017 that the company produced its first metal AM part, in titanium, for its MQ-9B SkyGuardian UAS platform (Fig. 3). Its interest in Additive Manufacturing, however, dates back even further, to 2011, when it started adopting Additive Manufacturing for shop aids, fixturing, and design iterations. The company began with a Polyjet machine, but its journey into AM progressed quickly. More polymer AM technologies followed, as did exploring new materials and design strategies. It was this ongoing investment in an 'AM ecosystem' that laid the groundwork for its metal AM activities.

In 2018, GA-ASI's leadership created a dedicated Additive Manufacturing department, which worked to develop a strategic roadmap for AM, grow an internal subject matter expert team, and establish flight hardware production capabilities. Three years later, in 2021, GA-ASI opened its Additive Design and Manufacturing Center of Excellence to bring additional synergies for developing and qualifying AM applications that would deliver a positive business case over conventional manufacturing methods (Fig. 4). The benefits of metal AM for GA-ASI's aircraft and customers were clear.

"This recognition that metal AM can progress towards its potential when combining multiple parts into one, and be even more effective when used to create completely new systems... meant that the potential of the Divergent Adaptive Production System (DAPS) for aerospace manufacturing was quickly recognised..."

Steve Fournier, Senior AM Manager at GA-ASI, explained the fundamental differences between GA-ASI's approach to polymer and metal AM, stating, "When thinking about metal AM for the long run, it's really about changing manufacturing through the integration of multiple components. For plastics, material properties don't allow for this. For example, you can find value in printing a plastic or composite bracket but, because of the material properties, you can't print a plastic heat exchanger with built-in brackets. Plastic can limit the ability to combine parts since structural loading typically increases with the level of part integration. Fortunately, metal AM can work well for this, and this kind of approach is necessary to justify the higher cost of the metal AM technologies."

This recognition that metal AM can progress towards its potential when combining multiple parts into one, and be even more effective when used to create completely new systems – such as airframe or subassemblies – meant that the potential of the Divergent Adaptive Production System (DAPS) for aerospace manufacturing was quickly recognised.

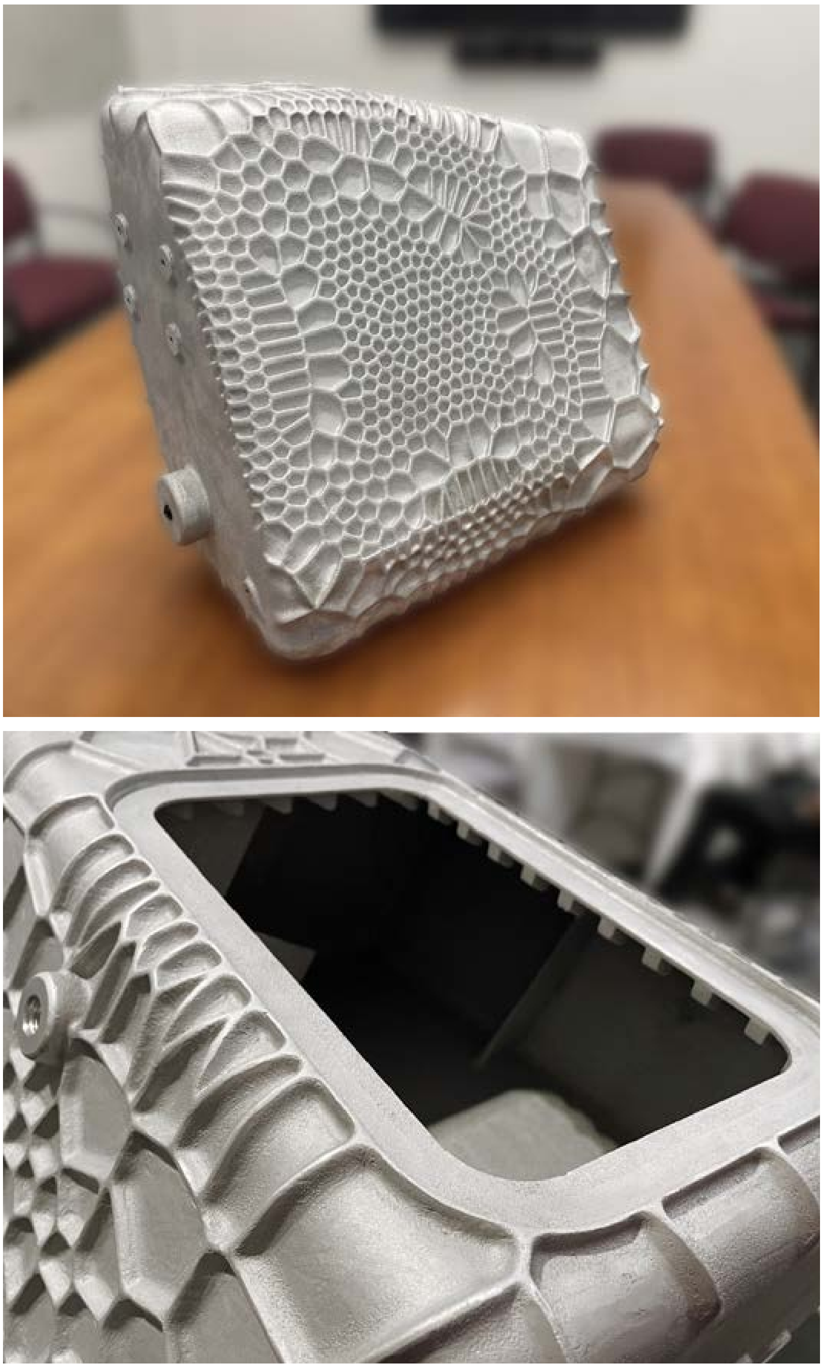

Fig. 5 Two views of a DAPS-optimised fuel tank for a large UAS platform (Courtesy GA-ASI)

"The process leveraged model-based, Artificial Intelligence-driven, and topology optimised designs, reducing total part count by over 95% while meeting weight targets."

DAPS as a catalyst for innovation

GA-ASI's first metal AM application, from 2017, combined four parts into one. Its new UAS airframe, developed using the DAPS system, took this to the next level, reducing 180 individual parts into just four modular nodes. Two of these nodes are shown in Figs. 5 and 6. The process leveraged model-based, Artificial Intelligence-driven, and topology-optimised designs, reducing total part count by over 95% while meeting weight targets.

Whilst such dramatic part consolation using metal AM is not new, GA-ASI and Divergent's wider focus was on using DAPS as a manufacturing solution to address system-level challenges. Given a set of digital requirements as the input, DAPS offers the capability to automatically computationally design, additively manufacture, and assemble complex structures.

The DAPS process inspected each metal AM component (or node) by creating a full digital twin of the small UAS (SUAS) which was then applied to a fully automated, toolless robotic assembly process that took less than 20 minutes to complete. This process enabled the team to go from a print-ready SUAS design to a fully assembled deliverable airframe in less than two days. The system can also move seamlessly between different products, with zero switchover time. This innovative approach to design and manufacturing results in performance-optimised designs that can be produced at a substantially lower airframe recurring cost.

Prior to its partnership with GA-ASI, Divergent Technologies had already achieved considerable success in the implementation of its digital manufacturing solutions in the automotive sector with DAPS. Having qualified as a Tier 1 supplier for additively manufactured chassis and suspension assemblies in automotive, seven global automotive manufacturers went on to select Divergent structures for future vehicle production.

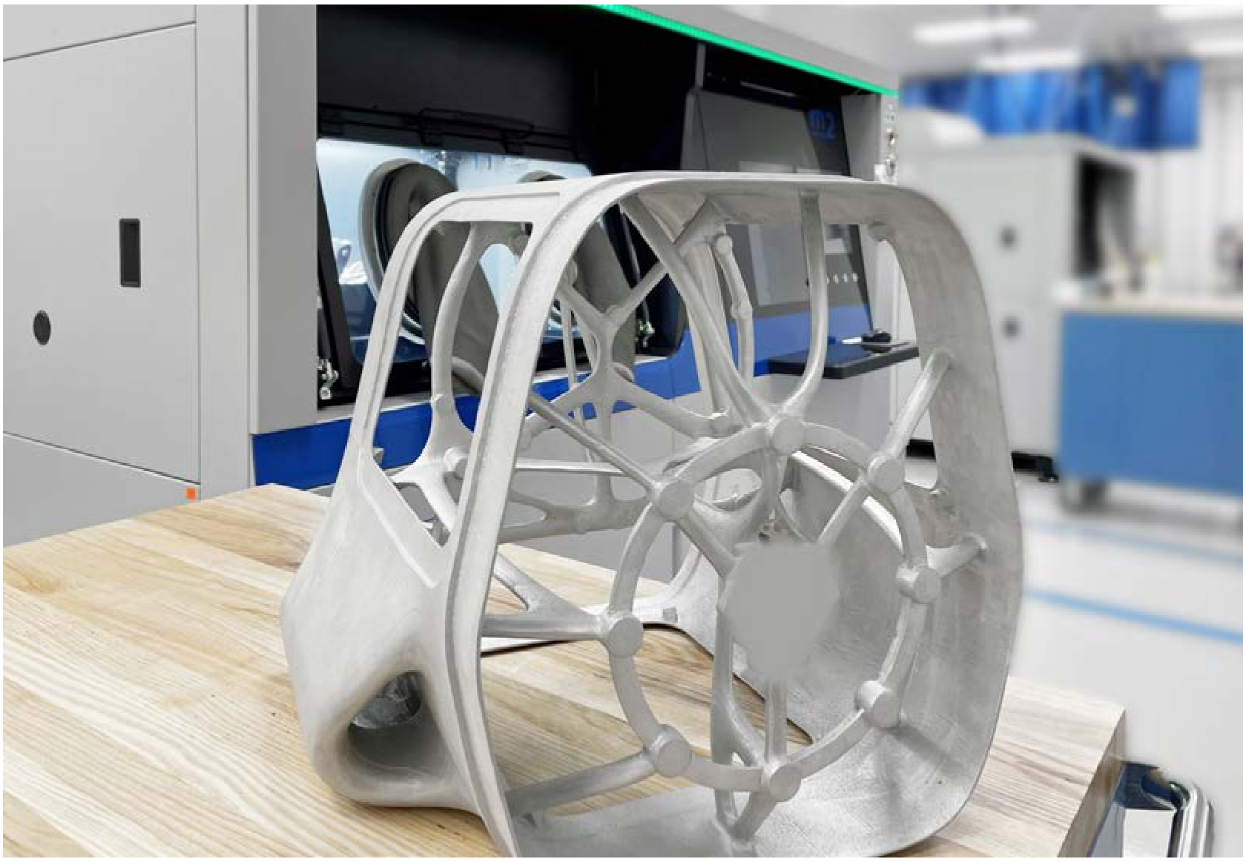

Fig. 6 Topology-optimised node of a unitised small UAS airframe structure at GA-ASI (Courtesy GA-ASI)

The applicability of the technology to the next generation of UAS is clear. "We are focusing on 'blank canvas' next-generation aircraft designs," stated Fournier, "A key aspect of the working relationship between the GA-ASI and Divergent is how effectively we can integrate and make those DAPS vs traditional decisions in a fully data-driven and digitally connected way, leveraging Divergent's developed software tools and GA-ASI system-level design approach and knowledge. DAPS also links, and leverages, all of the digital design and manufacturing data throughout the process. Every single component that is manufactured is scanned to optimise assembly and enable automated inspection. This critical data is then also used for redesigns or extrapolation of where opportunities are and how to make improvements to overall system performance."

"We are focusing on 'blank canvas' next-generation aircraft designs," stated Fournier, "A key aspect of the working relationship between the GA-ASI and Divergent is how effectively we can integrate and make those DAPS vs traditional decisions in a fully data-driven and digitally connected way."

Michael Kenworthy, CTO of Additive Manufacturing at Divergent Technologies, explained, "Fixed process and point qualification (e.g. tying production to a specific machine serial number) doesn't scale, but the type of massive data sets required to shift to a qualified process stance (600+ tensile and fatigue witness specimens as part of routine series production weekly) simply hasn't existed until now – we are focused on building out these key understandings and sharing what we have learned with our 1 of 1 DAPS solution to support our partners like GA-ASI. In the end, this will greatly accelerate AM adoption as we won't continue to waste massive resources on a global scale addressing the same concerns over and over again for each individual part."

With DAPS, GA-ASI and Divergent are able to bring together a host of advanced technologies with metal Additive Manufacturing at the centre. Knowing that each step, from devel-

Fig. 7 Robotically assembled small UAS using DAPS technology, without use of custom tooling (Courtesy Divergent)

"...there are clear synergies between DAPS and the Modular Open Systems Approach (MOSA), used in the field of defence and aerospace in particular, to design and develop complex systems based on the principle of modularity."

opment to assembly, is automated within one system provides a number of benefits that would otherwise be unachievable. "Divergent has created a system with the ability to avoid tolerance stack-ups regardless of the number of parts and design solutions to support automated assembly. Without fixtures or tooling, we can move rapidly between UAS mission variants. Additionally, advanced joining techniques enable complete galvanic isolation between nodes so it is easier to design with multi-material structures in mind," stated Fournier.

Divergent's joint architecture also ensures a high level of predictability. Structural designs and analysis models ensure failure modes are well-controlled and occur reliably and predictably within the parent substrate as opposed to the joint.

A modular future

The DAPS solution avoids the need to amass tooling and fixtures for production, both of which limit a company's ability to adapt quickly to design changes, new applications and production variations. However, the use of modular nodes by DAPS, driven in part by the need to produce them within the current size restraints of existing large format Laser Beam Powder Bed Fusion (PBF-LB) machines, is also a factor behind the system's flexibility.

Fortuitously, there are clear synergies between DAPS and the Modular Open Systems Approach (MOSA), used in the field of defence and aerospace in particular, to design and develop complex systems based on the principle of modularity. As with Divergent's nodes, modular components are designed with well-defined interfaces to integrate easily into designs that can be developed, tested, and deployed independently. This design and manufacturing architecture offers the potential for distributed manufacturing and assembly near-theatre.

Modular open systems balance customisable platforms with specific parameters and interfaces for standardised production. As technologies

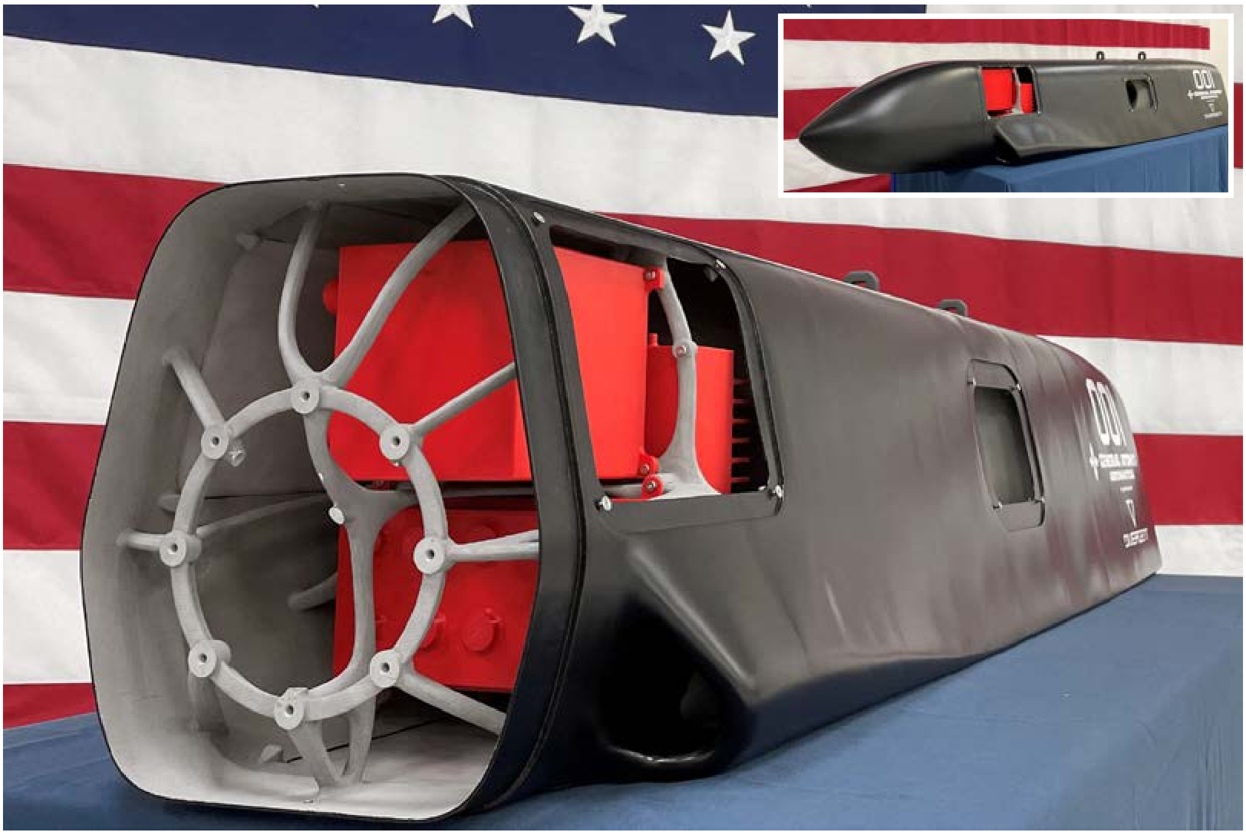

Fig. 8 Unitised small UAS airframe structure designed, additively manufactured and assembled using DAPS (Courtesy GA-ASI)

become seamless and open, the MOSA also makes it easier for others to enter the field. Increasing competition pushes companies that rely on old relationships and strategies, such as vendor lock-in, to think more dynamically and compete in an open systems environment.

Strategic implications for defence manufacturing

With the coming together of two advanced lines of innovation that appear to support and propel one another, the convergence of digital manufacturing and metal AM is seen as transformative for national defence supply chains. GA-ASI's contracts with the US Department of Defense (DoD) target improved speed and agility for defence supply chains.

GA-ASI aims to increase the proportion of additively manufactured parts on the Bill of Materials (BOM) of small UAS platforms to up to 90%. Additionally, it plans to increase the number of AM parts used on larger UAS platforms. DAPS is already AS9100 certified and uses advanced custom aluminium alloys that are ideally suited to advanced aerospace solutions.

> *"...governments and defence departments are not just interested in reducing part counts or developing advanced solutions to streamline supply chains, but in developing flexible and adaptable manufacturing systems, and there is no doubt that metal Additive Manufacturing is at the forefront of activities."*

Worldwide, governments and defence departments are not just interested in reducing part counts or developing advanced solutions to streamline supply chains, but in developing flexible and adaptable manufacturing systems, and there is no doubt that metal Additive Manufacturing is at the forefront of activities. GA-ASI is leading with the belief that if there is a better way to do something, and provide a strategic advantage to its customers, they should do it that way after proper engineering qualification. It is an approach to systems integration that fully leverages its capabilities as a 'technology scout' for the most appropriate advanced manufacturing solutions for the right DoD platform's risk posture.

Outlook

Partnerships such as that between GA-ASI and Divergent are creating manufacturing solutions that will inevitably become standard manufacturing practice. Of course, no single capability, technology, or process will shape the unmanned aerial vehicle industry or manufacturing more broadly.

When announcing its upcoming modular Gambit aircraft series, GA-ASI used this compelling metaphor that offered a glimpse towards the future of metal AM enabled digital manufacturing when it stated, "Imagine watching a wheelset, chassis, and powertrain produced on an automotive assembly line. One kit might turn left in the factory and become a luxury sedan. The next might turn right and become the family economy model. The common platform saves cost and complexity for the manufacturer. The different trim and other options offer choice and value to the buyer. Not only can this approach address wide market segments of customer needs, but it also provides affordability. High-rate manufacturing of the core system enables extreme cost savings to all the variants that come from the common platform," explained Fournier.

With fierce competition in manufacturing technology, companies that thrive may not be the strongest or the smartest, but the ones that adapt the fastest. GA-ASI is investing in metal AM technologies and associated partnerships for faster iterations, reduced time to market, simplified supply chains, dynamic mass production, and the ability to place production cells close to where they are strategically required.

The key to this is finding partners that excel in their niche and bringing them together in dynamic, flexible ways. The partnership between GA-ASI and Divergent may well be setting the foundations for new systems, standards, and practices as metal AM matures.

Divergent Adaptive Production System (DAPS) overview

The DAPS solution is an end-to-end digital thread which replaces traditional manufacturing with a completely modular digital factory, complete with generative AI, Additive Manufacturing, and robotic assembly. It begins with entering parameters into a generative AI CAD program, where the software creates parts or structural sections called nodes. Each node is designed with compatible interfacing in mind, creating the potential for modular variations, as well as the start of the digital thread that will evolve into a functional digital twin.

When the node design is complete, it is sent to a Laser Beam Powder Bed Fusion (PBF-LB) machine for production before going through automated post-processing to remove powder and supports. Each step is documented, and has inline management and inspection to ensure that the digital and real parts are similar. Finally, a team of robotic arms assembles each node into a finished assembly.

The technology allows for full scalability with the simple addition of more units. Furthermore, the information gathered from the digital thread of the product's lifecycle creates a digital twin, allowing real-world, physical data to enter the AI and be integrated into further iterations.

www.divergent3d.com

Further information

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Adrian Keppler on Additive Manufacturing: An insider's assessment from the outside

Dr Adrian Keppler has been an active participant in the AM industry for close on fifteen years. Based on his past experience as the Managing Director, and later CEO, of EOS GmbH, and his current role on the advisory boards of numerous AM startups, Keppler believes that more can, and should, be done to advance industrial applications of AM. Are the industry's efforts to develop new technologies without perfecting and industrialising existing technologies holding it back? Should the less exciting work of industrialisation be prioritised over the next shiny technology release? Joseph Kowen interviews Keppler for *Metal AM* magazine.

The *Wohlers Report*, an annual review of the state of the AM industry that publishes industry growth estimates for 1988 to 2022, suggests that the industry has grown about 20% per year on average during that time period. In many industries, such a healthy growth rate would be an admirable achievement. Newcomers to the AM market are often surprised to learn that the industry is over thirty years old. The overall perception is that AM is a young and dynamic segment, and while the latter is certainly true, the former is not completely accurate.

The report estimates that the total size of the AM industry reached $18 billion by the end of 2022. While that may be a worthy figure in and of itself, it is only 10% of the size of the machine tool market, and a small fraction of the global manufacturing market. Given the relatively small footprint of the industry despite having been around for so long, it is reasonable to question how the industry is really doing. A healthy and honest review of the state of the industry might lead segment players to put its finger on weaknesses that may be holding back growth, and what might be done to mitigate or eliminate them.

Adrian Keppler has had a front row seat in the Additive Manufacturing business for more than a decade, enabling him to observe at close range the development of the industry. Beyond just being an outside observer, he was also an active participant. From 2010 to 2021, he served as Managing Director, and later CEO, of EOS GmbH. As an industry pioneer for both polymer and metal AM, which began its journey in 1989, there are

Fig. 1 From 2010 to 2021, Adrian Keppler served as Managing Director, and later CEO, of EOS GmbH. He is the founder & CEO of the consultancy firm AM Scalation, and is on the advisory boards of a number of AM businesses

"It would be inaccurate to see Keppler's sentiment as a pessimistic outlook for the industry, but it does reflect a level of expectation, shared by many, that was not met in full by progress. There is nothing like a little disappointment to trigger some introspection and analysis into why the promise did not match the performance."

few better examples than EOS of companies whose history reflect the sweep of the industry's growth in general. Today, EOS remains a leading supplier of Laser Beam Powder Bed Fusion (PBF-LB) technology for both polymers and metals.

Keppler's tenure at EOS enabled him to witness firsthand the impressive progress of the industry, commercially and technologically. Since leaving EOS, Keppler has continued to advise companies in the AM segment as well as being involved in investments into the space, giving him a good vantage point not only on what has happened in the industry until now, but also on where new entrants are bringing innovative ideas to AM.

Keppler recounts his perceptions of the AM industry when he first entered it. "When I joined EOS, for me it was clear the technology could offer huge value for the end customer. At that time, I believed that the OEMs would understand the potential and would immediately jump into the technology and adopt this new way of manufacturing. Fifteen years later, I have to say I'm a little bit disappointed. The adoption rate has been much slower than expected."

It would be inaccurate to see Keppler's sentiment as a pessimistic outlook for the industry, but it does reflect a level of expectation, shared by many, that was not fully met by progress. There is nothing like a little disappointment to trigger some introspection and analysis into why the promise did not match the performance.

Post-COVID, Keppler says, many in the industry thought that the unique circumstances brought about by the pandemic would be a breakthrough event for on-demand manufacturing in an age of disrupted supply chains. Additive Manufacturing proved to be good at supplying specific needs, such as facemasks, nasal swabs, urgent medical device components and spare parts. The case of being able to produce things urgently, and locally, in times of crisis was well proven. When the pandemic was over, however, manufacturers went back to the 'old' ways of doing things, relying on conventional manufacturing processes.

AM has scored successes in specific industries such as medical and aerospace, mainly because they are high value, low-volume applications. AM has not managed to penetrate significantly into medium value/higher volume applications such as those in the automotive industry and consumer applications. The advantages of AM are obvious, says Keppler, listing such factors as freedom of design, functional integration combining several components into one, supply chain digitisation, manufacturing flexibility as well as sustainability. Given these convincing arguments for AM, what then are the factors holding the industry back?

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AM's maturity and scaling the supply chain

Keppler summarises a number of factors that need to be addressed by both users and suppliers. First is a greater maturity of AM technology. Compared to milling, turning, grinding, injection moulding and casting, AM is still at a relatively early stage of technical maturity. Machine reliability and uptime needs to improve, as well as machine consistency and repeatability, in order to ensure the same part quality regardless of the machine on which they were manufactured. In short, in order to increase the number of instances in which the use of AM makes sense, systems must offer greater quality and productivity.

Maturity of the technology plays directly into costs. Reduced uptime, and an increase in scrapped parts that don't meet quality standards, lead to higher costs. "Part costs are too high," says Keppler, "and this is hindering a movement to higher volume applications."

"Many AM machine manufacturers concentrate on the 'supply' side, trying to push as many machines into the market as they can," says Keppler. "These companies should emphasise the 'demand' side for AM parts – creating a 'pull' from the customer side."

That means assisting users in identifying the right applications with compelling use cases. The emphasis should be on the business case, not just making 'cool' parts. Sometimes 'boring' parts make sense for AM too. There are companies in the market that are already helping customers identify AM business cases. Not all companies have this capability inhouse, and until they acquire the know-how they can learn from the experience of others.

"There are only a few companies out there who offer end-to-end services from designing or redesigning the part, support in qualification, validation, part build, post-processing, surface treatment, quality assurance, final assembly," he

"Machine reliability and uptime needs to improve, as well as machine consistency and repeatability, in order to ensure the same part quality regardless of the machine on which they were manufactured."

Fig. 2 The automation of the depowdering process is one step towards the complete automation of metal Additive Manufacturing (Courtesy Solukon)

observes. "Offering integrated end-to-end solutions is, from my point of view, what is missing."

"It's not about just selling the part, it's about education, enabling licensing models, managed services, build-operate-transfer models. This will help lowering the entry barrier for end customers," he emphasises. "I strongly believed that if customers are successful, meaning they are earning money using my technology, then they will continue to invest. They will continue to buy material from me, machines from me, services from me."

If this is the case, then why are system manufacturers not doing more to encourage the development of business cases for more AM parts? "You have to invest – in application engineers and consultants supporting customers and translating their know-how into methodology and training curriculum. It takes time and it costs money. Most of the AM machine OEMs don't have time because they have to focus on generating revenue, achieving their targets, to fulfil the expectations of their investors quarter by quarter," Keppler concludes. "These companies focus on their own success. They do not focus on the success of their customers. For me this became obvious over the past year as the industry rebounded from the pandemic, everybody wants to sell and hardly anybody is willing to invest time and effort and money to support end users in speeding up their validation and qualification process for serial parts. But this is a prerequisite to scale the business – for both end user as well as the AM machine OEM."

The AM supply chain needs to be readied for scale, adds Keppler. It is dominated by smaller sized AM service providers who are – in most cases – ill equipped to scale their AM production. Only a few companies can offer end-to-end solutions, including upstream services like design and qualification support as well as downstream services like post-processing and quality assurance for AM parts.

Compounding the problem, service providers sometimes keep their manufacturing knowledge close to their organisations. Once service providers offer a full range of AM and post-processing-related manufacturing services that will ensure a supply of ready-to-use end parts, more applications will follow. In addition, this will enable them to address the issue of part cost, one of the most significant hurdles impeding a broader adoption of AM applications. Since a large part of the cost of AM parts is not related to the AM build process, an end-to-end optimisation of the entire manufacturing process is required to increase efficiency, reduce manual interaction and with this significantly reduce cost-per-part.

Designing for AM and beyond

It is commonly accepted that taking a part that was designed for, say, Metal Injection Moulding or casting, does not necessarily make the part optimal for AM. One has to add value if one is moving to a new technology. It is critical to understand the value drivers for the application. Designing just for AM is not enough, it must be designed for end-to-end manufacturing. "How do I optimise this design in a way that I can produce this part in an efficient way? Keep in mind, it will be a combination of AM and conventional technology. Especially with metal AM, 90% of the parts have to be post-processed, whether it's milling, grinding, or coating. So, we have to have somebody who is overlooking the entire design manufacturing process and finding the optimum design."

Committing to automation and standardisation

So how will the supply chain be scaled and part costs reduced? Improving automation is a key area that will require attention and investment. Many post-processes such as support removal are archaic by modern industry standards. Post-processing systems will have to be industry 4.0 ready. Automation will reduce costs by making processes more efficient, including the reduction of manual labour. In many cases there will be a shortage of skilled manual labour.

Automation might not just be the cheapest solution – it might, in some cases, be the only solution, explains Keppler. "Some companies are too narrow minded. They focus on their AM process and not on the entire process. So, stepping into the shoes of their customer is, from my point of view, important. Customers need a final part, which requires building and post-processing." Automation is an essential way to ease the interfaces between the various parts of the manufacturing chain.

Keppler states, "It's about interfaces. What you want to achieve is an end-to-end part flow and data flow from design to final product. The more interfaces and interruptions you have, the higher the cost of the part will be." He gives an example: If one has to cut the parts from your plate before you can do CNC milling, it is a manual interaction. This will incur additional cost and it's a source for additional quality issues. A standard interface defined between the AM machine and the CNC companies, in this example, would help. There are some first initiatives working on the standardisation of interfaces. Today, this flow is fragmented. Industry leaders must step up and say what needs to be done to lower part costs.

Can government or non-governmental bodies play a role? "I'm not a big fan of government projects because normally it requires a lot of documentation. A significant portion of resources are dedicated to documentation and not to working on the solution. I believe it must be for partnerships of companies who are willing to advance this, and who believe in the value of working together to find a solution."

The need for organisational commitment

Many companies are still probing the advantages of AM. "It is not just a question of buying a new manufacturing tool – it is about transforming companies into a more flexible, customer oriented, digital enabled organisation," emphasises Keppler. AM efforts in organisations often occur without top management's active involvement, from the bottom up. Additive Manufacturing can be transformational for companies and will require a different way of thinking throughout the organisation, including through facilitation from the top.

"You have to drive these topics top down and not bottom up. Moving from a technical view to a strategic view is mission critical if you want to see a broader adoption in these companies. It will need an openness and strong management support to evaluate shifting from analogue to digital manufacturing, from centralised to decentralised production, from mass products to more customised products, from physical to digital spare parts." If AM is adopted as part of a strategic plan, industry will see strong growth in applications, a significant uptake in AM service busi-

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ness, as well as demand for systems and materials.

Even if senior management is involved, at the end of the day decisions will be driven by business impact. Profits are in many cases calculated on a short-term basis. The challenge is for management to see the broader strategic question.

Future growth

Where does Keppler see the metal AM market headed? "I definitely see that we will have a much wider range of metal processing technologies in the future. Today, 80 or 90% is laser-based. This is where it all started. It's obvious that many companies follow this path and try to increase productivity by adding more and more lasers, which I believe is not the right way going forward. That said, PBF-LB is the perfect fit with this high value, low volume application we are targeting today."

"The output required for today's applications are high-quality components, high density and good mechanical properties. But the growth will not come from aero engines or industrial gas turbines. It may come from automotive, or maybe general industrial applications such as heat management equipment or tooling. For many of these applications, 95% or higher density is good enough. And this is definitely something which metal Binder Jetting [BJT] or other sinter-based metal AM technologies such as Vat Photopolymerisation [VPP] can achieve. We will also see stronger uptake for larger spare parts made by Directed Energy Deposition [DED], repairs, and so on," says Keppler. But these processes should be ready for automation, he adds.

Will newer processes address the part cost issue? The promise of these technologies is supposed to be lower part costs. "I visited a MIM company that is using Binder Jetting and VPP. It's unbelievable what they are doing – what parts they can produce. Very small, high detail resolution, perfect surfaces. But their expertise is in the sintering process, which is the most critical step in sinter-based Additive Manufacturing. It is always a mistake that we focus on one part of the process and forget about the rest."

And what is the direction of PBF-LB? "Everybody wants to go bigger and faster. Some new companies are trying to move from point and line exposure to more of an area exposure, which allows them to be significantly faster. And this makes sense because I don't believe that adding additional lasers, going from four to eight to sixteen and more, will be the answer." Paradoxically, the rush to add more lasers might be having a negative effect on the industrialisation of existing systems. New system development means less attention to perfecting and fine tuning existing platforms to bring them to a required level of maturity. New, more complicated products will have their own teething problems. In addition, new platforms mean revalidation and requalification, which is a time consuming and cost intensive process.

Keppler also urges people not to underestimate the critical role of materials in AM processes. "Material is important. Many years ago, everybody told me that materials are a commodity. No, materials are not just a commodity. If you have the right material with the right properties, you can increase the speed of your builds significantly. In addition, you can minimise the scrap rate of waste material."

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Investments cool

Keppler is realistic about the current level of investment into AM. "The willingness to invest into AM has cooled down significantly. This partly has to do with AM itself because we have seen some less successful ventures enter the market. A lot of companies are burning a lot of money and they have significantly overpromised and underdelivered. The industry is ready for strong consolidation."

In conclusion

Adrian Keppler's journey through the industrial end of AM makes his observations especially worthy of consideration. Sitting on the outside offering criticism to those on the inside is a relatively easy proposition, and so hearing the opinions of someone who has spent considerable time on the inside of one of the industry's most significant players has added weight. In some ways, questioning by an industry insider of the segment's performance entails a degree of self-reflection on decisions made and opportunities not taken.

Through Keppler's eyes AM is a work in progress, despite great strides taken and successes achieved. The collection of processes and technologies known as AM have demonstrated notable promise that is waiting to be realised. With some exceptions, applications of AM lack the maturity to fulfil the promise. Like a good wine, maturity cannot be achieved overnight, but there are things that can be done to speed up the maturation process. Some of those things are technical, such as improvements in machine reliability. Others are decisions and resource allocations within our control.

A holistic view of AM as a group of manufacturing methods complementary to, and on par in importance with, other conventional manufacturing technologies, must be backed up by efforts to ensure that getting to a final part using AM covers more than the AM process alone. Until parts are designed to exploit the potential of AM, and optimised for post-processing, and until the transitions between steps in the process chain are connected through efficient automation, AM will be hobbled by slower growth and fewer business cases that make sense.

Success breeds success, and industrialisation of AM will occur if there are enough successes to justify investments in the hardware, software and materials needed to get there. While technological progress will not stop, and new technologies will continue to be developed, perfecting AM processes will require more effort. The sooner we adopt an industrial end-to-end view of Additive Manufacturing, the sooner the industry will see a diversification of uses for AM, leading to the growth that the industry desires and the success its inventors deserve.

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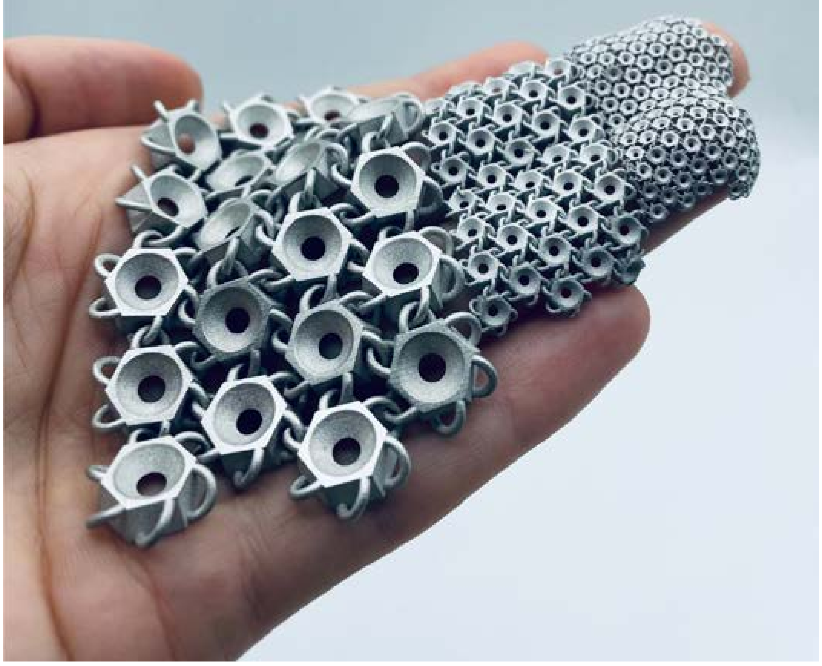

Fig. 3 Additively manufactured steel chain in three sizes, produced by the Vat Photopolymerisation (VPP) process (Courtesy Incus GmbH)

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Metal AM's journey to industrialisation: Are we there yet? And what does the destination even look like?

Metal Additive Manufacturing is on a long journey, from the early technology concepts of several decades ago to its current usage in a relatively small number of markets with specific, highly-specialised application requirements. If the journey leads to the widespread adoption of metal AM technology by industry, can we ask, 'Are we there yet?' Dr Maximilian Munsch, Dr Eric Wycisk, and Matthias Schmidt-Lehr, from strategy consultancy and AM market analysis specialist AMPOWER, delve into the evolution, current status, and future prospects for the industry, seeking to uncover the true extent of its potential.

In recent years, many in the metal Additive Manufacturing industry have promised us a world where complex parts can be effortlessly created with just a few clicks. A world where the boundaries of traditional manufacturing technologies are shattered, making way for unprecedented possibilities in both design and production. Metal Additive Manufacturing promised a technological paradigm shift, transforming industries and redefining the way we think about manufacturing. But the burning question is: are we there yet? Has metal Additive Manufacturing delivered on this bold ambition, or is the technology only just starting to reveal its full potential? Have we merely scratched the surface? In this article, we delve into metal AM's journey, its current status, and future prospects, seeking to uncover the true extent of its capabilities.

The history of Additive Manufacturing with metal dates back many decades, but it wasn't until the availability of energy sources capable of melting technical alloys, combined with the advancement of digitisation,

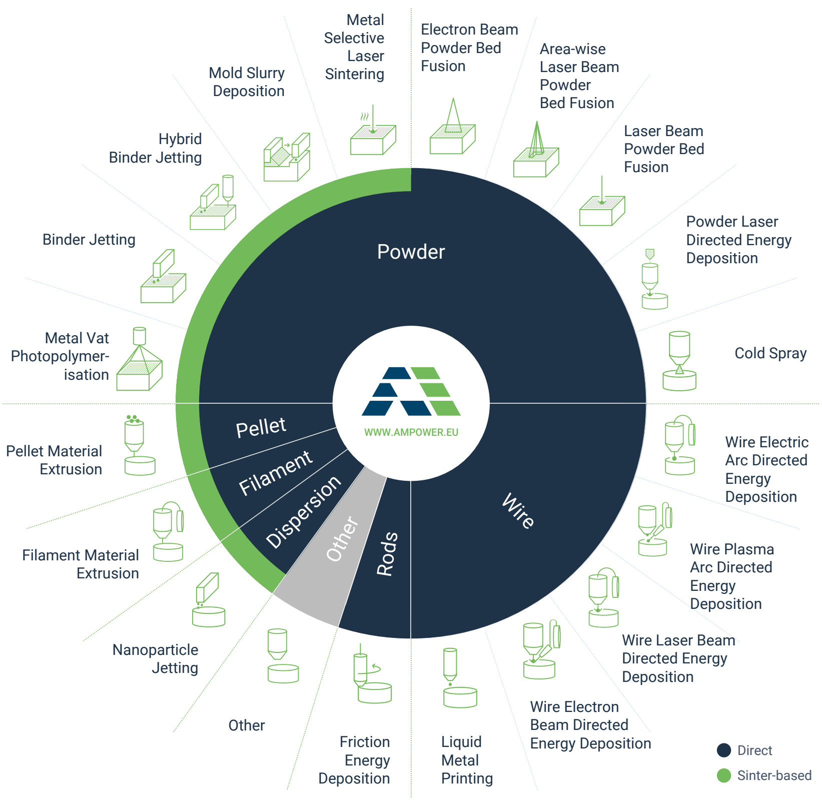

Fig. 1 The metal Additive Manufacturing technology landscape (Courtesy AMPOWER)

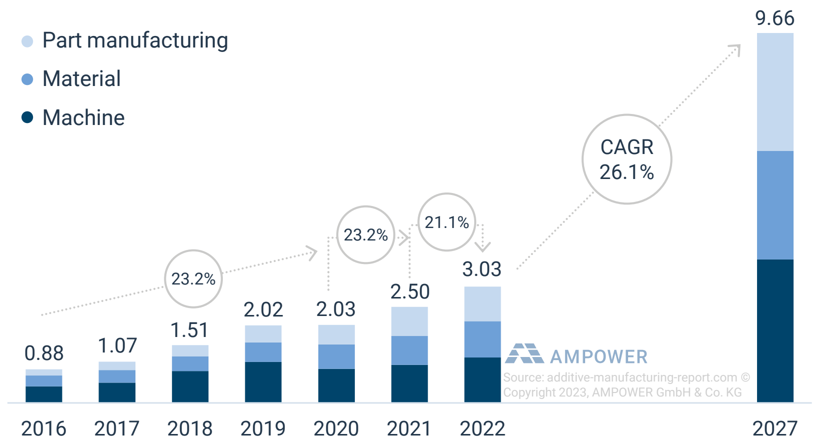

Fig. 2 The metal Additive Manufacturing market 2016 to 2022 and supplier forecast 2027 (€ billion) (Courtesy AMPOWER)

that the technology experienced significant progress. The promise of economically manufacturing highly complex components with minimal material usage led to the development of a multitude of metal AM processes. Today, there are essentially twenty different metal AM processes (Fig. 1), distinguished by raw material (powder, wire, etc.), binding mechanism (melting, sintering, etc.), and energy source (laser, electron beam, arc, etc.).

The dominant technology, Powder Bed Fusion (PBF), has been in use for nearly thirty years and has now been adopted by a select few industries as production technology. Several European companies played a crucial role in its development, placing the first research and production machines in industry and universities in the early 2000s. Today, there are over eighty suppliers of PBF equipment worldwide, accounting for more than 80% of globally installed metal AM machines.

During the 2010s, the metal AM market experienced rapid growth due in part to technological advancements, the intense qualification work of the early adopters, and significant media attention. Many machine suppliers saw annual revenue growth rates of 50% or more, and the market capitalisation of companies reached its peak between 2012 and 2015, a level that many have not surpassed since. After this hype period, market growth slowed to around 20% annually. While the market was initially driven by the growth of machine manufacturers, today metal powder suppliers and AM component producers contribute a significant portion.

From a user perspective, the motivations behind the purchase of metal AM machines have significantly shifted from back then versus now. In the 2000s and early 2010s, some invested in AM capacity out of fear that this technology would replace established processes like machining. Companies didn't want to miss out on the predicted manufacturing revolution. However, an understanding of where real value could be achieved through AM was often lacking, resulting in inefficient or underutilised technology. Even today, many metal AM machines installed at companies see very low utilisation.

The unfulfilled hype surrounding metal AM in the 2010s can be attributed to underestimating the implementation effort required, among other things. Users were promised a machine with a digital process chain that would enable easy, seamless, and waste-free manufacturing. It was claimed or assumed that 'everything' and 'all geometries' could be produced. However, users soon realised that there were significant learning curves to overcome during implementation and that AM is not economically viable in all application fields.

Further obstacles arose when AM technology attempted to transition from R&D to production. The reliability of machines often posed challenges and led to disappointment. Additionally, regulatory hurdles emerged in industries like aerospace and healthcare, where equipment qualification and process validation are necessary. In these high-value sectors, product failure has severe consequences, requiring extensive testing and safeguards beforehand. Due to limited experience with the technology and industry immaturity, in terms of procedures and standards, companies attempted to apply guidelines or standards that were only partially applicable. Furthermore, unexpected internal resistance from stakeholders surfaced as they were hesitant to take on the risks associated with the adoption of a new technology, preferring to stick with what had been proven to work.

However, the primary reason for the delayed implementation was a lack of widespread knowledge about the capabilities and limitations of AM technologies. Only when AM is applied in the right areas can it generate value that leads to acceptance and lasting establishment. The initial phases in many companies were often challenging and required time in order to demonstrate the advantages that AM has to offer.

Where is metal AM now?

The phase of rapid expansion has cooled down, but we continue to see strong growth in the industry. Based on our *AMPOWER Report* data, the revenue generated by metal AM machines, feedstock, and part

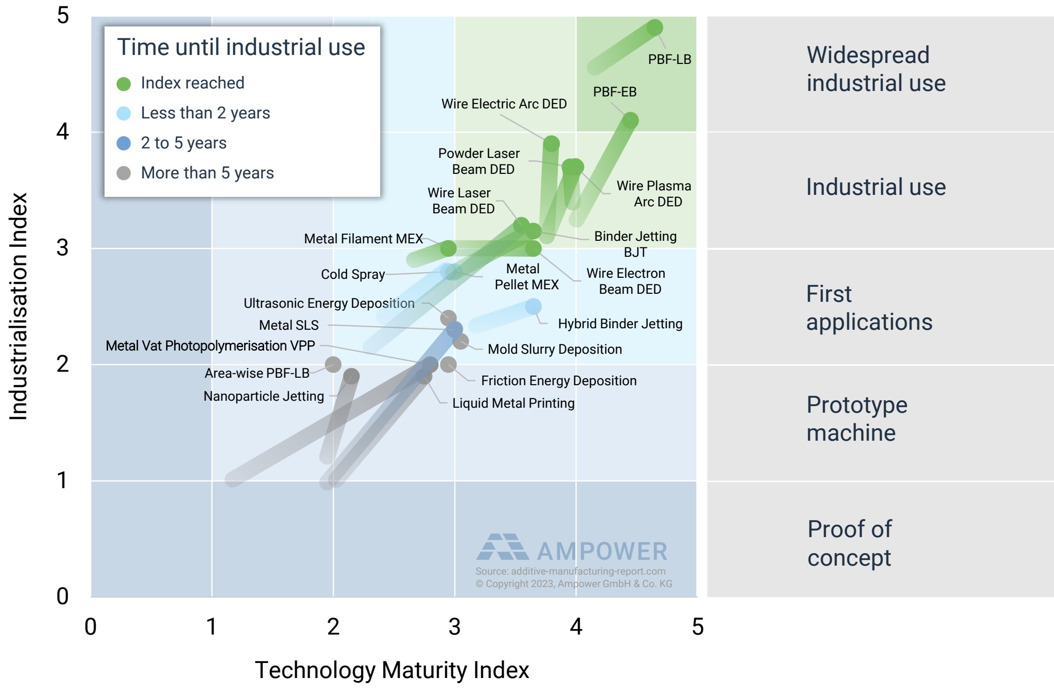

Fig. 3 AMPOWER Maturity Index: metal AM 2023 and development since 2019 (Courtesy AMPOWER)

manufacturing services currently stands at around €3 billion, with a projected steady growth of approximately 26% over the next five years (Fig. 2). While the overall market for metal Additive Manufacturing is still considered niche compared to other production tools, it is a niche that is experiencing strong expansion, with growth rates up to ten times higher than conventional metal manufacturing processes.

To assess where we are with Additive Manufacturing, we like to consider two indicators: the maturity of AM technologies and their adoption rate within the industry. These indicators vary significantly among different metal AM technologies. Some technologies have become essential in certain production chains, while others are still in their early stages, offering tremendous potential for cost-effective production in the future. There are also technologies that occupy a niche position today and are likely to continue doing so in the future.

AMPOWER has developed a model to characterise the maturity level of Additive Manufacturing technology based on two indices: the Industrialisation Maturity Index and the Technology Maturity Index. These indices describe and compare the capabilities and adoption rates of various AM technologies in an industrial environment (Fig. 3).

The Technology Maturity Index evaluates process capability, machine reliability and availability, and implemented quality control measures. The Industrialisation Index assesses the installed base of machines, supply chain, material availability, available public knowledge and research, and the standardisation of each individual technology. Each category is weighted according to its specific importance. Typically, technological maturity increases first, followed by industrialisation.

In recent years, many metal AM technologies have made significant transitions from research to initial industrial applications. However, only the PBF technologies with laser (PBF-LB) and electron beam (PBF-EB) are widely used in industrial settings. We estimate that, currently, there is an installed base of around 14,000 machines, with over 1,500 additional PBF machines added each year. With increasing industrial requirements, the machines are becoming more diverse. Machine size has significantly evolved to allow the building of parts up to 1.5 m in length, with the ability to utilise multiple lasers.

Many industries have now recognised the value of metal Additive Manufacturing. By leveraging manufacturing technology, product geometry, and materials, these industries have created unique components that can lead to performance improvements and cost savings in production or over the lifetime of a component's use. As a result, some industries have developed products specifically for Additive Manufacturing and have seamlessly integrated the technology into their production processes.

A good indicator of the success of AM technology in a particular area

"Still today, numerous companies in the AM industry, both young and established, rely on investments to finance their operations due to a lack of profitability. Hence, we anticipate increased market consolidation among participants in the metal AM industry to achieve the necessary scale."

is whether the build process itself is used in the marketing. In industries where an AM process has a viable business case and is generating profits, the marketing message is primarily focused on the improved properties, performance or functionality of the components produced, rather than on the intricacies of the build process; the technical details behind a process move to the background.

Where is metal AM headed?

Many discussions surrounding AM focus on sustainability through resource efficiency and optimised component design. The emphasis on functionality, weight savings, and feedstock recycling holds potential for saving valuable resources across various industries in the future. Additionally, the development of new materials specifically designed for AM will enable innovations such as mechanical stability at high temperatures, performance of electrical components, or higher efficiencies in heat exchangers. However, despite these noble goals of achieving a more sustainable future, the ultimate objective for suppliers and users of metal AM technology remains simple: to generate profit.

For many suppliers, growth has been the primary goal to achieve critical mass and enable profitable operations. Still today, numerous companies in the AM industry, both young and established, rely on investments to finance their operations due to a lack of profitability. Hence, we anticipate increased market consolidation among participants in the metal AM industry to achieve the necessary scale. Moreover, there is a growing risk of displacement in the largest segment of metal AM technology, specifically the PBF-LB sector. Currently, there are over seventy technology providers whose machines share similar characteristics and often do not offer clear differentiation from a customer's perspective. Additionally, advancements in larger format 'area-wise' Powder Bed Fusion technologies are being closely observed as they have the potential to render today's PBF technology outdated.

For users, the goal of the journey remains the same: to create value with AM technology that ultimately leads to lower manufacturing costs or higher profit margins. However, the distance to reach this goal varies significantly from industry to industry. The healthcare sector is at the forefront, integrating metal AM as an established alternative for production and successfully bringing products like bone replacement implants and dental restorations to market for over a decade.

Other industries, such as aerospace, defence, and energy, are currently experiencing enthusiasm about the possibilities arising from increasingly larger machines, new materials, and maturing software tools. These industries are progressing rapidly, taking leaps in their development cycles. While the civil aviation sector is currently stagnant, partly still due to the impact of the COVID-19 pandemic, it is expected to witness a boost in AM technology adoption when new programmes for the next generation of aircraft are launched. Extensive research and development efforts over the past decade combined with AM training of the engineering staff have laid the foundation for targeted use in redesigning components and functions, followed by production and quality assurance methods.

In the automotive sector, metal AM has been a challenging topic for several years. While considerable success can be noted from motorsport and high-performance cars, large series of low- to mid-end models lack metal AM applications. Some OEMs have even scaled back their efforts. The high expectations placed on sinter-based technology have not yet been confirmed. However, there are also ongoing efforts by OEMs, as well as some tier 1 and tier 2 suppliers, to make metal AM competitive despite immense cost pressures. The aim is to introduce new materials and optimisation strategies fitting the requirements of the automotive industry.

Players in the industrial verticals have significant potential to utilise metal AM for production tools or general engineering components. However, many in this sector are still not fully aware that they are on this journey. For example, adoption in fields such as heavy industries, shipbuilding, and rail is varied, with many only recently starting to explore AM, with one barrier being the large dimensions of the parts required and the high material deposition rates that are necessary.

From an investor's perspective, the sought-after destination is achieving exponential growth at

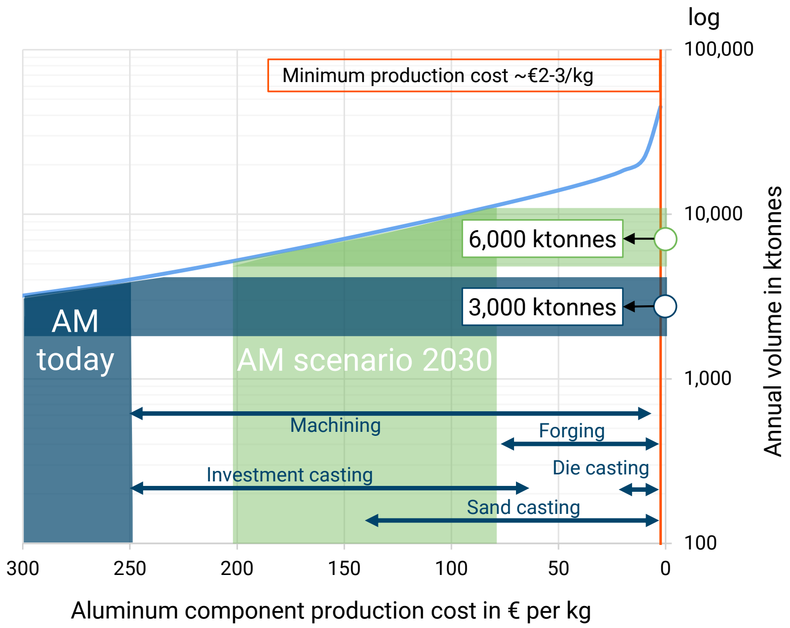

Fig. 4 Assessment of the addressable market for metal AM aluminium: present and future (2030) scenarios (Courtesy AMPOWER)

the right time – the 'hockey stick'. Currently, the metal AM market is considered a niche one, but it is a rapidly growing niche with past annual revenue growth rates of 20% and similar projections for the coming years. Will it take a technological breakthrough such as the area-wise PBF technology to create yet another paradigm shift? Will this lead to such a hockey stick effect for the industry? Current data predicts a continuous growth at considerably high levels in the years to come.

How far can metal AM go?

One important aspect to consider on our journey is the distance we can travel. In the case of the metal Additive Manufacturing market, this can be determined by examining the total addressable market and the potential coverage through AM technology.

Naturally, metal AM competes with other production technologies. The added value it offers, such as functional integration, performance, and the elimination of tools, is ultimately translated into a metric enabling comparison: costs per unit size (e.g. € per kg). This allows for comparisons with other technologies and enables an objective decision to be made with regards to the choice of manufacturing method during the design phase. By plotting the production cost against material consumption, we can estimate an addressable market depending on the cost per unit. Additionally, the adoption rate can be assessed by comparing this estimate with the current feedstock consumption of AM materials.

For instance, in aluminium AM applications, the production cost of components is approximately €250 to €300 per kg. According to data from the *AMPOWER Report*, around 600 tons of feedstock are currently consumed annually in powder, rod, or other forms. This represents an adoption rate of only 0.02% of the addressable market, which currently stands at around 3,000,000 tons.

In the future, technological progress will lead to increased productivity and simultaneous cost reduction. This will expand the potential addressable market. By generating a scenario that accounts for potential AM productivity improvements by the year 2030, we can anticipate a reduction in cost to between €100 and €200 per kg. At this stage, AM will enter broader competition with machining, investment casting, and to some extent, sand casting. Therefore, it is expected that the addressable market for metal AM and aluminium materials will double to 6,000,000 tons by 2030 (Fig. 4).

When comparing the size of the future addressable market with the feedstock consumption predictions from the *AMPOWER Report*, significant growth in the adoption rate for many alloys becomes evident for the 2030 scenario. On one hand, we expect feedstock consumption to increase annually between 20% and 40%, depending on the alloy group. On the other hand, the addressable market doubles due to the aforementioned technological progress. By combining these projections we can predict that between 40% and 60% of the addressable market for

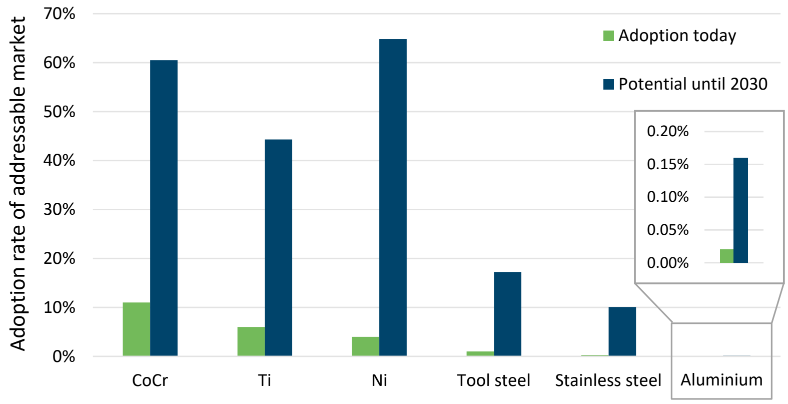

Fig. 5 Metal AM adoption rate of addressable market by alloy group and future potential (Courtesy AMPOWER)

> *"Companies require a certain level of predictability when using AM as a production technology. Once a technology is qualified, it should not become obsolete within a year... identical machines must be available for scaling and replacement, especially when long-term delivery obligations exist for parts like turbine components."*

titanium, nickel, and cobalt-chrome alloys will be produced using AM by 2030, bringing us closer to our journey's destination (Fig. 5).

The substantial growth in the adoption rate for these alloys is not a coincidence. They have already found numerous applications in various industries, and their success will lead to even faster adoption. Industries such as medical, aerospace, and energy have been relying on AM technology for many years, benefitting greatly from the temperature stability, toughness, or biocompatibility provided by these alloys. Other metal alloy groups, however, are projected to have a lower adoption rate by 2030. Steel alloys are expected to reach approximately 10% to 15%, while for aluminium, the relative adoption rate is expected to increase eightfold. Nevertheless, even with this increase, only a fraction of the potential market will be addressed.

When will metal AM finally arrive?

So, when will we reach our destination? Two conditions have to be met to reach a desired state of series production with AM technology.

1. A reliable level of technology maturity

The technology must reach a reliable level of maturity, with incremental leaps of innovations becoming smaller. For PBF-LB machines we are gradually approaching this level of maturity. It can be observed that currently-available PBF-LB machines have minimal differences between them. In the past five years, there have been smaller steps of innovation, such as the transition from two to four (and more) laser beams. However, maintaining this condition is an ongoing challenge. Innovative companies have been expanding their machine portfolios, doubling the build volume and tripling the number of lasers in a short time. Why is this point crucial? Companies require a certain level of predictability when using AM as a production technology. Once a technology is qualified, it should not become obsolete within a year. Furthermore, in the coming years, identical machines must be available for scaling and replacement, especially when long-term delivery obligations exist for parts like turbine components.

2. Sufficient successful applications need to demonstrate AM's success

The first series applications must generate sufficient data and instil confidence among customers as well as generate revenue. Companies like MTU Aero Engines, General Electric, Siemens Energy, LIMA, and Stryker have done pioneering work with their initial serial applications, taking significant risks. It takes several years for these companies and their competitors to fully undergo the technological shift in new programs, leading to real scaling effects. However, in certain industries we now see these risks bearing fruit with more and more applications being shifted to AM production. The dental, medical, aerospace, defence and energy sectors are, especially, utilising AM as the new 'go-to' production technology.

Keeping both the Maturity Index and adoption rate in mind, we believe that PBF technology for high value alloys such as CoCr, Ni and Ti will become 'fully grown' in the next five to seven years. In order to establish itself alongside casting and machining for steel and aluminium alloys, additional innovation leaps will be needed to significantly reduce costs and increase productivity. With ongoing developments, such as area-wise PBF-LB, these leaps can be seen on the horizon, however long-lasting adoption and qualification processes push the final destination further in the future.

The same is true for other metal AM technologies. While some technologies will become obsolete in the near future, or lead a niche existence, other technologies, such as Binder Jetting and Wire Arc DED, will still have to go through the lengthy education, adoption and qualification process that PBF went through in the past fifteen years. The first serial applications are currently hitting the market, yet the final destination is at least another ten years ahead.

In conclusion, while there are still challenges to overcome, the progress made so far and the growing confidence in AM technologies indicate that we are steadily advancing towards our destination. With ongoing advancements, increasing adoption in various industries, and the trust gained through successful applications, we can look forward to a future where AM plays a significant role in manufacturing processes.

So, are we there yet? Not quite, but soon!

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A stronger future, layer by layer: How next-generation software will drive adoption of metal AM

The growth of metal Additive Manufacturing has been held back, believes Oqton's Dr Ben Schrauwen, by a specific set of challenges: repeatability, cost, and the need for a high level of expertise. This article considers how next-generation software solutions that leverage Artificial Intelligence, cloud computing, and hybrid modelling are improving metal AM workflows. By addressing all three challenges, Schrauwen believes that metal AM can achieve faster and deeper adoption, leading to a more efficient and innovative future.

The benefits of Additive Manufacturing are undeniable. The technology creates opportunities for part consolidation and lightweighting, incorporating organic structures that are impossible to reproduce with conventional techniques. It opens the door to advanced customisation and small batch production, even batches of one. It enables rapid prototyping and faster iterations during design. It reduces waste, inventory stock, and energy consumption. It is rapidly maturing, becoming more easily available, and is being adopted for growing range of applications.

So why is AM's growth so slow when it comes to the manufacturing of metal applications? The disparity in market size is very clear. The global metal AM market was valued at $2.5 billion in 2021, while the global plastic AM market was valued at $45.6 billion — nearly twenty times larger than its counterpart [1,2]. Numerous reasons for this disparity come to mind, including perhaps the fact that plastic '3D printing' technology has found a major market in the consumer, hobbyist and SME markets. However, the reasons behind the current state of the metal AM industry aren't that much of a mystery – metals pose a specific set of challenges in AM, three of which come to mind immediately: repeatability, cost, and expertise.

Repeatability

It is important for any manufacturer to be able to reproduce the exact same part on multiple machines, at different locations, and at different times. This requires tight control

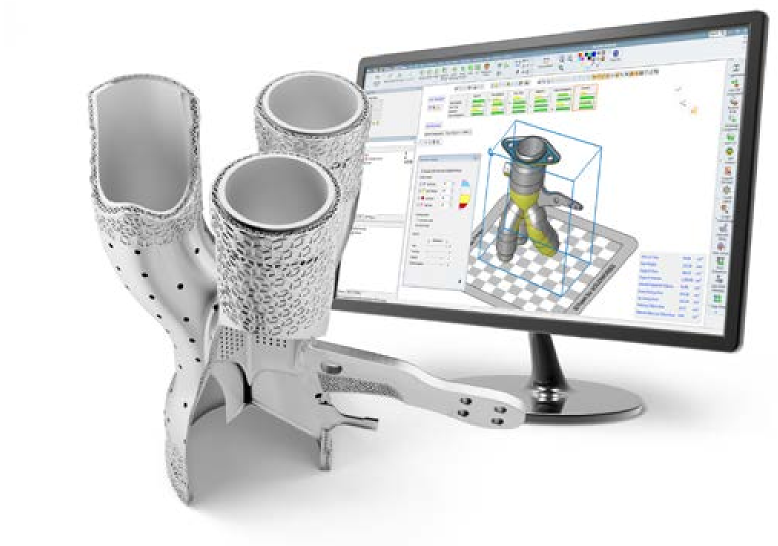

Fig. 1 Software can facilitate leveraging complex geometries that are only possible with Additive Manufacturing (Courtesy Oqton)

Fig. 2 Artificial Intelligence (AI), more specifically machine learning (ML), can dramatically reduce the complexity of the metal AM workflow. When combined in the same software platform, these technologies help pave the way for fast, flexible and (in some cases) entirely autonomous metal AM production (Courtesy Oqton)

of numerous variables. Metal AM systems complicate repeatability because builds can be inconsistent.

Many factors contribute to this inconsistency, starting with machine setup, configuration, stability and even environmental variables across the entire build process. All industrial machine calibration can be tricky and time-consuming, but especially so in metal AM. The genealogy of metal powders may also drive greater variability from one part to the next. All of this means it can be challenging to certify that metal AM parts meet specific characteristics.

Cost

In order to facilitate the adoption of AM for metal parts, we have to find ways to decrease the cost per part. Once this is achieved, more business opportunities for different applications will become valid for AM. Metal parts are expensive for many reasons: starting with the cost of the material; the AM machine itself; the highly skilled staff; resources that are needed for serial production; down to the quality and standard certifications that manufacturers often need to provide.

> *"Manufacturers have had many decades to optimise all of the processes related to conventional metal parts production, and institutional knowledge has been steadily accumulated. Adopting a fundamentally different way of making products necessarily involves a great deal of change..."*

Expertise

Metal AM design, data preparation, build preparation and post-processing have all historically required a relatively high degree of experience and expertise. On the design side, even experts are hesitant about the time and cost associated with part preparation, especially when it comes to the full geometric freedom that allows part consolidation, lightweighting and performance optimisation. As a result, the industry has been dependent on expert users to master the complex Additive Manufacturing process.

Of course, metal AM is relatively new compared to other well-established production technologies. Manufacturers have had many decades to optimise all of the processes related to conventional metal parts production, and institutional knowledge has been steadily accumulated. Adopting a fundamentally different way of making products necessarily involves a great deal of change, and, currently, only a limited number of manufacturers have been willing to take the plunge.

What's missing from the current situation is a way to tackle all three of these challenges at the same time: equipping manufacturers to improve repeatability; increase cost-efficiency; and make metal AM more accessible to a wider range of professionals.

Conventional manufacturing execution systems (MES) hint at the right idea, but they are simply not designed to take advantage of processes that could help improve the quality of metal AM parts, drastically reduce delivery times, and respond to customer requests more efficiently.

Fortunately, a new generation of software has arrived. These new platforms fully leverage the inherent strengths of metal AM, addressing all of the current challenges and pointing the way to a more efficient and innovative future. Let's take a look at the ways in which next-generation software will drive faster and deeper adoption of metal AM.

Fig. 3 Packing as many parts as possible into the metal AM machine helps increase volume and reduce costs. AI can provide optimised 2D and 3D nesting to boost machine output, including interlocking nesting (Courtesy Oqton)

Artificial Intelligence

Artificial Intelligence (AI), more specifically machine learning (ML), can dramatically reduce the complexity of the metal AM workflow and help manufacturers get started more easily. When combined in the same software platform, these technologies help pave the way for fast, flexible and, in some cases, entirely autonomous metal AM production.

AI-empowered software is the key to accelerating metal AM because it can streamline and automate many steps within the process, including those typically handled by MES software in addition to repetitive tasks that are done manually. For example, next-generation software with AI can be used to prepare files for a build automatically instead of relying on manual preparation by operators and technicians. Automated file preparation could have a powerful impact on overall workflow. Steps that can be fully automated today include:

Part identification
After design file upload, software has the capability, if needed, to automatically classify it into a pre-defined category, such as 'dental' or 'fixture'. More granular sub-categories are available, of course. This classification determines a sequence of downstream tasks.

Part segmentation
This refers to AI's ability to identify areas of interest for a given part, such as the teeth in a gear or the location of a target surface or feature. Accurate segmentation helps establish how and where support structures need to be placed, and where labels should automatically be created and positioned.

Part orientation
AI suggests various rotational orientations on the build plate for a part based on similar parts that have been previously built successfully. Orientation can affect build speed, supports, surface finish, and part strength.

Nesting
Packing as many parts as possible into a metal AM machine helps increase production volumes and reduce part costs. AI can provide optimised 2D and 3D nesting to boost machine output, including interlocking nesting (Fig. 3)

With AI and ML working under the hood, next-generation software will empower users of all levels of experience to become more productive. This will help bring down the total cost of metal AM workflows and eventually lead to complete production runs optimised for lights-out performance.

Cloud

Next-generation metal AM software is designed to be more modular and service-based, allowing individual components to scale production up or down to suit the manufacturer's needs. The cloud is critical for this kind of easy scalability.

In fact, the cloud is one of the key technologies of Industry 4.0. It may seem like a simple development, but its impact on manufacturing has been monumental. It ushered in the era of software as a service (SaaS), making it far easier for manufacturers to work on the same files from different sites with only an internet connection and a browser.

This means there is no need to run software on-site, which means you do not have to buy, install, maintain, or upgrade racks of servers, which has an obvious effect of lowering total cost of ownership (TCO). For example, for companies considering metal AM, the cloud means you can be sure that two parts made at two separate sites will be built from the exact same file, in the exact same way, with the same required machine and material configuration, to ensure consistency and repeatability.

Security

The security of information stored in the cloud is a critical concern for manufacturers using SaaS because the models in metal AM workflows represent extremely valuable intellectual property. To move forward with a next-generation software solution, manufacturers need to be confident this data will remain safe, secure, and private. With the right measures in place, the cloud is often the safest option for storing valuable data. Here are some of the reasons why:

Less burden

Manufacturers are not typically data security experts and adding a full-fledged data security management team would be too expensive. Moving data to the cloud offloads security responsibilities to the SaaS provider. These providers do specialise in backing up files for redundancy as well as protecting data from a wide range of threats.

Control

Not that long ago, the more conservative manufacturers were convinced that local networks and local storage were the only way to know exactly who accessed what data at what time. In reality, cloud platforms offer the same control, access and audit capabilities. Today enterprises large and small use these services, safe in the knowledge they have full insight into who uses the data.

Certifications

Certifications prove that the right security measures are in place. The best-known cloud security certifications are SOC 2, which originated in the US, and ISO 27001, which is popular in Europe. SOC 2, considered the 'gold standard,' describes an auditing procedure that ensures service providers manage information securely. Auditors assess the extent to which a SaaS provider ensures security, availability, processing integrity, confidentiality and privacy. Auditors issue a certificate based on their findings.

Encryption

Cloud SaaS providers should encrypt both data in transit (when it moves from a computer to the cloud) and data that is stored. In addition, files should always be encrypted first and stored second, not the other way around.

Hybrid modelling, beyond meshes

Additive Manufacturing creates unprecedented opportunities to design and produce metal parts that push the envelope of innovation, taking advantage of complex lattice structures, triply periodic minimal surfaces (TPMS – a surface that is locally area-minimising when spanning the specific boundaries of shape), infills, weblines, and other organic geometries. These unique structures are what enable designers to create better-performing parts. Designers can pursue lightweighting, part consolidation, topology optimisation, thermal management, and even osseointegration.

So far, the barrier to broader acceptance of complex design techniques has been software. Many solutions can only create a single type of geometric representation, while designing and building

"The barrier to broader acceptance of complex design techniques has been the software. Many solutions can only create a single type of geometric representation, while to design and build high-performing parts engineers can use a combination of geometries."

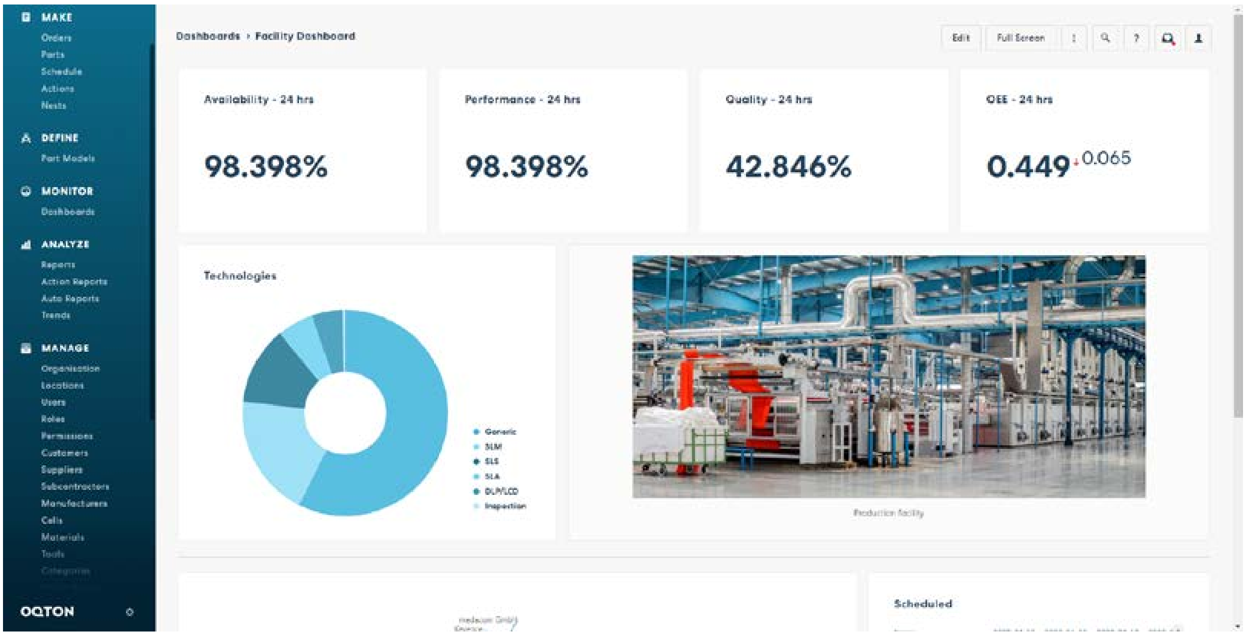

Fig. 4 End-to-end AM solutions with live dashboards give full insight into the process with information about AM machines, post-processing equipment, machine status, schedules and sensor data (Courtesy Oqton)

high-performing parts requires a combination of geometries. As a result, designers and engineers have had to switch between multiple software solutions to manage different types of geometries into a single part.

Next-generation software is circumventing this issue with hybrid modelling, the capability to accommodate all file formats and geometries in a single solution. Hybrid modelling combines various geometric representations so they can be edited and converted into build instructions from their native format. This means manufacturers can use implicit modelling for complex lattices, solid (CAD or BRep) models for a smooth connection with intakes, meshes for custom parts, or voxel grids for limitless geometrical formulations.

Designers create a part using various native geometries and when the design phase is complete, instructions be sent directly to the metal AM machine from the same application with no need to transfer or translate the data.

Repeatability

Repeatability issues are inherent in metal AM due to the number of variables in the process, each of which is a point of vulnerability to creating consistent, high-quality parts on different machines, at different times and in different locations. Next-generation software can help eliminate many of these vulnerabilities by expanding the scope of operational control and unifying the experience.

End-to-end AM solutions provide much greater process transparency, offering automated reports that itemise every step in the metal AM process and help generate insights into improving efficiency and control. Live dashboards allow full transparency into AM machines, post-processing equipment, machine status, schedules, and sensor data, so you can compare productivity between sites or systems to identify trends and analyse root causes of issues. In some cases, you can also leverage data from other enterprise systems, such as ERP, MES, PLM, QMS and CRM for a truly holistic view of operations (Fig. 4).

Most importantly, end-to-end AM platforms will make it possible to fully automate metal AM production, from orders and material management to planning, preparation, and output. As a result, you can expect to execute all process steps more consistently, greatly reduce the risk of human error and ultimately maximise repeatability.

Quality control

Quality control processes are well integrated into existing metal manufacturing workflows. Metal AM, however, requires a slightly different approach as complex parts may need to be CT scanned to measure the internal structure and material characters. This, combined with costly post-processing, means that preventing and detecting errors close to where they happen can bring significant advantages. Next-generation software provides the capabilities necessary to control AM quality without reinventing the wheel.

The ability to monitor all build jobs from one consolidated view is a good example. This feature makes it easy to know the status of all jobs in process, track changes in status, see video feeds of the build platform as jobs progress and keep tabs on live sensor values. All of these machine monitoring capabilities help manufacturers identify potential problems earlier, react quickly and prevent them from happening in the first place.

While this may sound like a conventional MES, these systems are typically configured to execute a single, fixed plan and often struggle to accommodate rescheduling or other real-time process changes. In fact, a MES is often unaware of changes happening on the shop floor because planning, execution and monitoring are isolated and organised in a waterfall. Deviations from the plan are resolved manually, and any attempt to shoehorn the manual changes into the existing workflow creates inefficiencies.

For a truly flexible setup that can accommodate the technologies required for metal AM, manufacturers need a next-generation solution that sources information from various machines and applications in a unified experience that can detect problems and suggest solutions.

During part inspection, for example, additional contextual data could help manufacturers move beyond a basic understanding of how a part is deformed and towards identifying the root cause of deformation as well as how to avoid it within future builds. The quality inspection software should be able to generate reports based on 3D scans of a part flagged for a problem, and the overarching manufacturing software should be able to ingest the production details about the part. With metal AM parts, manufacturers could determine if a deformation is linked to part orientation or build plate position or see if a certain part of the machine is degrading over time and producing the defect.

When combined with end-to-end automation, all of these quality control measures could help manufacturers significantly reduce the risk of failed builds that compromise the budget and schedule.

Orchestration

Next-generation software not only improves transparency and error prevention, but it also enables manufacturers to rapidly develop and deploy efficient workflows with the help of AI.

What this means is that manufacturers do not have to start from scratch when making the decision to implement metal AM. The software provides a template for metal AM production planning that takes into account a wide range of business requirements and technical capabilities. This will help manufacturers get quick wins right out of the gate and then adopt metal AM for a wide range of parts, use cases and applications over time.

AI-powered orchestration can help to reduce material waste by tightly managing how powders are handled, how build parameters are established, and how quality measurements are applied. This can have a significant impact on total spend.

Cost

The previous examples have the potential to systematically reduce the TCO for metal AM, making the entire enterprise more affordable for manufacturers to implement. Consider the cumulative effect of the following cost reduction opportunities:

- AI engines that eliminate the cost of hiring metal AM specialists, empowering more operators to become productive more quickly
- Cloud platforms that remove the need to pay for IT infrastructure capable of handling the intense computations that metal AM involves
- Security measures that virtually eliminate the risk of priceless IP finding its way into the hands of the competition
- End-to-end process controls that make it easier to identify and resolve inconsistencies from machine to machine and site to site
- Quality control tools that improve error detection and the success rate of every build, resulting in less waste and higher output
- Orchestration techniques that help bridge the gap from current to new workflows and reduce material waste

In isolation, each one of these may not tip the scales far enough in favour of metal AM. But the whole point is that next-generation software delivers all of these benefits in a single solution, which can indeed change the ROI equation in metal AM's favour.

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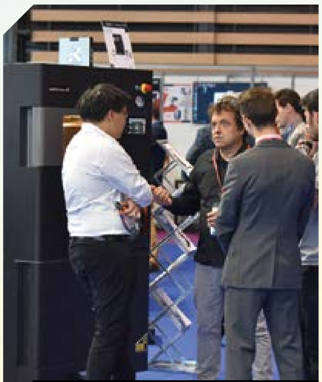

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Volkmann: Making the case for the complete automation of powder handling in AM

Two worlds collide in Additive Manufacturing. Consider that a Laser Beam Powder Bed Fusion (PBF-LB) machine completes its job fully automatically over many hours. Yet, before and after that, a multitude of manual tasks often still need to be completed. Employees may be required to perform these tasks while wearing personal protective equipment (PPE) to protect themselves from metal dust, compounded by the high labour costs that this manual work incurs. Is this the future of cost-efficient, 24/7 production? Christian Mittmann and Manuel Henser, from Volkmann GmbH, believe that the real solution can be found in the complete automation of powder handling.

The first 3D printer was introduced approximately forty years ago. Things have changed beyond recognition since then and the industrial Additive Manufacturing of metal parts has expanded rapidly over the past ten years, resulting in highly innovative application areas. Initially used for small prototypes and limited series, the technology has evolved and the components produced have become larger and more complex. Bigger components require larger AM machines and, correspondingly, larger quantities of powder, particularly if there is not just one machine, but several operating in a group or production cell.

Economical high-volume production by Additive Manufacturing can only be achieved with a high degree of automation. This statement applies to all AM processes and specifically concerns pre- and post-build activities. The goal is to achieve fully automated production in 24-hour operation, 365 days a year, trouble-free and virtually operator-free. Due to the rapidly growing production volumes in the AM industry, these requirements are increasingly coming to the fore. Large quantities of metal powder must be quickly conveyed and prepared between the AM machine, the unpacking station and a powder removal/reprocessing station, a task that can no longer be viably performed manually. Not only is it becoming increasingly difficult to find suitably skilled workers, but the need to reduce labour costs continues to grow. This problem is further exacerbated with the return on investment requirement for the AM machines to operate on a 24/7 basis. The motto is 'Only a printing printer earns money' rings true.

Historically, AM machine manufacturers have concentrated on the build process itself. The automated

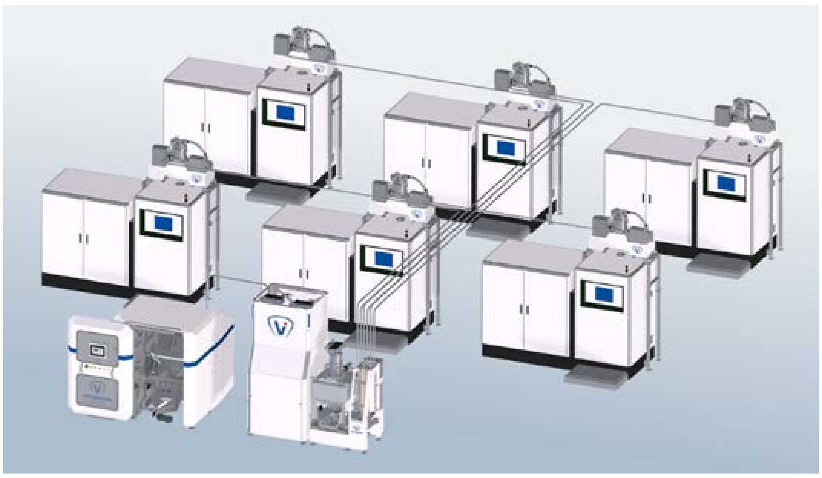

Fig. 1 AM production with automatic unpacking and depowdering, powder preparation and central supply of metal powder to the AM machines (Courtesy Volkmann GmbH)

Fig. 2 Protective equipment during manual depowdering (Courtesy GKN Additive)

handling of the metal powder in the immediate vicinity of the AM machine was too often neglected. Yet the handling of the powder has a considerable influence on powder properties, and thus on the end component. For example, an increased moisture level leads to significantly poorer flow properties, which has a negative impact on the quality of the part produced.

In addition, metal powders can not only be highly explosive – especially as dust – but they are also potentially harmful to health via inhalation. For this reason, occupational health and safety regulations have become increasingly stringent, as has the REACH regulation. All these factors, combined with the ever-increasing scale of powder usage, mean that automated powder handling is essential for efficient and economical Additive Manufacturing, particularly when operating multiple systems. How then is it implemented?

Volkmann GmbH first considered this question when entering the AM market approximately ten years ago. As pioneers in the field of powder conveying, Volkmann had already been able to gather considerable experience in safely transporting powder, expertise which they have successfully transferred to the AM sector. In addition to segregation-free conveying, it was primarily Volkmann's expertise in equipment for potentially explosive atmospheres (ATEX) that resulted in the first contacts in Additive Manufacturing.

From experience gained in the industry, it quickly became clear that conveying or powder transfer alone was not enough. The market increasingly demanded an all-encompassing powder handling process around the AM machine. Additionally, automation, with constant monitoring of the relevant parameters, could ensure significantly increased process reliability with consistent material supply to the AM machine guaranteed.

"...occupational health and safety regulations have become increasingly stringent, as has the REACH regulation. All these factors, combined with the ever-increasing scale of powder usage, mean that automated powder handling is essential for efficient and economical Additive Manufacturing."

Turning old into new – the reprocessing of used metal powder

The excess metal powder in a build chamber – powder that has not been formed into a part or support structure – must be completely recycled and made available for subsequent builds. This makes optimum use of expensive powder and achieves more sustainable, economical production. For this reason, Volkmann introduced its first screening system, the PowTReX, in 2018 and has continued to develop and refine it to this day. The minimal space requirement allows it to be set up in the direct vicinity of the AM machine and thus easily integrates into the production process. Agglomerates and foreign bodies are removed by a highly-efficient ultrasonic screener. The system has proven its reliability with a wide range of metal powders including aluminium, copper, titanium, Inconel and even tungsten. It is used in the aerospace, automotive, medical technology industries, and many more.

Fig. 3 PowTReX next to an EOS M 290 PBF-LB machine (Courtesy GKN Additive)

The path to the 'closed powder loop'

Closed powder loop is the term used to describe the completely closed circuit of powder handling around Additive Manufacturing. This loop includes the following process steps:

- filling the AM machine with metal powder
- the unpacking and depowdering of the build job, and thereby the extraction and collection of the unused metal powder
- the cleaning and reprocessing (sieving) of the used powder
- the mixing of reclaimed metal powder and virgin powder in a defined mixing ratio
- the intermediate storage or buffering of the metal powder
- and closing the loop: refilling the AM machine with metal powder.

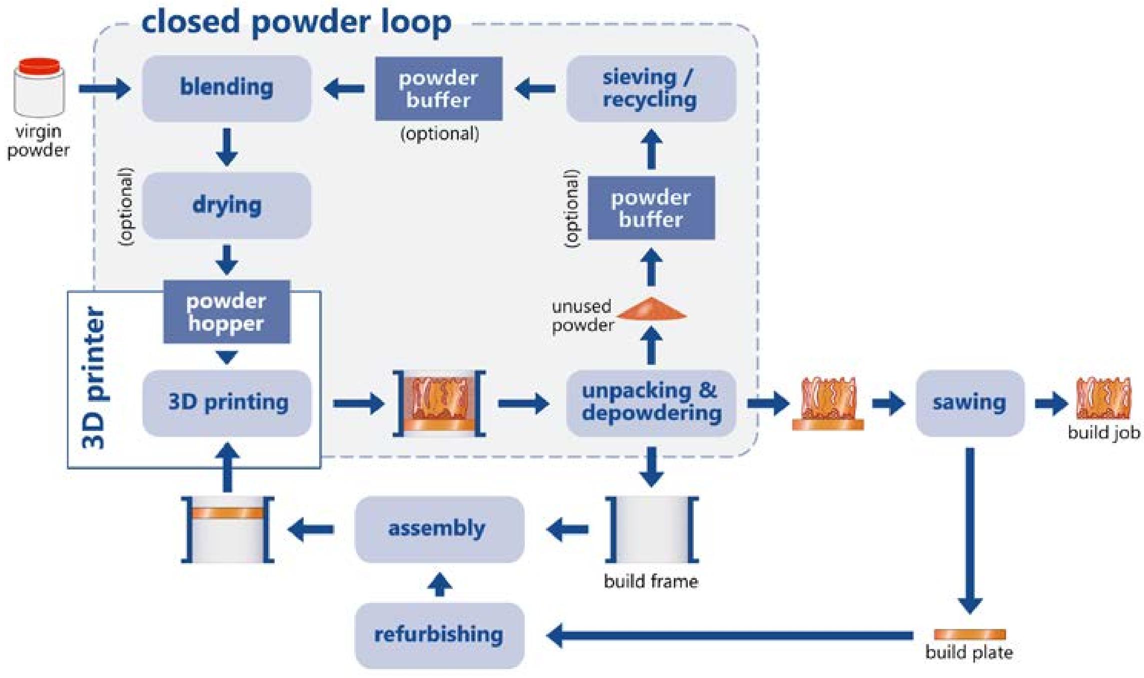

Fig. 4 Schematic of the material flow in a closed powder loop (Courtesy Volkmann GmbH)

Fig. 5 The IDAM pilot plant at BMW Group. In the IDAM research project, fully automated AM production lines for automotive series production were developed by 12 companies and research institutes under the leadership of the BMW Group and GKN Additive from 2020 until 2022 [1] (Courtesy BMW Group)

With Volkmann's participation in the IDAM research project [1] (Fig. 5), however, a complete and fully automated powder closed loop was achieved for the first time, integrated with the AM machine. In addition, the automatic unpacking and depowdering of the build job and frame was also integrated into this process. This represents a new milestone in the automation of Additive Manufacturing.

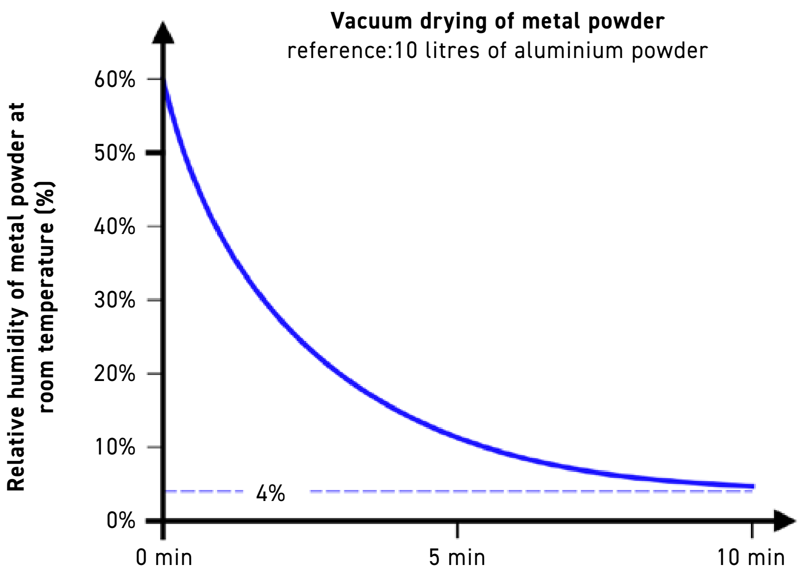

Fig. 6 Vacuum drying can dry a wet metal powder within ten minutes (Courtesy Volkmann GmbH)

During the IDAM research project, Volkmann developed the world's first single-step fully automated unpacking and depowdering station for PBF-LB components. The build job is completely depowdered in a single step until it is completely free of powder residues, with the unused metal powder recovered for reuse. The direct removal of powder after a build results in significant advantages of reduced process times and increased productivity. This is a significant improvement over current processes that require the initial bulk unpacking of powder at the AM machine, followed by a separate second step of removing the remaining powder residue from the part in a different piece of equipment.

Does powder handling degrade the quality of the metal powder, and what is the effect of contact with the ambient air and exposure to oxygen? After many years of research and countless tests during the IDAM project, the parameters relevant to the build process were increasingly narrowed down. The results identi-

Fig. 7 Laboratory test of flowability of moist and dry stainless steel powder (Courtesy Volkmann GmbH)

fied that oxygen has no significant influence over most metal powders in regards to build quality. During handling, conveying and storage, costly displacement of the atmosphere by an inert gas can thus be dispensed with. Closed loop inert gas operation can still be implemented where regulations or customer process standards require a specific low oxygen content.

However, the adsorption of moisture by the metal powder has a very serious effect on its flow properties, and is noticeable, among other things, when the powder layers are applied in the AM machine. The investigations were able to prove that components produced from moist metal powder have a poorer quality, a lower material density and higher porosity. Metal powders are generally highly hydrophilic and adsorb moisture even from relatively dry gases, including some inert gases.

The influence of humidity on metal powder has been analysed in a number of studies, including one by the Fraunhofer Institute of Laser Technology (ILT) together with FH Aachen – University of Applied Sciences and RWTH Aachen University – Chair for Laser Technology (LLT) [2].

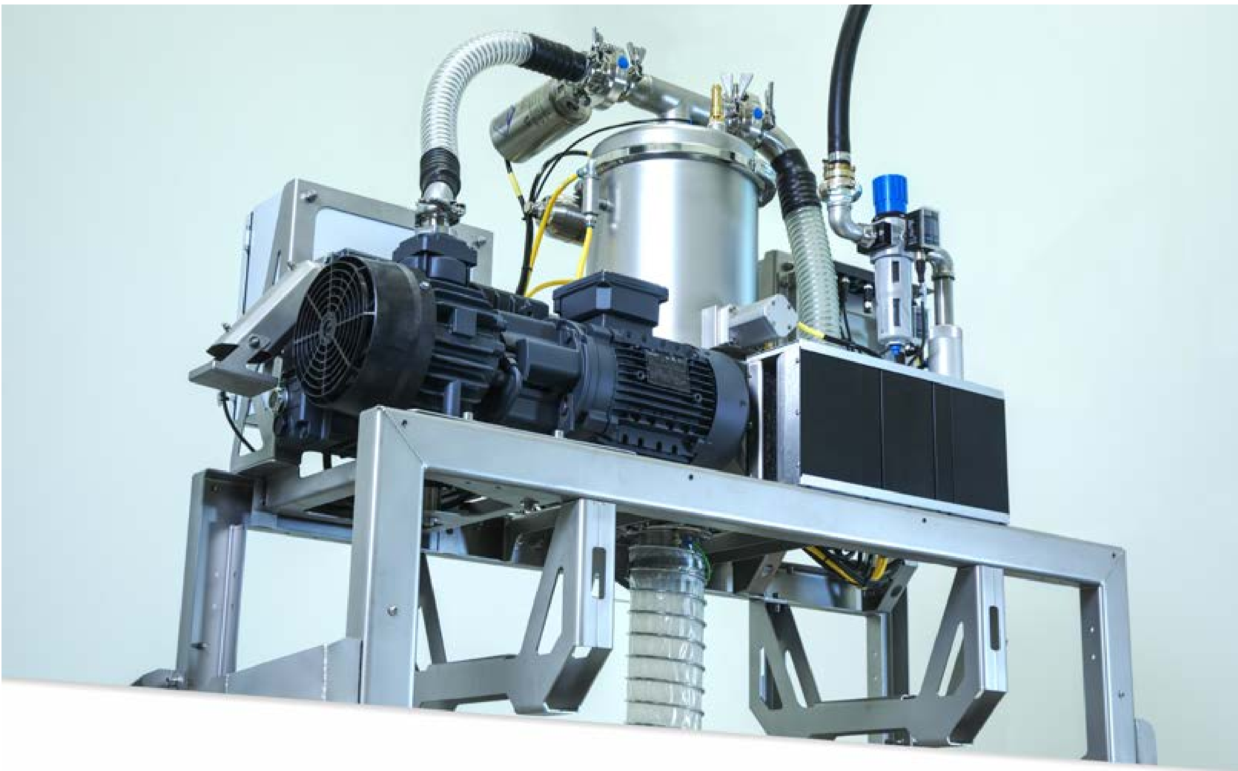

Fig. 8 Automated powder loading to an AM machine with powder transport by a vacuum conveyor and integrated powder drying (Courtesy Volkmann GmbH)

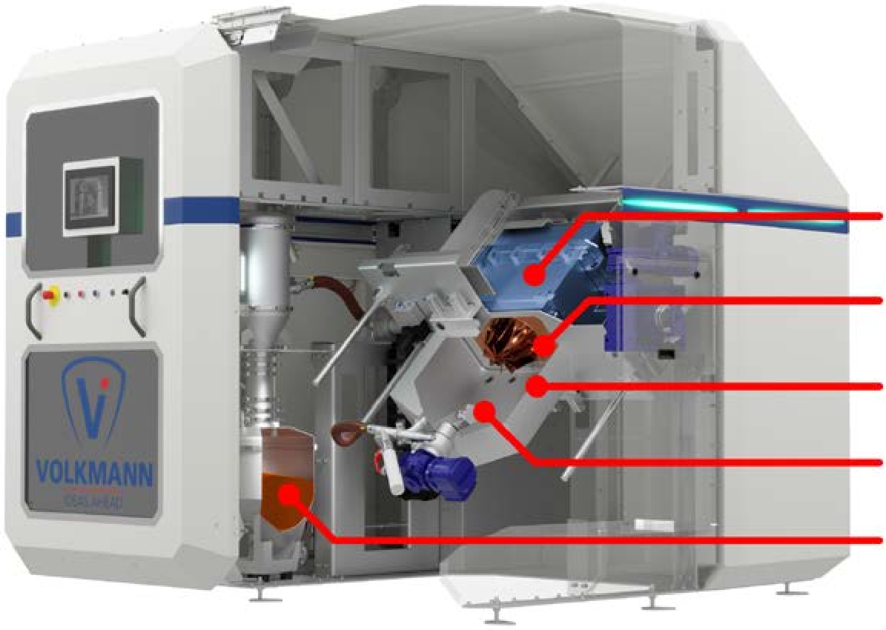

Fig. 9 Cross-sectional view into the new unpacking and depowdering station. The cleaning chamber, docked on the build frame, is shown tilted by approximately 135° (Courtesy Volkmann GmbH)

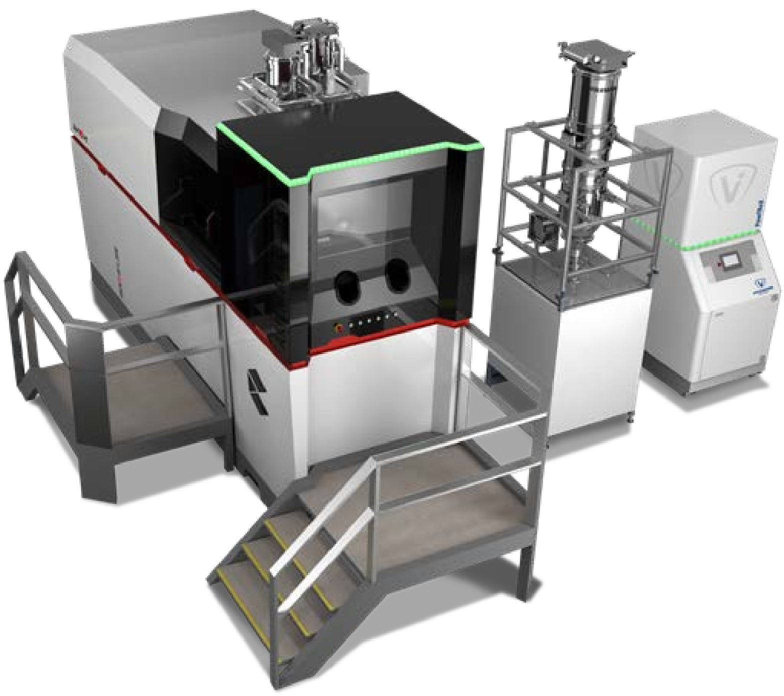

Fig. 10 An AMCM-M4K large format PBF-LB machine with an automatic powder supply at an installation in the USA for the AM of large components (thrust chambers etc.) for rocket engines (Courtesy AMCM GmbH)

The good news is that drying can fully restore the original powder quality. Even in batches with variation in moisture content, the metal powder can be dried to a uniform and reproducible level. Surprisingly, virgin metal powder should also be dried before use since it may also have adsorbed moisture during transport and storage. When using a vacuum, drying a batch of metal powder only takes a few minutes. In addition, the technological effort for vacuum drying is comparatively simple and can be implemented in a compact design. The optimal solution is to integrate the vacuum drying process into the vacuum conveying system, whereby drying takes place directly before the AM machine is filled.

Volkmann incorporated all of these findings into the two pilot lines of the IDAM project at their project partners BMW and GKN, building the world's first prototypes with an unprecedented degree of automation, while at the same time reducing component costs. From the findings and prototypes of the IDAM project, Volkmann developed new, market-ready and significantly more compact modules with minimal space requirements.

Aiming for the stars

These new developments are tested and applied almost exclusively in two industries: motorsports and aerospace. Additive Manufacturing technology is already state of the art in both industries; nevertheless, the market for additively manufactured parts in aerospace, and the commercial space industry in particular, are experiencing high growth. Entire rocket engines can now be Additively Manufactured in one piece. Southern California is, as it has so often been, the epicentre of the new technology.

An example of Volkmann's complete powder handling automation for Additive Manufacturing can be seen in a customer's new production plant in California, USA. The first expansion stage comprises of a four AM machine cell and was scheduled to begin operations in June 2023. Components for rocket engines and other aerospace items will be manufactured at the facility, with Volkmann supplying the fully automated closed loop handling powder system.

Many manufacturers of AM machines are now increasingly involved in solutions for the handling of metal powder. Volkmann is integrally a part of this through close cooperation with several machine manufacturers who understand that users expect a more holistic concept for the entire AM production chain.

Furthermore, end users are increasingly taking the initiative. In most projects, this takes place in the context of production expansion and the acquisition of new AM machines. For existing equipment, however, a closed powder circuit can be retrofitted.

Fig. 11 Aerospike rocket engine with the most complex internal structures – designed using artificial intelligence by Hyperganic, built by AMCM on the AMCM M 4K with integrated Volkmann closed loop powder handling technology (Courtesy of AMCM)

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Metal AM on an industrial scale: GKN Additive draws on decades of sintering expertise to commercialise Binder Jetting

Binder Jetting's position as an accepted mass production technology for precision metal components is on the near horizon. The coming success will, however, rely as much on expertise in the sintering process as it does on expertise in jetting binder onto a powder bed to make 'green' parts. This article reports on how GKN Powder Metallurgy's Additive Manufacturing division, GKN Additive, has leveraged decades of sintering expertise in high-capacity continuous furnaces, combined with its application development expertise, to deliver the series production of special filters by Binder Jetting for Schneider Electric.

GKN Additive's use of HP's metal Binder Jetting (BJT) technology made headlines in the industrial media in September 2022 when it was announced that commercial production of a special filter for Schneider Electric was underway. The announcement highlighted the enormous potential of metal Binder Jetting for industrial applications, including clear cost advantages in serial production, a fast time-to-market, the ability to add innovative product features, and the ability to flexibly adapt products and components to customers' specific requirements.

Whilst most attention at the time of the announcement was focused on the capabilities of the Binder Jetting process itself, what was also crucial to the success of the project was the sintering expertise that GKN Additive was able to leverage, thanks in large part to its decades of experience producing high performance structural components by Metal Injection Moulding (MIM) and Powder Metallurgy for the automotive industry.

Whilst sintering is becoming a more widely understood process within the metal AM community, what is notable about GKN's achievement with the filter for Schneider Electric is that these parts were produced on GKN's continuous sintering furnaces, in contrast to the batch furnaces that are more commonly associated with the sintering of BJT parts.

By demonstrating its capability to sinter BJT parts in a continuous furnace system, which lends itself to the production of much higher volumes of components in a more efficient manner than batch systems

Fig. 1 GKN Additive has produced thousands of filters for Schneider Electric using HP's metal Binder Jetting technology, Metal Jet, with sintering taking place in high-capacity continuous furnaces (Courtesy GKN PM)

Fig. 2 HP's Metal Jet solution installed at GKN Additive. This image shows, from left to right: build unit, curing station, and printers (Courtesy GKN PM)

are capable of, another hurdle on the route to high-volume production by metal BJT has been overcome.

It should, of course, be noted that the use of batch versus continuous furnaces is alloy-dependent, and the advantage of one furnace type over the other is influenced by factors such as production volume, component size and the specific requirements of an application.

The filter: features and development

Schneider Electric, global leader in the digital transformation of energy management and automation, developed its metal BJT filter solution for its ComPacT® circuit breakers, used in large-scale industrial plants and marine applications. In case of a short-circuit, these filters capture the ionised particles and reduce the gas exhaust pressure and temperature induced by the electric arc, allowing a more compact switchgear footprint and leading to a cost-effective solution for its global customers. The filters must withstand extreme temperatures and high pressure due to the plasma, among other things.

Sheet metal assemblies were originally used for the filters, but these came with performance limitations. While developing a new solution, Schneider Electric tested various manufacturing processes, but none of them met the required performance. Using AM, the filter mesh, grid and frame could be manufactured as a monobloc – i.e. in one piece. Laser Beam Powder Bed Fusion (PBF-LB) brought successful results, but proved to be too costly for series production due to the filter's complex internal structures. The Binder Jetting process proved to be attractive, however, the depowdering of the filter itself presented some initial challenges.

"Using AM, the filter mesh, grid and frame could be manufactured as a monobloc – i.e. in one piece. Laser Beam Powder Bed Fusion (PBF-LB) brought successful results, but proved to be too costly for series production due to the filter's complex internal structures."

In order to advance the project, HP brought GKN Additive onboard. GKN Additive, an early partner for the commercial development of HP's Metal Jet technology, benefits from the wider expertise of GKN Powder Metallurgy, the world's largest producer of sinter products and the second largest manufacturer of metal powders. The company has developed extensive expertise in multiple metal Additive Manufacturing technologies over recent years. As a result of this, and its existing manufacturing capabilities, GKN Additive is able to offer cost-effective industrial-scale production for its customers, while leveraging the significant innovation potential that AM offers.

"As consultants and product developers, we take a very close look at the design of a product and, whenever possible, optimise it for a customer's requirements and the production process. We refer to this approach as 'Design for Sintered AM'," said says Stefan Hundrieser, Global Product Centre (GPC) Manager Additive Manufacturing at GKN PM. After just eight weeks, GKN Additive was able to provide functional sample parts for validation testing.

"With metal Binder Jetting, the production process is the same for sample parts as it is for series production. This is a decisive advantage over other manufacturing technologies when it comes to sample production. Sample parts are traditionally manufactured using a different process and there is always uncertainty about the extent to which the samples represent the later series parts," emphasised Hundrieser.

"Metal Binder Jetting, in contrast, is not limited to prototype or low-volume production. Even the sample parts have almost the exact same specifications as the finished series parts. Thus, the process enables scalable Additive Manufacturing of metal with precise reproductions of the most complex shapes on an industrial scale – on time and on budget."

Fig. 3 Detail views of the filter types produced by GKN Additive for Schneider Electric (Courtesy HP Inc)

Fig. 4 Metal BJT filters installed in a ComPacT® circuit breaker (Courtesy Schneider Electric)

Fig. 5 MIM-Master continuous sintering furnaces, produced by Cremer Thermoprozessanlagen GmbH, and installed at GKN's Bad Langensalza facility. The furnaces are designed for the high-volume production of MIM parts, but are capable of processing metal BJT parts with minor modifications (Courtesy GKN PM)

'Design for Sintered AM': important impetus for product development

The challenge in this project was to set up robust, profitable series production within a short timeframe. In order to do so, the entire process had to be coordinated and optimised.

"At the beginning of a product's development, we have the ability to decisively and positively influence the design for improved function and manufacturability. This also influences cost, taking into account cost drivers such as part size (furnace space), weight (powder cost) and depowdering (labour cost) in the overall process. In addition, we can give our customers important impetus for their product development at this stage. This is a fundamental part of our consulting and coaching services and is what makes our 'Design for Sintered AM' unique," stated Hundrieser.

This includes a push to achieve maximum 'part density' in the design space – creating a component to be as compact as possible so that it can be produced cost-effectively. The more compact the product, the smaller the space required in the BJT machine and sintering furnace.

"Other key considerations include managing shrinkage and distortion during sintering. Without a deep understanding of the sintering process, there is a risk of poor dimensional accuracy in the final parts – and thus a great amount of scrap."

Other key considerations include managing shrinkage and distortion during sintering. Without a deep understanding of the sintering process, there is a risk of poor dimensional accuracy in the final parts – and thus a great amount of scrap. Designing a component that can be sintered without expensive sintering supports or setters, or eliminating the need for post-processing, can save significant process costs. Powder development is also extremely demanding; precise matching to the build and sintering process requires extensive metallurgical expertise.

"It is vital to understand that part design and the creation of the 'green'

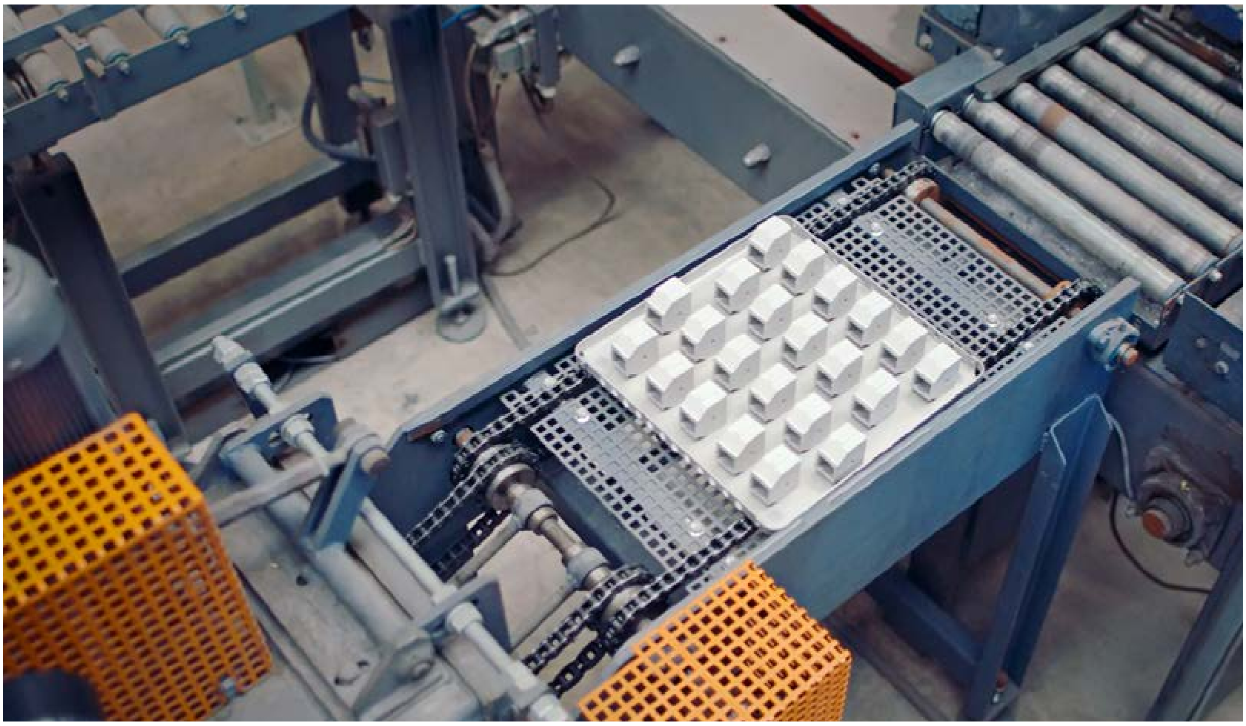

Fig. 6 A view of a sintering tray loaded with metal BJT filters being conveyed through a continuous sintering furnace system (Courtesy GKN PM)

part in the Binder Jetting machine aren't the whole story," explained GKN PM R&D engineer Johannes Bergfeld. "It is not until sintering that the ready-to-use product is created. To ensure that it turns out stable, consistently precise with tight tolerances, and well reproducible, you have to know the entire complex process chain very well. This includes the product design and the composition of the powder as well as the build process, depowdering, sintering, post-processing and quality assurance."

Metal Binder Jetting + Sintering = 'Sintered AM'

"Sinter-based Additive Manufacturing – or 'Sintered AM' as we call it – requires enormous know-how. This is precisely where our expertise lies," stated Hundrieser. "We have extensive experience in Powder Metallurgy, as well as a high level of expertise in metal Binder Jetting and high-volume sintering. We are able to optimally coordinate all components and parameters – while of course observing the needs and specifications of our customers. We are just as familiar with managing complex projects as we are with maintaining the highest quality standards, such as those often found in the automotive industry. That's why we have mastered the entire process and can accompany major industrial projects on an equal footing."

Only nine months after the initial contact with Schneider Electric, GKN Additive was already able to start series production of the filters. For this purpose, the Binder Jetting process was connected to all systems (logistics, production planning, quality assurance, etc.) at the GKN plant in Bad Langensalza, which usually produces far higher quantities of parts for the automotive and other industries – thus creating the conditions for highly efficient process development.

"The plants in which we use Binder Jetting combine the standards of the automotive industry with Additive Manufacturing series production. This allows us to meet even the most complex industrial requirements – far beyond the Additive Manufacturing world," explained Hundrieser.

Production was carried out in a three-shift operation with three Binder Jetting machines (expandable to up to twelve machines if required), three curing stations, and a sintering furnace modified for the Binder Jetting process, which can handle up to six machines. Through this approach, up to 1,300 parts per month could be produced in a short timeframe and, with scaling, multiples of this are possible. Over 5,000 parts were delivered for the pilot series.

Another advantage of the Binder Jetting process: the results of process optimisations, such as build parameters or design adjustments, can be quickly evaluated and integrated into the next development step. A special flow test ensures that all parts supplied meet the required specifications. "We have the know-how to meet even demanding quality assurance and documentation requirements. This

Fig. 7 Quality inspection of binder jetted parts (Courtesy GKN PM)

"Binder Jetting makes metal Additive Manufacturing scalable for industrial medium- and high-volume production. But there is much more to this technology: it offers huge optimisation potential for many components."

also applies to our broad base of suppliers used for all possible post-processing operations," commented Hundrieser.

"The joint project with GKN Additive and HP has completely convinced us of the sinter additive process," confirmed Thomas Rivoire, Industrialisation leader at Schneider Electric. "Thanks to GKN Additive's tremendous know-how, we benefit from a highly innovative and flexible process with clear cost advantages in volume production".

Dr Guillaume Fribourg, Additive Manufacturing expert at Schneider Electric added: "In addition, the redesigned filters feature significant improvements: increased stiffness which results in higher efficiency, and easier integration. However the key benefit is for our customers: reducing the size of the cabinets by 20-30%, thus reducing the global electrical switchgear footprint, and as a consequence the related material consumption, including copper busbars."

"We master the entire process from powder production to design, part build, sintering and post-processing, and we offer everything from a single source. We have a global presence in Additive Manufacturing and we know the pitfalls and impacts and know which adjusting screws to turn – that is the exclusive added value we offer our customers. We can produce components with complex geometries on an industrial scale and demonstrate additional added value in the products," stated Hundrieser.

"Binder Jetting makes metal Additive Manufacturing scalable for industrial medium- and high-volume production. But there is much more to this technology: it offers huge optimisation potential for many components," stated

Johannes Bergfeld. "Time-to-market is significantly reduced, and by integrating findings from the process back into the design, we can introduce new ideas and product features at any time – even at short notice. This can include, but is not limited to, optimising flow paths in hydraulics or overcoming installation space or performance problems, for example, in the off-highway sector, or with high-pressure hydraulic components."

This enables users to respond more quickly to market requirements, adapt products with a high number of variants rapidly and flexibly to customer wishes, while at the same time significantly reducing their inventories. When a series production has long since stopped, products can still be additively manufactured on-demand because the files are available in digital form.

Enormous potential for all industries

Industrial companies from all sectors can benefit from these advantages, especially if they are under high pressure to innovate and are reaching their limits with conventional technologies such as Metal Injection Moulding. "We help discover new dimensions of products and add new value to them: for example, when new functionalities are needed, when the design is not yet fully defined, when delicate geometries or complex components with complicated compositions are involved, or when customised mass production is required. There are still millions of possible applications and project ideas to be discovered," stated Hundrieser.

"The earlier we are involved in the development process, the better we can implement 'Design for Sintered AM' and generate the maximum added value. Yes, Binder Jetting is more expensive than conventional standard manufacturing technologies, but significantly cheaper than other Additive Manufacturing processes. We should also remember that, technically, many products could be produced by BJT, but not all are commercially worthwhile – other processes may be a better fit."

"As a global industry partner and one of the leading Additive Manufacturing parts producers, we understand the needs and processes of the industry," said Hundrieser. "We consult and support customers and interested parties in realising their ideas from the initial concept phase to industrial series production."

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International Conference on Electron Beam Additive Manufacturing: Highlights from EBAM 2023

Since the first conference on electron beam Additive Manufacturing in Nuremberg in 2016, the EBAM conference series has been the central meeting point for industry and academia to exchange knowledge on this dynamic area of AM. After the event was forced to go virtual in 2020 due to COVID-19, attendees were finally able to meet face-to-face again in Erlangen, March 22-24. Marie Franke-Jurisch and Dr Matthias Markl report on recent developments in materials, process, and machine technology, all of which serve to demonstrate that electron beam-based technologies are once again firmly established in the metal Additive Manufacturing world.

The EBAM conference series was launched in 2016 by Prof Carolin Körner and Dr Matthias Markl from Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) to address technological and process-related hurdles and challenges in the field of electron beam-based (EB) Additive Manufacturing. The goal was to bring all experts in the field together to accelerate developments in both research and industry. The presentations covered the complete process chain, from powder production and reuse to the post-processing of components. From a materials perspective, the focus was on the processing of titanium alloys, steels, and nickel-base alloys. Additionally, process monitoring approaches, modelling and simulation were featured with a view to contributing to a better understanding of physical effects during the build process.

This successful conference format remained unchanged for this year's fourth edition of the conference, held in Erlangen, Germany, from March 22-24, and attracted the interest of a broad international community with participants from seventeen countries.

Since well before 2016, electron beam-based technologies had already gained a foothold in a wide range of industrial sectors. This was reflected well in the focus of the presentations as well as in the number of participants at this year's event. Noticeably, process-related variability and the monitoring of reproducible and optimised materials properties and microstructures are coming to the fore among topics. This is being driven by advances in simulation-

Fig. 1 EBAM 2023 was organised by Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany, from March 22-24 (Courtesy Friedrich-Alexander-Universität)

Fig. 2 EBAM 2023 attendees outside the conference venue (Courtesy Friedrich-Alexander-Universität)

supported alloy design, process simulation, and, above all, by software and AM machine innovations that increase both the degrees of freedom in scientific development and the feasibility in industry of both Electron Beam Powder Bed Fusion (PBF-EB) and wire-based Electron Beam Directed Energy Deposition (DED-EB). While these topics were the subject of numerous virtual poster contributions in Nuremberg in 2020, their ongoing development was explored in greater depth in several presentations in Erlangen. For the first time, this year's conference was also accompanied by a small exhibition.

The following review presents some highlights from EBAM 2023 covering process development, new machine concepts, alloy development, scan path optimisation, process monitoring, powder production, and material processing.

> ***"According to Koptyug, materials and powders, as well as machine technology, in-process control and simulation techniques, influence the success and efficiency of the process chain. In combination with post-processing, these issues have a significant impact on the quality of the final components."***

Areas of focus for PBF-EB research

The fact that the combination of the previously discussed research and development approaches are the basis for the complex processing of materials was made clear by Prof Andrey V Koptyug from the SportsTech Research Centre at MidSweden University, who gave the opening lecture at EBAM 2023 [1].

At the beginning of his presentation, the main research areas in the field of PBF-EB were summarised. According to Koptyug, materials and powders, as well as machine technology, in-process control and simulation techniques, influence the success and efficiency of the process chain. In combination with post-processing, these issues have a significant impact on the quality of the final components and provide insight into the great potential of the technology.

While the importance of these topics was barely recognised in the shadowy early days of all metal-based

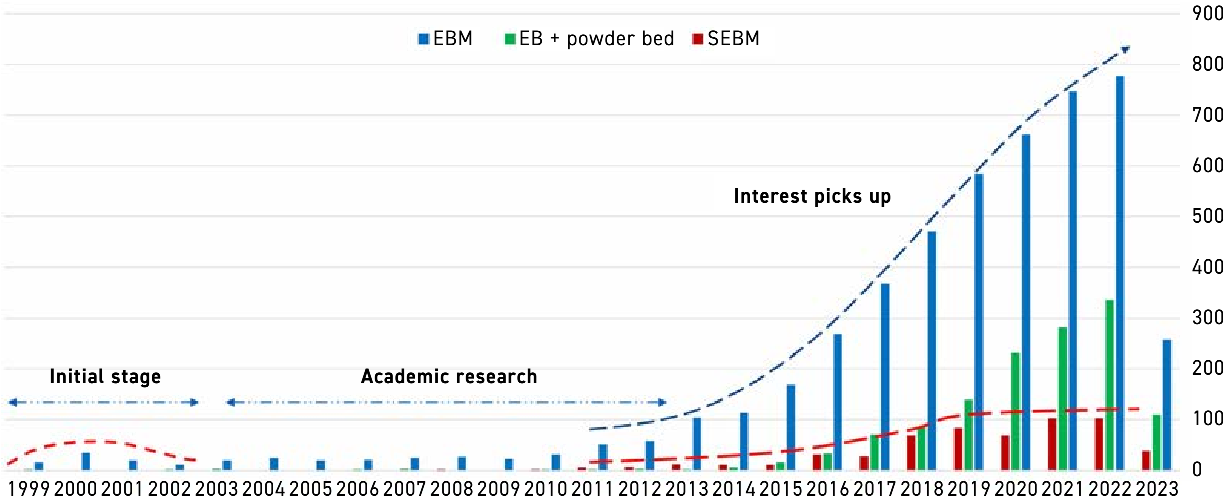


Fig. 3 A quick search in ScienceDirect database including covers, research papers, books, and book chapters among the two categories of "Find articles with these terms" and "Title, abstract, keywords" for the terms "Electron beam melting", "Selective Electron Beam Melting", "Electron Beam + Powder bed" [1]

AM technologies, the PBF-EB process is now experiencing a significant boost in public interest. Koptyug illustrated this with a simple random search on ScienceDirect, which gives an idea of the historical development of scientific publications on the PBF-EB process (Fig. 3).

Furthermore, he reported on a major existing bottleneck of the technology: powder removal from porous or lattice structures. PBF-EB medical implants rely on a level of surface porosity to enable osseointegration (bone ingrowth into the surface of the implant), but the technology is also used in other functions such as lightweight construction, energy absorption, or the tailoring of physical properties.

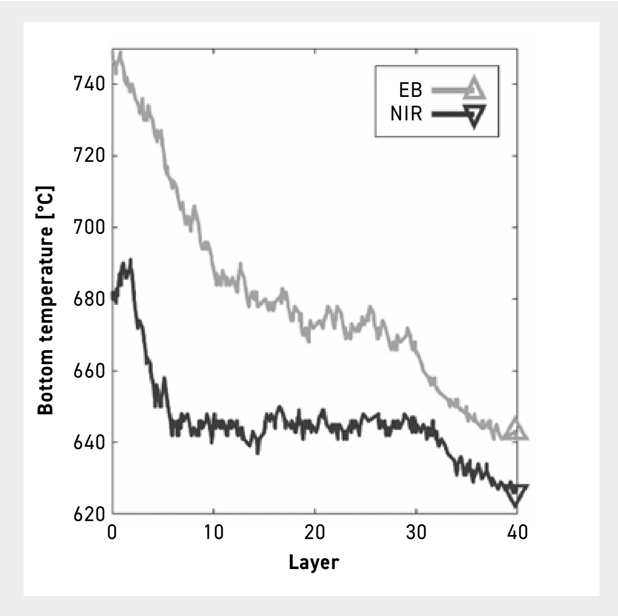
In a study, the team investigated the influence of different post-processing approaches for powder removal from lattice structures. Here, they compared the standard solution, the powder recovery blast system (PRS), with ultrasound vibration-assisted powder removal and chemical etching. While powder remained in the grid with increasing density when the PRS was used, subsequent etching did not result in further powder removal. It also affects the mechanical properties by removing surface layers and, consequently, changing the cell geometry.

> *"Koptyug considered materials development as an important branch of PBF-EB research. Here, he showed insights into the in-situ alloying of powder mixtures, which can be used advantageously in PBF-EB due to its increased build temperatures..."*

In contrast, the ultrasonic vibration method proved effective for powder removal after using PRS. However, very fine lattice walls were damaged. It is also interesting to note a potential effect on the microstructure, as these workers reported a fine-grained structure as a result of the vibrations [2].

In addition, Koptyug considered materials development as an important branch of PBF-EB research. Here, he shared insights into the in-situ alloying of powder mixtures, which can be used advantageously in PBF-EB due to its increased build temperatures, among other things. He investigated the microstructures and properties from a Ti-Nb powder blend using scanning electron microscopy (SEM), electron backscatter diffraction (EBSD) measurements, and nano-hardness indentations.

Koptyug emphasised the difficulty of microstructural homogeneity, which is strongly dependent on individual melting points, among other factors. If the difference is too great, this can lead to inhomogeneities, for example, due to non-melted areas and local material vaporisation, or contribute to the formation of viscous melts that make processability difficult. On the other hand, the powder blending approach enables the development of high-cost materials such as high entropy alloys, shown here on an $Al_{0.5}Cr_{1.0}Mo_{1.0}Nb_{1.0}Ta_{0.5}$ alloy, or magnetic materials such as AlMn(C) or metal matrix composites



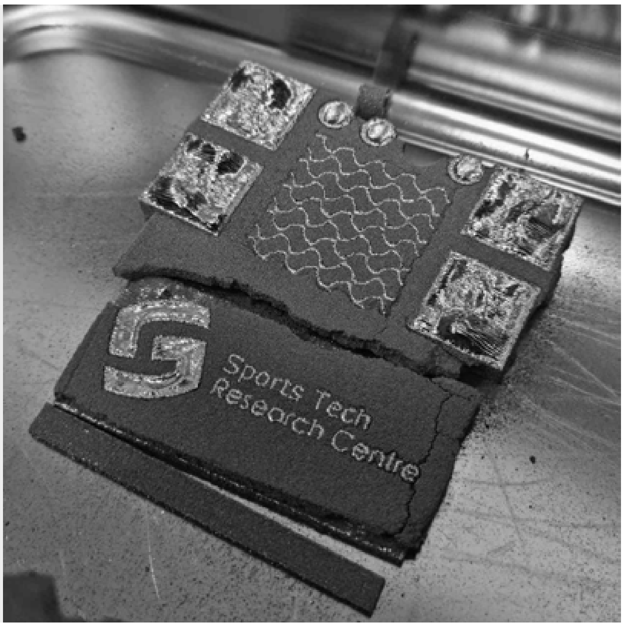


Fig. 4 Left: Bottom temperature during the first forty layers using NIR- (near-infrared) and conventional EB-preheating, Right: EB-built structures using NIR-technology for preheating. [1], reprinted from [3] under a CC BY 4.0 license

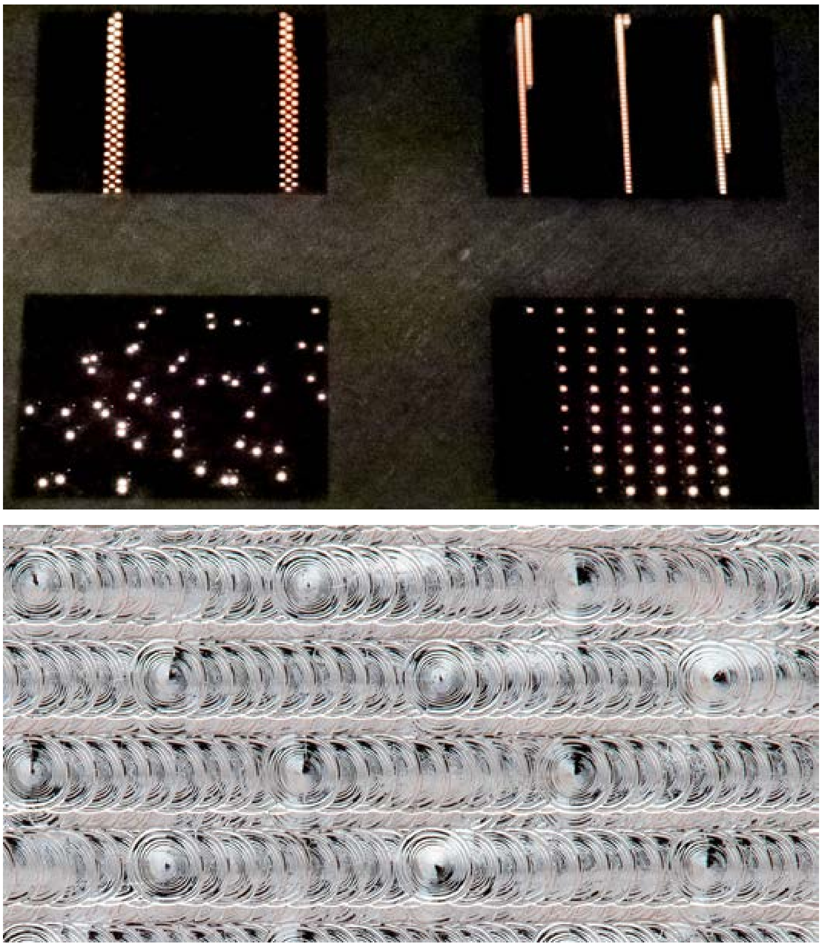


Fig. 5 Spot melting in PBF-EB. Above: various types of spot melt patterns easily created with Freemelt's Pixelmelt software; below: ordered spot melt pattern in tungsten (Courtesy Freemelt)

(MMC) using the example of a powder blend of gas atomised 316L and WC. He also postulated the potential for functional graded materials and bulk metallic glasses.

Finally, as a highlight, he reported on the integration of an additional infrared source into the machine for temperature adjustment. Fig. 4 shows promising results, which make it possible to reduce layer times, save energy, reduce filament damage, avoid so-called 'smoke events' and even build without a start plate.

According to Koptyug, the aforementioned capabilities offered by PBF-EB lead to spatial control of properties, thus opening what was described as a 'fourth dimension' in Additive Manufacturing.

New PBF-EB machine concepts

In contrast to previous conferences, EBAM2023 had seven AM machine manufacturers present: Freemelt, GE, ALD, Wayland, Pro-Beam, JEOL, and QuickBeam Technology.

In his presentation [4], Ulf Ackelid, principal scientist and co-founder of Freemelt, Sweden, referred to the open structure of the company's software, Pixelmelt, and addressed an emerging topic in the PBF-EB world – beam scanning patterns – which also found resonance in other presentations, including those by Christoph Breuning [5] and Paria Karimi [6].

Software provides easy access to previously script-based scanning strategies. According to Ackelid, the electron beam can jump between tens of thousands of melting points per second, enabling a balanced distribution of heat. Developments around this topic help to understand the thermal history of a material as a result of its melting and allow us to modify it so that a material's structure – and thus its mechanical and physical properties – can be targeted, even within a component.

It was stated that melting powder layers in discrete spot patterns is particularly beneficial in Freemelt's PBF-EB technology because of the consistent e-beam spot quality over the whole power range up to 6 kV in Freemelt's diode electron gun. Spot melting at very high beam power will lead to higher productivity, according to Ackelid. This is demonstrated in Fig. 5 by various spot melt patterns and a resulting tungsten-based melt surface [4].

It was not just on the machine software side that innovations were announced. Martyn Hussey from Wayland Additive, UK, presented a way to avoid smoke events by using the so-called 'NeuBeam' technology [7]. When the electron beam strikes the powder, the charge cannot be dissipated due to the low conductivity of the loose particles, causing the powder particles to become electrically charged. In the Wayland process, the particles can reach potentials up to the level of the incident beam (e.g. 60 kV), Hussey stated.

Due to the Coulomb repulsion of the negatively charged particles to each other, a smoke event can occur. Instead of the known solution of setting a low conductivity by slightly sintering the powder bed, the charges of the particles are neutralised using NeuBeam technology. This is done by an initial flooding of the powder bed with positively charged Ar ions before starting the electron beam. Charge neutralisation follows, while energy is delivered freely to the powder bed.

According to Hussey, this technique is already established in other industries, such as X-ray photoelectron spectroscopy and Auger electron spectroscopy, and it has now been transferred to the Calibur3 machine. Another advantage is that the powder bed no longer needs to be sintered, which should have a positive effect on the flowability of the powder cake and, thus, on powder removal in internal structures, as Fig. 6 shows.

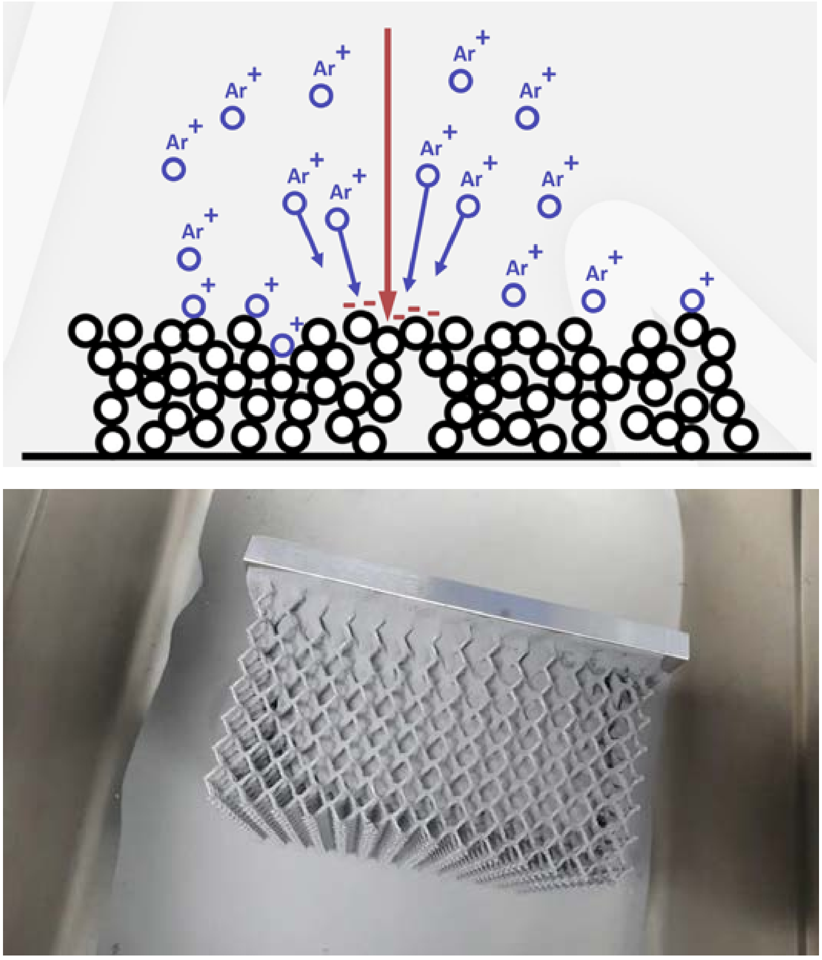


Fig. 6 Active charge neutralisation (top) and the sinter-free depowdering of a lattice structure (bottom) [7]

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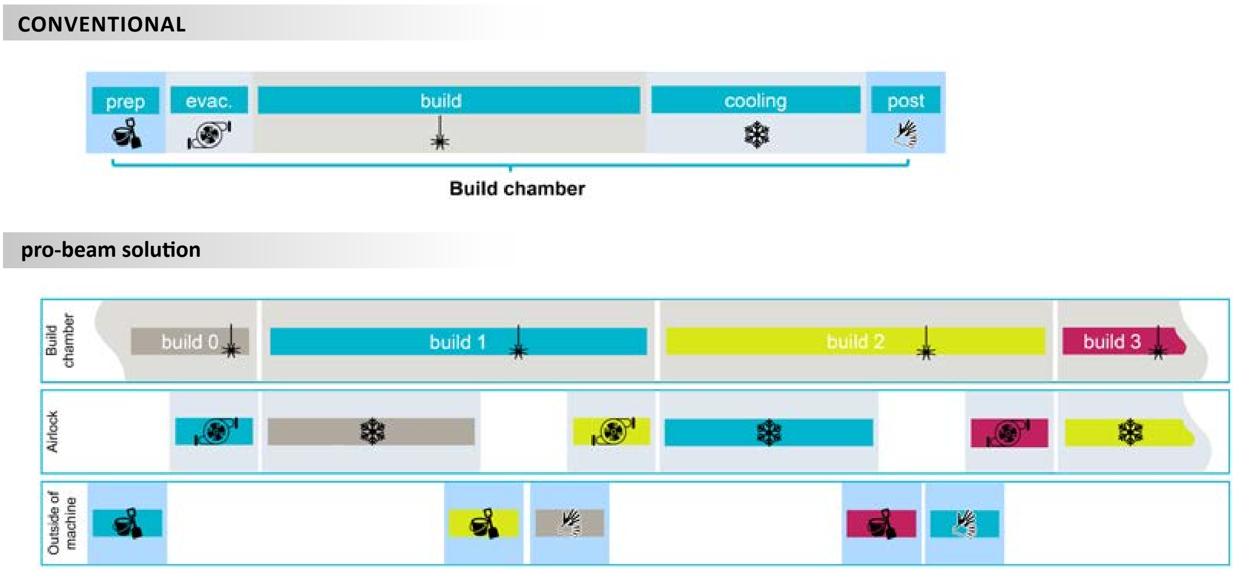

Fig. 7 The parallelisation of process steps at pro-beam [11]

Fig. 8 Specimen (height 300 mm) built with highly-productive process parameters on ALD's EBuild 850. Bottom as-built, and top, machined (Courtesy ALD Vacuum Technologies)

The smoke issue was also approached by other equipment manufacturers and in further scientific contributions such as the NIR technology described at the beginning [1]. For example, Camilo Medina Viramontes from Freemelt, Sweden, also reported in his poster on the development of the ProHeat® technology [8], in which the powder bed is already slightly sintered from above via infrared radiation to eliminate the propensity to smoke.

Viramontes claims that this patented technology will expand the range of processable alloys for PBF-EB. Using ProHeat, all types of powders can be pre-sintered without the risk of smoke, regardless of powder size and electrical conductivity. Furthermore, Ralf Edinger from Canmora Tech, Canada, reported on ball milling as a method of reducing charges in the powder bed [9]. He showed that it could be used to process steel powder smoke-free at room temperature. Finally, Dongfang Wang [10], from Tsinghua University, China, also spoke about the earliest possible detection of the initiation of a smoke event and its possible prevention.

Another highlight from the series of equipment-related innovations was the presentation of the PB EBM

30S machine concept by Sebastian Pohl [11] from pro-beam additive, Germany. The technology is distinguished by its high beam energies of up to 15 kW. For practicable implementation in existing production environments, the BuildUnits as well as a transport unit help to simplify the powder handling problems to a large extent. Pohl also reports that by using several BuildUnits, both the build process and the relatively slow requirement for cooling under vacuum conditions, can run in parallel. This leads to a further increase in productivity (Fig. 7).

Fuad Osmanlic [12] from ALD Vacuum Technologies, Germany, presented another unique selling point in terms of system technology. Due to both the size of the machines and the development towards highly productive process parameters, the need for very large build spaces can be addressed, which, according to Osmanlic, targets two markets. First, PBF-EB technology is expected to compete with the multi-laser PBF-LB market by allowing large numbers of components to be produced simultaneously. Second, large AM components can also be produced, as illustrated in Fig. 8.

In the talk by Professor Feng Lin from Tsinghua University, China, [13], the focus lay on the problem that the powder bed temperature frequently drops sharply as a result of the successively switched preheating and melting steps, thus additionally inducing stresses and cracks in the components. The solution, he suggested, is the development of a dual-gun machine (Qbeam G350, QuickBeam Technology Co., China), in which preheating and melting are decoupled by means of two independently running guns (see Fig. 9). Verification was carried out on a component made of the crack-prone material IN738, where the large cross-sectional jumps that originally led to cracks remained defect-free with the help of the new dual-electron-gun preheating technology.

Where the market is heading is certainly not yet clear. The fact is that the sum of the innovations

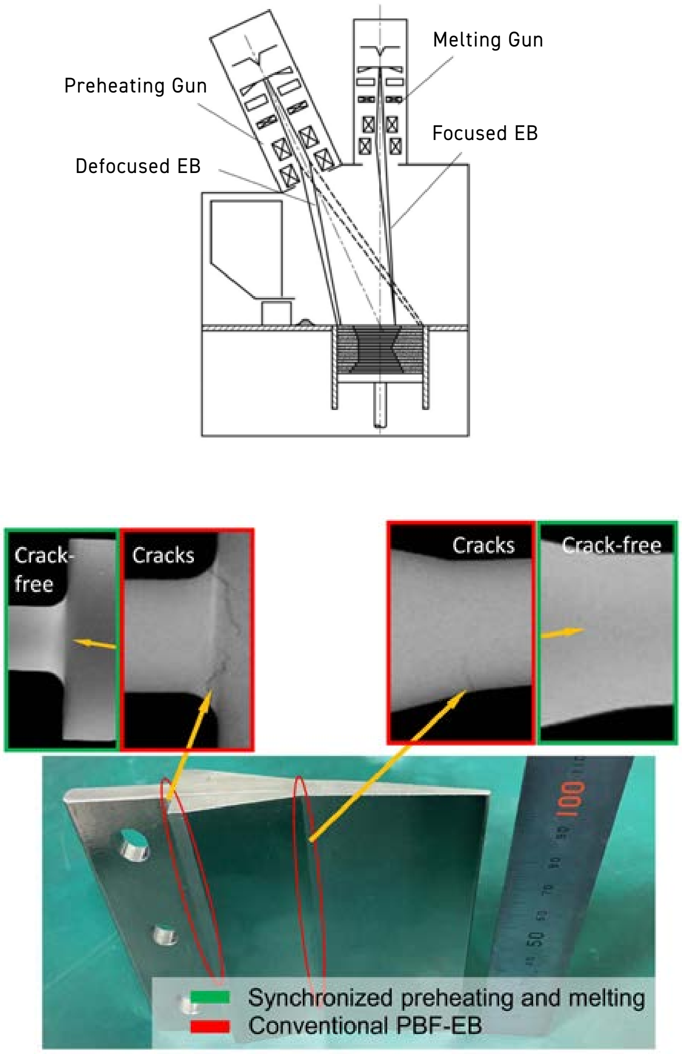

Fig. 9 Top: Schematics of the dual-gun-same-region for synchronising preheating and melting scan; Below: Photo and computed tomography scans for an IN738 part using conventional PBF-EB technology (red) and synchronised preheating and melting (green), the latter leading to elimination of cracks [13]

"Verification was carried out on a component made of the crack-prone material IN738, where the large cross-sectional jumps that originally led to cracks remained defect-free with the help of the new dual-electron-gun preheating technology."

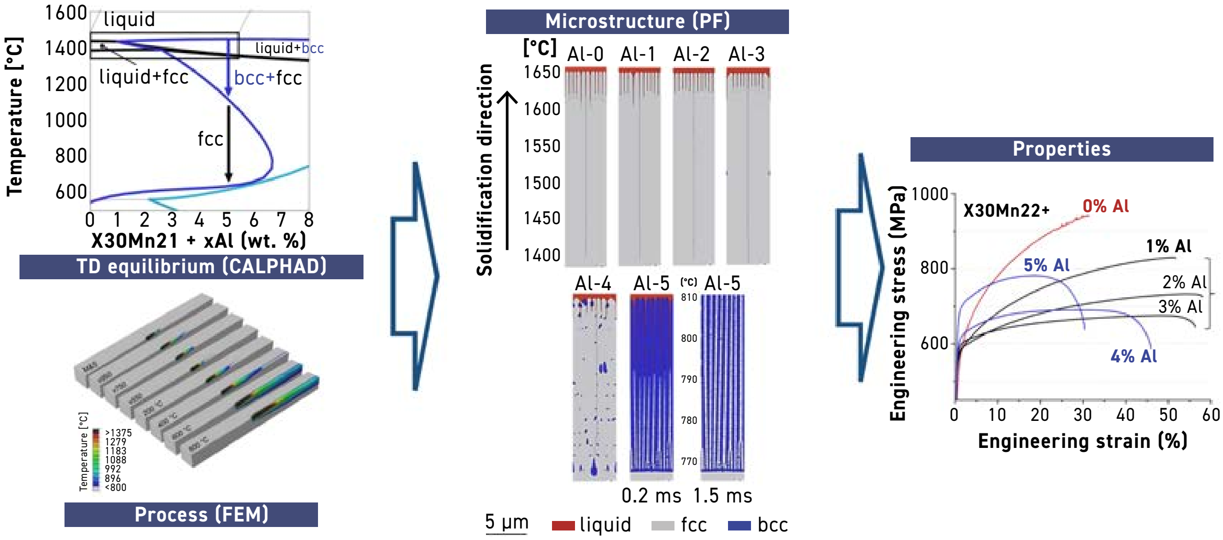

Fig. 10 Virtual laboratory for determination of process-microstructure-property linkages for fast process and alloy screening [14]

mentioned definitely means a major impact on the Additive Manufacturing world.

Acceleration in alloy design

Christian Haase from RWTH Aachen University, Germany, addressed the issue of the still small number of fully validated materials for Additive Manufacturing [14], which represents a hurdle for a widespread implementation in the industrial landscape. He reported that most available materials are based on existing, conventionally processable alloys, with only a few specifically designed for AM, limiting the potential of components. Moreover, predictable microstructure development as a function of process parameters and alloy composition enables the 'fourth dimension' of location-dependent microstructure control outlined by Koptyug [1].

The resulting further degrees of freedom increase the design space for alloy and process adaptation enormously, making experimental trial and error validation extremely costly for one material already. In the case of the crack-prone Ni-based material MAR247, for example, Haase spoke of 150,000 possible combinations for solving this multi-layered problem. According to Haase, this can only be countered by the interplay of rapid experiments and simulations (Fig. 10).

Using the extreme high-speed laser material deposition (EHLA) process based on different powder mixtures, compositional analysis via large-area EBSD mappings and property determination via automated micro-indentations, he was able to generate a high throughput of experimentally obtained data using the example of the high-strength steel X30Mn22. Haase combined these with simulation results from CALPHAD, Scheil-Gulliver, phase-field and process simulations. Thus, he was able to significantly improve the performance of the material by adjusting both the alloy composition and the process parameters with respect to tailored material solidification [15].

The interplay of experimental and computer-aided design and machine learning may be considered as a future optimisation step for process-structure-property relationships, but it is currently hardly used for AM alloy development, Haase said.

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One reason for this is the difficulty in interpreting machine learning algorithms. Haase referred to this as the concept of black-box models. However, work is underway to develop the first interpretable algorithms [16].

When and how these groundbreaking developments can also be applied to PBF-EB remains to be seen. What is clear, however, is that the additional degrees of freedom in PBF-EB allows further degrees of freedom in microstructure tailoring.

Scan path strategies for alloy development in PBF-EB

Paria Karimi and the team from the University of Waterloo, Canada, precisely addressed the possibilities of process-controlled microstructure development in their presentation [6]. Karimi began by describing the complexity of various applications. In the future, she stated, it will no longer be sufficient to establish a material with a single microstructure for certain applications, for instance. Thanks to its electromagnetic lenses, the PBF-EB method's electron beam quickly and precisely scans the layer as programmed.

Karimi illustrated a turbine blade, among other components, to demonstrate the various requirements such as creep resistance, thermal conductivity, rigidity, and fatigue resistance. Aspects of geometry can also be used to examine the properties. Nevertheless, the microstructure presents some room for optimisation from equiaxed microstructures to creep-resistant directionally solidified and single crystal microstructures, as Karimi explained.

With conventional scanning strategies, in which the beam is guided in linear trajectories along the cross-section, it is more difficult to control the local microstructure in a homogeneous and targeted manner. Approaches such as the process parameter-based compensation strategies impressively described by Christoph Breuning of Friedrich-Alexander-Universität Erlangen-Nürnberg FAU in Erlangen in his presentation [5] can produce a uniform melt pool geometry over complex cross sections but offer limited intervention options in the formation of microstructures.

Fig. 11 is a slide from Karimi's presentation, in which she discussed a study that compared various previously programmed Python scripts for known and novel spot-melting strategies. Karimi explained that the ultimate objective of the research

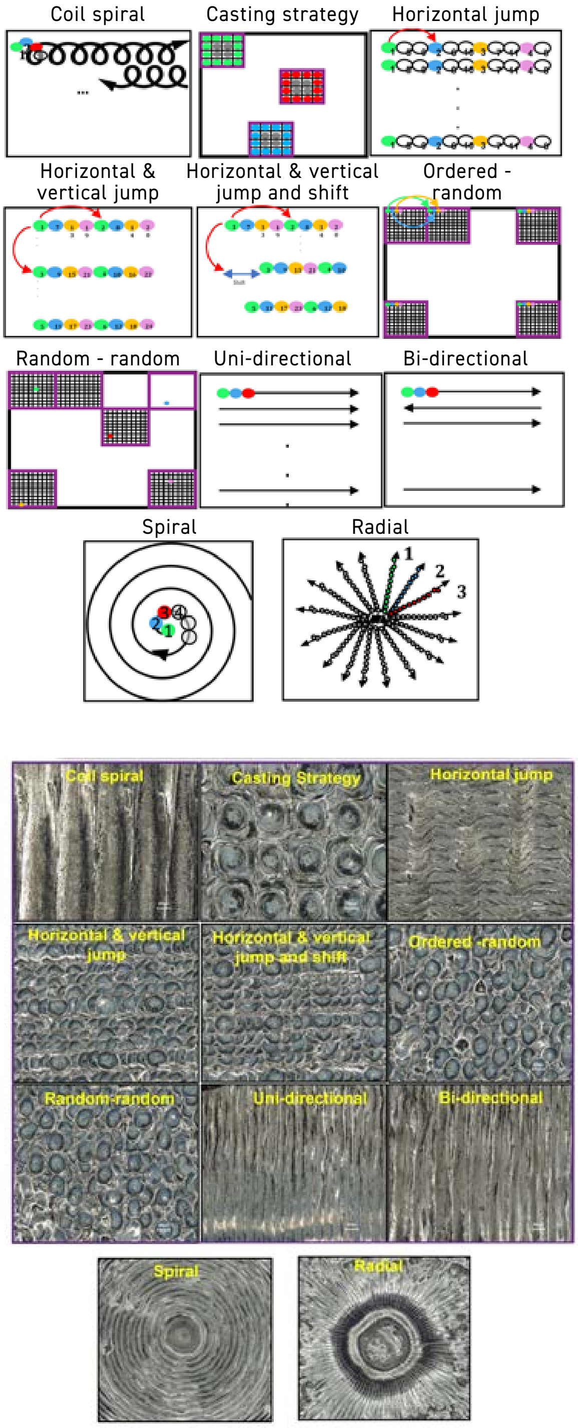

Fig. 11 Diverse beam path strategies for microstructural engineering in PBF-EB and associated melt surfaces [6]

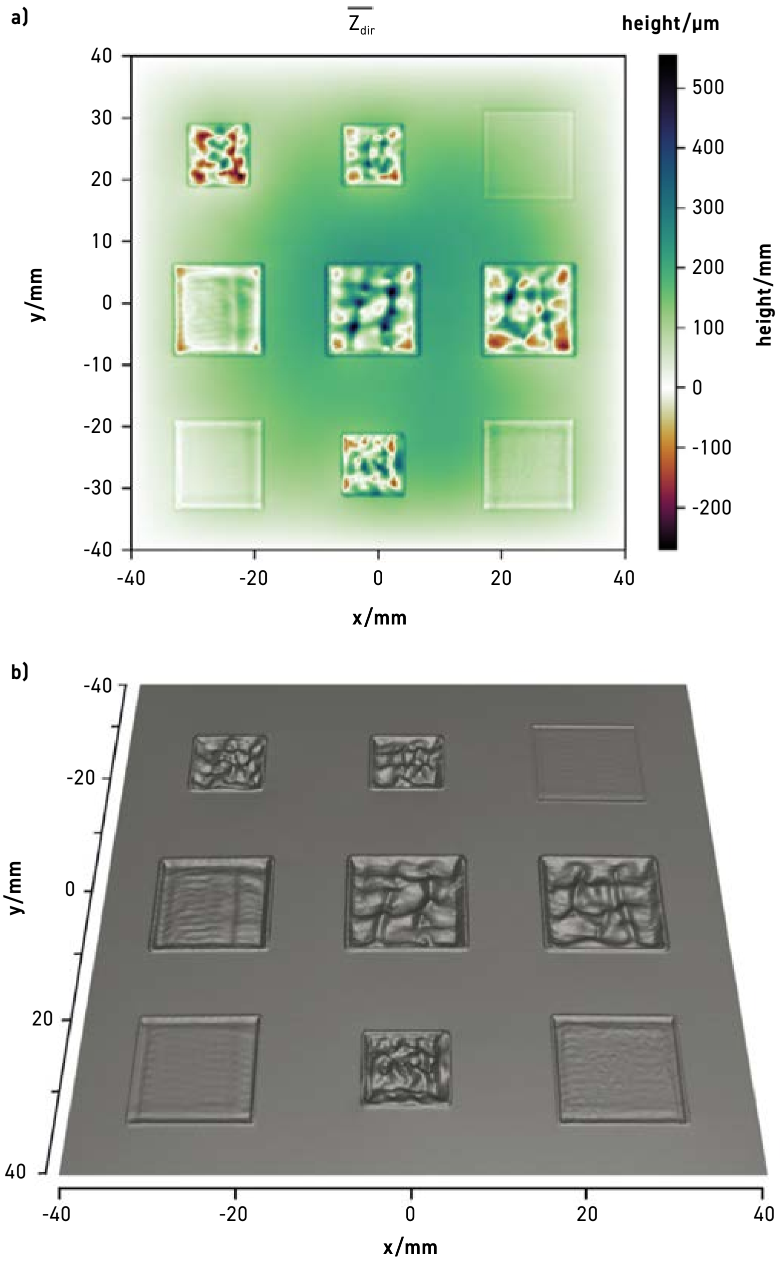

Fig. 12 Reconstruction of the actual melt surface: (a) height map of the complete Ti-6Al-4V plate, (b) 3D visualisation of the melting surface [19], reprinted from [20] under a CC BY 4.0 license

is to manipulate grain morphology and crystallographic textures in the resultant microstructures of complex geometries in any specific location. Using spot melting, she expects to infer an effect on the shape of the melt pool and, by extension, the rate of solidification and thermal gradient, which are the subject of ongoing research.

The implementation and subsequent experimental tests on the material Ti48Al2Nb2Cr, among others, were conducted on a PBF-EB machine with the 'Research mode key' provided by GE Additive Arcam EBM and the OptiMaL3D software package released by the OptiFab company, which enables a wide variety of customised and ready-to-implement programmable scan path plans. Fig. 11 shows the resultant melt surfaces of the different beam scan patterns. Karimi *et al.* varied scan patterns, using constant spot time or spot spacing and scan path plans spanning from ordered or random beam jumps to spiral or radial strategies.

She additionally mentioned a type of island melting resulting from the geometric partitioning into individual scan regions and the variation of process parameters along individual scan lines. In this context, the new surface morphologies generated by spot melting differ significantly from those generated by line melting. This influence will undoubtedly be reflected in the microstructures, allowing for additional degrees of freedom in the development of the materials for multiple applications, such as aerospace or medical.

In-situ process control via multi-detector systems

Process monitoring in PBF-EB was an important topic during EBAM 2020 in Nuremberg. While monitoring via light-optical cameras has proven itself useful in other processes, it is difficult in PBF-EB since the process creates conditions characterised by X-ray radiation, evaporation and high temperatures. At that time, Christopher Arnold [17, 18] pointed out the suitability of single electron-optical (ELO) detectors for process monitoring. The study reported by Jakob Renner [19] of Friedrich-Alexander-Universität Erlangen-Nürnberg FAU, Germany, was based on these prior developments, but now utilises a multi-detector ELO system. While single-detector ELO systems can be used to accelerate process development, multi-detector systems enable quantitative in-situ measurement of the build surface topography.

According to Renner, the advantage of multi-detectors is the possibility to record the build surface from various viewing directions. Topographical information based on different images allows reconstruction of the build surface morphology in subse-

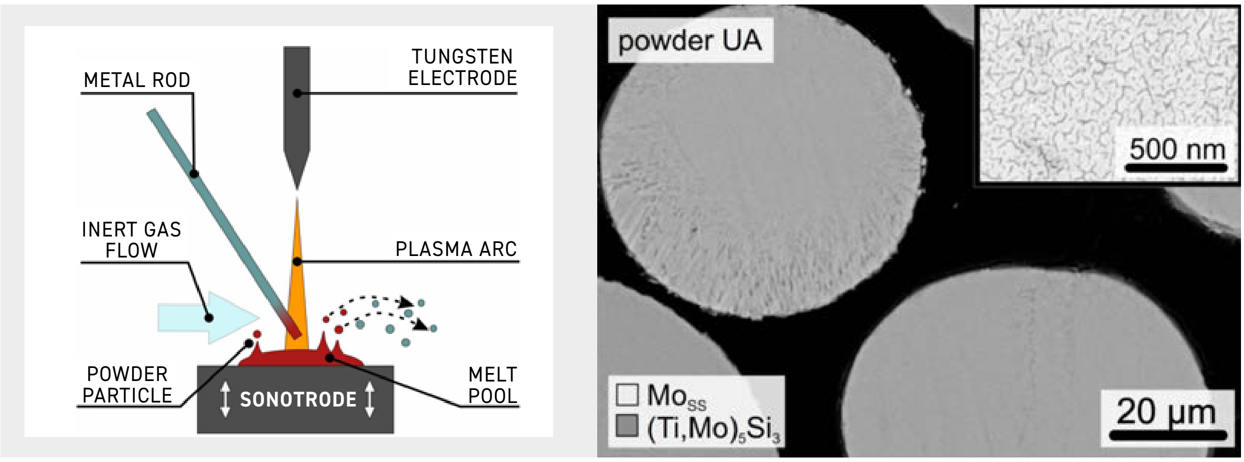

Fig. 13 Process scheme of the Ultrasonic Atomisation of spherical powders for AM material development [21], reprinted from [22] under a CC BY 4.0 license

quent computation steps. However, a requirement for ELO imaging is that the beam position is always known, meaning that this research was only possible on freely programmable machines, such as the PBF-EB system Athene. Thereby, the recorded backscattered electron signal can be mapped from the time to the spatial domain.

A four-detector ELO system is used to reconstruct the 3D melt surfaces produced on a Ti-6Al-4V plate, as shown in Fig. 12, using a computation chain published in [20]. Now, the same computation chain can be used in the PBF-EB process to measure the build surface topography evolution in situ for every layer of a build. The usual process cycle was extended to the following: powder layer application → preheating → ELO scan of the applied powder layer → melting→ ELO scan of the melt surfaces. This permitted monitoring the quality of the applied powder layer as well as the surface quality of additively manufactured parts. Comparison of the reconstructed and the real sample surface topographies resulted in nearly identical shapes.

This illustrates, according to Renner, that build surface topography monitoring using a multi-detector ELO system is feasible and allows early detection when a component's surface properties, for example local swelling or porosity, deviate from the intended condition.

Small batch powder production of spherical powders

Frauke Hinrichs from the Karlsruhe Institute of Technology, Germany, emphasised the role of powder production in Additive Manufacturing [21]. Suitable powder size distribution and sphericity or flowability are considered decisive factors for the processability of powders in powder bed processes. Gas atomisation has become the standard method used here. As already described by Haase [14], the development of new materials optimised for Additive Manufacturing requires small batches of processable powders to be made available in the shortest possible time.

In the area of expensive, high-melting and reactive materials, such as the refractory metal alloy Mo-20Si-52.8Ti (at.%) investigated in their study, this is already proving difficult. In addition to the powder blending approach mentioned earlier in this article [1, 14], which is subject to its own challenges, for example, different melting temperatures, Hinrichs presented an alternative method for the flexible production of small batches: the ultrasonic atomisation (UA).

At the same time, her study addressed scalability to gas atomisation using electrode induction gas atomisation (EIGA) technology, in which the brittle electrode was produced using powder blending and densification via Hot Isostatic Pressing. The ATOLab + machine, from 3DLab, Poland, was used for her study. To evaluate the process stability, three batches were produced from previously cast bar stock. Fig. 13 (left) illustrates the process scheme of the UA, in which the input material, supplied in wire or bar form, is liquefied using a plasma arc. The molten metal reaches the sonotrode, where it is ultrasonically stimulated to oscillate. As a result of vibration instabilities, spherical metal droplets detach from the melt, solidify in a stream of inert gas and are directed out of the melt pool region.

The resulting small powder quantities from the UA process are characterised by a narrow powder size distribution, in which 85% of the particles lie between 40 and 80 µm. The very fine and homogeneous microstructures are also notable, as well as the exceptionally high sphericity, which can be achieved with this method, as shown in Fig. 13 (right).

Together with theoretically competitive atomisation rates and the alloy-specific good impurity levels of less than 1,500 ppm, the process would be optimal for powder bed-based processes such as PBF-EB, to the extent that a continuous feed of material in the form of wire would

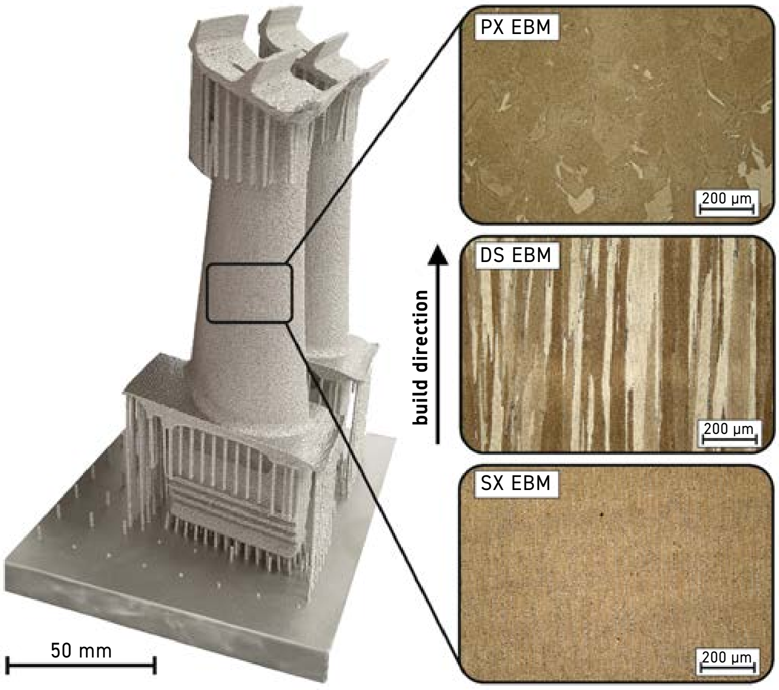

Fig. 14 Generic Alloy 247 turbine-blade demonstrator processed via PBF-EB and the associated microstructures, indicating the possibility of tailoring microstructures on demand even within a single part [23], reprinted from [24] under a CC BY 4.0 license

be available, Hinrichs notes. To date, regarding brittle materials, the process has been merely academic in nature, but it allows for rapid screening for material development. Therefore, the comparative approach for further processing of these materials using EIGA technology is promising.

Processing hard-to-weld materials: nickel-base Alloy 247

Markus Ramsperger from GE Additive Arcam EBM Center of Excellence, Sweden, reported on PBF-EB of the non-weldable nickel-based superalloy Alloy 247 for high-temperature applications, such as turbine blades in aero-engines [23], Fig. 14 (left). In addition to building defect- and crack-free material, the goal of the study was to tailor the microstructure depending on application requirements, which is a unique capability of the PBF-EB process, Ramsperger said, and echoing the sentiment of Karimi from the University of Waterloo in Canada.

The complex crack formation in this alloy in Additive Manufacturing, which was originally designed for casting, is based on different effects. Among them are rapid solidification, which results in high residual stresses, superimposing with partly remelted microstructure, plus segregation effects and the issue that in-situ heat treatment further develops the microstructure in case of carbides and gamma prime phases. Ramsperger mentioned the use of PBF-EB and advanced scanning strategies to influence the shape of the melt pool and thus the solidification, on the one hand, and thermal balance during processing, on the other hand.

> *"Ramsperger showed the feasibility of using the PBF-EB process to produce single crystalline microstructures (SX) from Alloy 247 on test structures. Subsequent Hot Isostatic Pressing, followed by a solution heat treatment at temperatures up to 1,295°C and a two-step ageing, should further improve the mechanical properties."*

In this way, the temperature gradient can be influenced, he explained.

Final experiments were done on an ArcamEBM SpectraH machine from GE Additive, with its improved electron beam unit, software and temperature monitoring. The resulting microstructures ranged from equiaxed to columnar grains, as shown in Fig. 14 (right). While deep and sharp melt pools supported polycrystalline (PX) microstructures based on equiaxed and elongated grains, broad and flat melt pools rather led to directionally solidified, highly anisotropic, columnar grained microstructures (DS).

Furthermore, Ramsperger showed the feasibility of using the PBF-EB process to produce single crystalline microstructures (SX) from Alloy 247 on test structures. Subsequent Hot Isostatic Pressing, followed by a solution heat treatment at temperatures up to 1,295°C and a two-step ageing, should further improve the mechanical properties. The resulting material generally yielded superior high-temperature properties, especially for fracture elongation above 500°C, in comparison to other Additive Manufacturing technologies.

For the polycrystalline microstructure, tensile strength was additionally measured and this exceeded those of the conventionally cast alloy, Ramsperger said. Finally, and most importantly for this material, the creep properties of the Additively Manufactured DS microstructure were comparable to those of cast directionally solidified material, which is still the benchmark.

Conclusion

In conclusion, the EBAM2023 conference highlighted the rising interest in electron beam-based Additive Manufacturing, due to the emerging innovations in machine technology and process observation as well as capabilities in alloy design through machine software, process strategies and computer-aided developments. These topics were combined with other focus discussions such as powder or materials qualification.

This gives rise to many questions. How can we further improve process observation technologies and the interpretation of the measured data? When and how can developments on process monitoring actively feedback into the process to enable process control?

How can promising approaches, such as locally adapted grain morphologies, graded structures or multi-materials, gain acceptance in the industrial landscape? How will existing standards and specifications be addressed, in that case, and how are such components to be tested? How do machine suppliers position themselves to make the transfer of materials among one another as simple as possible and, thus, accelerate the industrial establishment of the process?

Will the new freedom in process control promote alloy development towards EBAM-only materials? Is virtual material alloy-design increasingly going to replace experimental validation?

It remains exciting to see how these and numerous other open issues will progress. What is certain is that they will be discussed at the next EBAM2025.

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Industry events

Metal AM magazine is dedicated to driving awareness and development of metal Additive Manufacturing and its related technologies. Key to this aim is our support of a range of international partner conferences and exhibitions. View our complete events listing on www.metal-am.com

2023

EPMA Powder Metallurgy Summer School
July 17–21, Dresden, Germany
www.summerschool.epma.com

ImplementAM 2023 – Denver
July 20, Denver, CO, USA
www.implement-am.com

America Makes MMX
August 15–16, Youngstown, OH, USA
www.americamakes.us/event/mmx

ImplementAM – Milwaukee
August 17, Milwaukee, WI, USA
www.implement-am.com

Sustainable Lightweight Materials Congress 2023
August 22–24, Detroit, MI, USA
www.sustainable-lightweight-materials-automotive.com

Formnext + PM South China
August 29–31, Shenzhen, China
www.formnext-pm.com

If you would like to see your Metal Additive Manufacturing related event listed in this magazine and on our websites, please contact:

Merryl Le Roux
Operations and Partnerships Manager

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Formnext forum Austin
August 28–30, Austin, TX, USA
www.formnextforum.com

T.I.C.'s 64th General Assembly
September 10–13, Rio de Janeiro, Brazil
www.tanb.org

Powder Handling and Flow for Additive Manufacturing
September 11–15, Virtual event
www.gre.ac.uk/engsci/research/groups/wolfsoncentre/coupro/sc/am

TCT Asia
September 12–14, Shanghai, China
en.tctasia.cn

4th Workshop on Sinter-based Additive Manufacturing
September 13–14, Bremen, Germany
www.ifam.fraunhofer.de/en/Events/sinter-based-additive-manufacturing-workshop-2023.html

AMSI – AM2023
September 13–15, Bengaluru, India
www.amsi.org.in

EMO Hannover 2023
September 18–23, Hannover, Germany
www.deutschemesse.co.uk/emo

AM Summit 2023
September 21, Copenhagen, Denmark
www.amsummit.dk

ImplementAM – Austin
September 21, Austin, TX, USA
www.implement-am.com

Middle East ReAM
September 25–27, Dubai , UAE
www.ream3d.com

AM Ceramics
September 27–28, Vienna, Austria
www.am-ceramics.dkg.de

Formnext forum Tokyo
September 28–29, Tokyo, Japan
www.formnextforum.jp

Euro PM2023
October 1–4, Lisbon, Portugal
www.europm2023.com

3D Print Paris
October 11–12, Paris, France
www.3dprint-exhibition-paris.com

MAMC 2023
October 17–19, Vienna, Austria
www.mamc.at

America Makes TRX
October 17–19, Knoxville, TN, USA
www.americamakes.us/events/trx-fall/

ASTM ICAM 2023
October 30 – November 3, Washington, D.C., USA
www.amcoe.org/event/icam2023/

Formnext
November 7–10, Frankfurt, Germany
www.formnext.com

Space Tech Expo Europe
November 14–16, Bremen, Germany
www.spacetechexpo-europe.com

Asean Ceramics
November 28–30, Hanoi, Vietnam
www.aseanceramics.com/vietnam/

ISAM 2023
November 29 – December 1, Dresden, Germany
www.isam.network

2024

MIM2024
February 26–28, Raleigh, NC, USA
www.mim2024.org

AMUG
March 10–14, Chicago, IL, USA
www.amug.com

Hannover Messe
April 22–26, Hannover, Germany
www.hannovermesse.de

Rapid + TCT
April 23–25, Anaheim, CA, USA
www.rapid3devent.com

Space Tech Expo US
May 14–15, Long Beach, CA, USA
www.spacetechexpo.com

3D Print Lyon
June 4–6, Lyon, France
www.3dprint-exhibition-lyon.com

EPHJ
June 11–14, Geneva, Switzerland
www.ephj.ch

PowderMet2024 / AMPM2024
June 16–19, Pittsburgh, PA, USA
www.powdermet2024.org | www.ampm2024.org

World PM2024
October 13–17, Yokohama, Japan
www.worldpm2024.com

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