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THE MAGAZINE FOR THE METAL ADDITIVE MANUFACTURING INDUSTRY

METAL AM

in this issue

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METAL ADDITIVE MANUFACTURING

Waving the flag for AM in a year of digital transformation

I have no words of wisdom when it comes to the global economic outlook and the impact of the COVID-19 crisis on the metal AM industry. The only thing that is certain is uncertainty. On some mornings it looks like there is light at the end of the tunnel, whilst other mornings bring a fresh dose of caution.

What the crisis has done – in the short term at least – is transform the way that the world of business communicates, networks and shares knowledge. Zoom meetings, digital conferences and a plethora of webinar offerings all compete to find a spot in our weekly schedule.

The digital distribution of in-depth knowledge has been at the heart of what we do at *Metal AM* magazine from our very first issue back in 2015. Embracing the opportunities offered by the digital world allows us to reach the widest possible audience and deliver on our core mission: to wave the flag for the technologies that we represent.

Through this digital platform, combined with a magazine format ideally suited to delivering the type of high-quality, long-form journalism that we aspire to, we believe that the seeds can be sown for the future exploration of AM.

In this new era of uncertainty, it is more critical than ever that we collectively expand and diversify our reach to deliver on the potential of metal Additive Manufacturing. With this issue set to reach new audiences in the jewellery and automotive sectors in particular, we hope that we can play our role in inspiring designers, engineers and end users to take a further step towards embracing AM in all its diverse forms.

Nick Williams
Managing Director

Cover image
A bracelet from the 'Embrace' collection by Marie Boltenstern consisting of rows of 4 mm gemstones woven into additively manufactured protective geometric spheres (Photo www.loupiosity.com)

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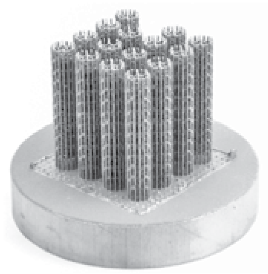

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Industry news

BMW Group opens its new €15 million Additive Manufacturing campus

BMW's Additive Manufacturing campus employs up to eighty associates and operates about fifty industrial AM machines (Courtesy The BMW Group)

The BMW Group has officially opened its new Additive Manufacturing Campus in Munich, Germany. The new centre, which began development in April 2018, is said to bring together the production of metal and plastic prototype and series parts under one roof, as well as research into new AM technologies, and associate training for the global rollout of toolless production.

The campus is the result of an investment of €15 million and is expected to allow the BMW Group to develop its position as technology leader in the utilisation of Additive Manufacturing in the automotive industry. In 2019, BMW produced about 300,000 parts by AM. The new AM Campus currently employs up to eighty associates and operates about fifty industrial AM machines that work with metals and plastics.

Speaking at the opening ceremony, Milan Nedeljković, BMW AG Board Member for Production, stated, "Additive Manufacturing is already an integral part of our worldwide production system today, and established in our digitalisation strategy. In the future, new technologies of this kind will shorten production times even further and allow us to benefit even more fully from the potential of toolless manufacturing."

"Our goal is to industrialise 3D printing methods more and more for automotive production, and to implement new automation concepts in the process chain," added Daniel Schäfer, Senior Vice President for Production Integration and Pilot Plant at the BMW Group. "This will allow us to streamline component manufacturing for series production and speed up development."

"At the same time, we are collaborating with vehicle development, component production, purchasing and the supplier network," he continued, "as well as various other areas of the company to systematically integrate the technology and utilise it effectively."

Cooperating with the AM industry to drive development

The advancement of AM at BMW has been the result of many years of in-house expertise and cooperations to advance the technology. Jens Ertel, Director of the Additive Manufacturing Campus, explained, "Over the last thirty years or so, the BMW Group has developed comprehensive skills, which we'll continue to enhance on our new campus, which has the latest machines and technologies."

"In addition, we develop and design components that are faster to produce than by conventional means, offer flexibility in terms of their form, and are also more functional," Ertel continued. "We are working hard to mature Additive Manufacturing fully and benefit from it as far as possible throughout the product life-cycle, from the first vehicle concept through to production, aftersales and its use in classic vehicles."

Access to the latest technologies is reportedly gained through long-standing partnerships with leading manufacturers and universities, and by scouting for industry newcomers. In 2017, the BMW Group became involved with Desktop Metal's sinter-based metal AM technologies, and continues to collaborate closely with the company.

In the same year, BMW I Ventures – the group's venture capital division – invested in the US startup Xometry, a platform for on-demand manufacturing, including advanced technologies such as AM.

Its latest investment was in the German start-up ELISE, which allows engineers to produce 'component


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DNA' containing all the technical requirements for the part, from load requirements and manufacturing restrictions to costs and potential optimisation parameters. ELISE then uses this data, along with established development tools, to automatically generate optimised components.

Additive Manufacturing in research and pre-development at BMW Group

The pre-development unit of the Additive Manufacturing Campus optimises new technologies and materials for comprehensive use across the company. The main focus is on automating process chains that have previously required large amounts of manual work, to make AM more economical and viable for use on an industrial scale over the longer term.

For the development of AM processes for use on an industrial scale, research projects are especially important. BMW is involved in several of these projects, such as the Industrialisation and Digitisation of Additive Manufacturing for Automotive Series Production (IDAM) project, supported by the German Ministry of Education and Research.

With IDAM, the BMW Group and its twelve project partners hope to pave the way for the integration of AM into series production environments within the automotive industry. At the Additive Manufacturing Campus, a production line is being set up that replicates the entire process chain, from the preparation of digital production through to manufacture and reworking of components.

The IDAM team is now preparing it for the specific requirements of series, individual and spare-part production. According to the group, production targets confirm the status of this collaborative undertaking as a lighthouse project: output is expected to total at least 50,000 series components a year, with over 10,000 individual and spare parts, all produced to a very high quality.

Applications in series production

The BMW Group first began its Additive Manufacturing of prototype parts in 1991, for concept vehicles. By 2010, both metal and plastic AM processes were being rolled out across the group, initially in smaller series, to produce items such as the AM water pump wheel in DTM race cars.

Further series production applications followed from 2012 onward, with a range of components for the Rolls-Royce Phantom, BMW i8 Roadster (2017) and MINI John Cooper Works GP (2020), which contains four AM components as standard.

www.bmwgroup.com

BMW's Additive Manufacturing campus employs up to eighty associates and operates about fifty industrial AM machines (Courtesy The BMW Group)

VDM Metals acquired by stainless steel manufacturing group Acerinox

Acerinox, S.A. a multi-national stainless steel manufacturing group based in Madrid, Spain, has acquired VDM Metals GmbH, Werdohl, Germany, in transaction valued at €532 million. VDM Metals is a global supplier of metals which, among its products, offers a range of metal powders for Additive Manufacturing. The acquisition has received approval from the European, US and Taiwanese competition authorities.

The activities performed and products manufactured by Acerinox and VDM in their respective fields are said to complement each other, and the transaction will have clear manufacturing, sales and distribution benefits for both companies. The new group company is expected to be a global leader in the development and manufacture of special nickel alloys, as well as high-performance stainless steels, as well as an R&D and innovation benchmark in the industry.

"In the circumstances we are currently living, this acquisition makes more sense than ever, since it diversifies our risk, adds a business line and establishes a strategy that we believe will be successful, in addition to strengthening the group's competitiveness and robustness. Furthermore, the cash generation and decrease in debt recognised last year leaves us in an optimal situation for taking on this challenge," stated Bernardo Velázquez, CEO of Acerinox.

VDM has seven production plants in Germany and the USA and employs almost 2,000. In 2018/19, VDM achieved sales of €852 million and EBITDA of €97 million. Its incorporation into Acerinox is expected to increase its net sales and billings by more than 20%.

www.vdm-metals.com
www.acerinox.com

Metalpine opens new production site for highly spherical metal powders

Metalpine GmbH, Graz, Austria, a manufacturer of metal powder and part of the htm Group (hightech metal investment GmbH), has opened a new production site based at its Graz headquarters, which will primarily produce highly spherical metal powders for use in Additive Manufacturing.

An opening ceremony for the plant was attended by numerous representatives from politics, science and business, including Dir. Karl-Heinz Dernoscheg from WKO Steiermark; Dr Robert Brugger from ICS Styria; Dr Gerald Sitte from Spaceone; and Klaus Fronius and Brigitte Strauß from Fronius.

Metalpine has opened a new production site which will produce metal powder for use in Additive Manufacturing (Courtesy Metalpine GmbH)

According to the company, the total capacity of the new production site will gradually be increased to 400 tons per year, and using the in-house developed process, metal powders can reportedly be produced in a unique quality from a very wide range of metals and metal alloys (including copper, steel, nickel-base alloys, titanium, molybdenum, tungsten, etc).

Metalpine states that all its materials are produced using a flexible, environmentally friendly inert gas process under cleanroom conditions, and are aimed at highly demanding applications such as Laser Beam Powder Bed Fusion (PBF-LB), metal sintering, powder build-up welding or surface coatings.

Additionally, the new production site is believed to have a good network for industrial and academic research and development in the field of Additive Manufacturing, with research in the areas of production processes, materials and additives fields of application being carried out by the Montanuniversität Leoben and the Graz University of Technology.

www.metalpine.at

H.C. Starck Tungsten Powders sold to Masan Resources

H.C. Starck Tungsten Powders, Goslar, Germany, a leading global provider of customer-specific tungsten powder, and part of H.C. Starck Group GmbH, has been acquired by Vietnamese-based Masan Resources. A subsidiary of Masan Group, Masan Resources is a supplier of critical minerals including tungsten, fluorspar and bismuth.

According to the H.C. Starck Group, all required approvals by government authorities have been received, allowing completion of the transaction.

H.C. Starck Tungsten Powders develops and produces high-performance powders made from the refractory metal tungsten and its compounds. It has a patented recycling process with which it extracts tungsten in what it states as the highest quality from secondary raw materials. The business has approximately 540 employees across three production sites in Germany, Canada and China, as well as sales offices in the USA and Japan.

Masan Resources is reported to have one of the world's largest tungsten deposits and associated refining facilities outside of China.

"The entry of a strategic owner on time for the hundredth anniversary we are celebrating this year marks the beginning of a new era for our company," stated Dr Hady Seyeda, CEO of H.C. Starck Tungsten Powders.

"We can now fully focus on global growth as a technology and quality leader in tungsten powder. Direct access to primary raw materials as a complement to our recycling expertise means even more flexibility and security for our customers all over the world."

Craig Bradshaw, CEO of Masan Resources commented, "The competencies of both companies in the field of raw materials on the one hand and the highly specialised processing on the other complement each other perfectly. For us, this transaction is the next strategic step in executing on our vision to become a leading global vertically integrated high-tech industrial materials platform."

www.hcstarck.com
https://masangroup.com

Kymera closes transaction to acquire Reading Alloys business from Ametek

Kymera International, Raleigh, North Carolina, USA, has closed its transaction with with Ametek, Inc., Berwyn, Pennsylvania, USA, and has now acquired 100% of the shares of the Reading Alloys business.

Founded in 1953, and acquired by Ametek in 2008, Reading Alloys designs, develops and produces master alloys, thermal barrier coatings and titanium powders. The business is a supplier for producers of high-quality titanium and superalloy mill products that are used in aerospace and aircraft applications.

"Reading Alloys is an outstanding company with highly skilled people and an excellent product and end market portfolio that fits in perfectly with our existing business," stated Barton White, CEO of Kymera. "For Kymera, we believe this is a transformative acquisition that will give our combined company strong technical and commercial resources to help fuel our growth in the aerospace, defence, medical and industrial markets."

www.kymerainternational.com
www.readingalloys.com

Severstal eyes Binder Jetting with acquisition of carbonyl iron powder producer Sintez

PAO Severstal, a leading steel and steel-related mining company headquartered in Moscow, Russia, has acquired 100% of the shares of Sintez-CIP Ltd and Sintez PP Ltd, the owners of the only producer and supplier of carbonyl iron powders in Russia and the CIS region. Sintez-CIP will become part of Severstal's metalware manufacture division, under the operational management of Sergey Kovryakov, CEO of Severstal-metiz.

Sintez-CIP produces a wide range of unique carbonyl iron powders for firms around the world. Carbonyl iron powder is used in Metal Injection Moulding and other Powder Metallurgy-based technologies. It is also widely used in electronics, primarily in the automotive industry (electronics in cars, electric vehicles), as well as in the manufacture of household appliances, mobile phones, computers, and televisions.

Sintez-CIP is reported to be the second-largest producer of these products globally, holding approximately 10% of the market share. The company produced more than 1,500 tons of finished goods last year, and exported more than 95% of its sales.

Alexander Shevelev, CEO of Severstal, commented on the acquisition, "This investment reflects our focus on two of Severstal's strategic priorities – 'New Opportunities' and 'Excellent Customer Experience'. Through the implementation of breakthrough technologies, we are bringing unique solutions to the market in order to satisfy the needs of modern customers, as well as, in some cases, anticipating their future demands."

"Integrating Sintez-CIP into Severstal will add a new trajectory of development for the company into promising markets such as electronics, where we expect sustained growth through key developments," he continued. "Examples include the electrification of transport, the development of telecommunications infrastructure, mobile electronics, and finally 'Binder Jetting', which is considered to be an important technological breakthrough due to its high processing speed and low costs."

Andrey Laptev, Director of Business Development and Corporate Venture Projects at Severstal, added, "Sintez-CIP has unique competencies that have enabled it to occupy 10% of the fast-growing global carbonyl iron market, and continually increase its presence in the most promising segments of the sector."

"We are aiming for consistent growth in this high-margin market, using the broad competencies and market opportunities Severstal has cultivated," he explained. "Our overarching goal is to create a world-class Powder Metallurgy centre of excellence within the business. Sintez-CIP allows us to expand our market influence, and also creates a springboard for us to enter international markets."

www.severstal.com | https://en.sintez-cip.ru

AM part maker 3DEO reports 600% revenue growth in 2019

3DEO, Inc., a metal Additive Manufacturing technology company based in Los Angeles, California, USA, has announced a 600% growth in revenues for 2019 over 2018. The company also reported a 394% increase in the number of additively manufactured parts shipped in 2019, with approximately 25% of parts being for aerospace, 35% for medical and 40% for defence applications.

The number of employees at 3DEO was also reported to have increased to sixty, up 172% compared to the twenty-two employees in 2018. AM machines used at 3DEO for part production were said to have increased by 566%. 3DEO's AM machines are built with proprietary technology, specialised for serial production and manufactured in the USA.

"We are very proud of the growth that was accomplished over the last year," stated Matt Sand, President of 3DEO. "It is clear that 2020 will be another record-setting year for 3DEO as our pace of adoption across all industries is accelerating. More than a metal 3D printing company, 3DEO is a solutions provider helping our customers tackle their most challenging manufacturing problems."

The company started as an Additive Manufacturing business with its patented metal AM technology, Intelligent Layering®, at its core. However, in order to compete in high-volume traditional manufacturing, the company stated it evolved into a vertically integrated, next generation factory. This new business model allows manufacturers to gain the cost savings, design freedom, and manufacturing flexibility needed to compete – without having to incur millions of dollars for a metal AM machine and the supporting infrastructure.

Amidst a downcycle in manufacturing jobs in America, 3DEO reports that its new solution-focused business model is creating new jobs. High-tech production workers work with robotics and automation and its most noteworthy employee increase was in the R&D department. With over twenty-five engineers, 3DEO states it is continuously improving core processes and technology up and down the production line.

Sand added, "What's more, almost every customer we are working with is using metal 3D printing in production for the first time. We are in the trenches with our customers, and our growth curve is a testament to the demand for these solutions. In the end, our mission is to do for manufacturing what Amazon's AWS did for the internet by offering low-cost access to flexible, scalable, and world-class manufacturing infrastructure."

Matt Petros, 3DEO's CEO, commented, "We're doing things in manufacturing that previously couldn't be done. And we're doing it by leveraging several enabling technologies that are converging right now in manufacturing – in a way that finally allows metal 3D printing to shift the serial production paradigm."

www.3deo.co

voestalpine reports impact of 'economic meltdown' as revenue falls

Austria's voestalpine Group has reported that both revenue and earnings in its business year 2019/20 have been impacted by 'economic meltdown', non-recurring effects and the consequences of the COVID-19 pandemic. The group reported a year-over-year decline in revenue of 6.2%, from €13.6 billion to €12.7 billion, with profit from operations (EBIT) falling to €-89 million (previous year: €779 million) due to impairment losses. Profit before tax dropped from €646 million to €-230 million, and profit after tax from €459 million to €-216 million.

The business year 2019/20 was said to be defined by a massive dampening of sentiment in the economic environment, owing to worldwide trade conflicts. These developments hit Europe's export-driven industry, which accounts for about two-thirds of the group's revenue, particularly hard.

The automotive segment, which is important to the voestalpine Group, slumped worldwide. Add to that globally rising iron ore prices in the face of simultaneously falling steel prices, and an upward trend did not make itself felt until the start of the business year's fourth quarter, stated the company, only to be brought to a sudden standstill by the outbreak of the COVID-19 pandemic.

"The decline in the voestalpine Group's revenue for the business year 2019/20 reflects the economic downturn on the whole throughout the business year. But negative non-recurring effects also had an impact on the results. Given the intensifying deterioration in the economic environment on account of COVID-19, we will consistently pursue current programs that are aimed at cutting costs and boosting efficiency," stated Herbert Eibensteiner, Chairman of the Management Board of voestalpine AG.

The COVID-19 pandemic and its economic consequences forced voestalpine to curtail production and temporarily shut down plants in almost all of its areas; this included a small blast furnace in Linz, Austria, that has been shut down until further notice. In May 2020, about 10,400 employees in Austria and about 3,000 employees in Germany were registered for short time work, and another 2,400 employees internationally for similar schemes.

"Given the continued volatility of the economic environment, we expect the voestalpine Group to generate EBITDA of between EUR 600 million and EUR one billion in the business year 2020/21," concluded Eibensteiner.

www.voestalpine.com


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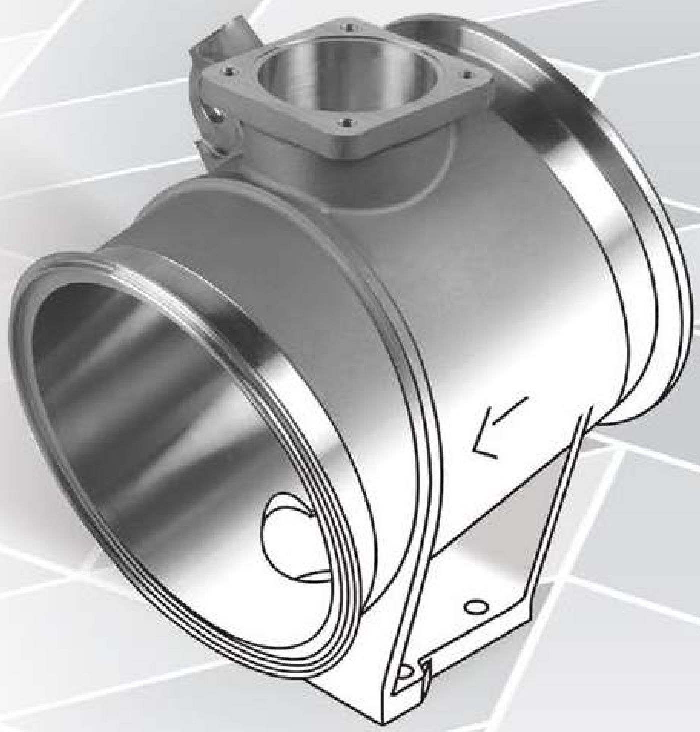

Falcontech to install fifty Farsoon metal AM systems at Super AM Factory

Aerospace manufacturing service provider Falcontech co., LTD., Wuxi City, Jiangsu, China, has announced plans for a Super AM Factory which will see the installation of fifty metal Additive Manufacturing machines from Farsoon Technologies, Changsha, Hunan, China. Falcontech reportedly plans to enhance its capacity for series production, and will begin adding further metal AM machines, bringing its total to twenty Farsoon machines by the end of this year.

Founded in 2012, Falcontech has three business units: Metal AM Powder, Metal AM Solution and Advanced Manufacturing. The AS9100-certified company states that it is able to offer a comprehensive portfolio of industrial metal AM solutions, from materials to manufacturing, post-processing, application and servicing.

The company has over seven years' experience operating Laser Beam Powder Bed Fusion (PBF-LB) machines from various international brands, and has reportedly developed a deep in-house expertise in industrial metal AM production. The company's Super AM Factory initiative aims to expand its capacity and focus on real world production.

Falcontech entered into a long-term partnership with Farsoon by significantly investing in its metal AM systems in 2019. In recognition of this collaboration, Falcontech and Farsoon have jointly worked on a customised large-format metal AM system for aerospace, as well as on the development of Falcontech's metal AM powders.

Based on this collaboration, Falcontech has scaled up its manufacturing capacity by installing multiple Farsoon metal systems including an FS421M, FS301M, FS271M, and the customised large-format metal system, which has a build envelope of up to 620 x 620 x 1100 mm. This system is used at Falcontech for the production of large aerospace applications; the company has succeeded in supporting the development and series production of spacecraft components in a number of key aerospace projects.

With the joint effort between Farsoon's metal AM team and Falcontech, significant technical progress has reportedly been made in areas including productivity optimisation, the achievement of thin wall structures as small as 0.5 mm, improved dimensional-accuracy ± 0.5 mm/800 mm, improved build surface roughness of Ra 6.3 μm, and metallurgical quality control of parts produced on Farsoon machines.

Thanks to Farsoon's 'Open for Industry' philosophy, Falcontech reports that it is able to operate with a higher degree of flexibility in parameter settings and material development, which has contributed to the development of a total of twenty material processing parameters for aerospace applications, including multiple types and grades of titanium alloys, aluminium alloys and nickel-based superalloys. This has also enabled the establishment of a processing database for aerospace materials for future development and manufacturing quality control.

"We see an exceptional performance and stability in the Farsoon FS421M metal system via multiple series production jobs since the installation," stated Yu Hai, General Manager of the Metal AM Solution Unit at Falcontech, "We are thrilled by the high-quality parts manufactured taking advantage of the benefits from Farsoon AM. With the increasing demand of manufacturing orders, Falcontech will further expand our production capacity and improve turnaround time for delivery with more Farsoon metal systems."

http://en.farsoon.com
www.falcontech.com.cn

Falcontech will install fifty Farsoon metal AM machines in its production facility (Courtesy Falcontech)

Submitting news..

Submitting news to *Metal AM* is free of charge. For more information contact Paul Whittaker: paul@inovar-communications.com

Altair releases its most significant software update to date

Complex FE models can be managed more easily in the new Altair HyperWorks user interface (Courtesy Altair)

Altair, Troy, Michigan, USA, has announced what it states is the most significant software update released in the company's history. All of its software products have been updated with advancements in user experience and a large number of new features, including intuitive workflows said to enable users to streamline development and bring products to market faster. The software update release expands on the number of solutions available for designers, engineers, data analysts, IT and HPC professionals, facility managers and more, and reportedly enables access to more physics, data analytics and machine learning.

"Our teams are always driven to develop and provide access to a range of different technologies that enable our customers to break through complex problems, and explore and discover on their own terms," explained James Scapa, chairman, founder and Chief Executive Officer of Altair. "This software update release is the largest collection of our applications for design, simulation and data analytics."

Enhancements and new capabilities added in the update include a new interface for Altair HyperWorks for high-fidelity computer-aided engineering (CAE) modelling and visualisation, increasing productivity, as well as a new subsystem entity for modular model configuration. Fatigue optimisation has also been added to Altair SimLab and the integration of Altair SimSolid in Altair Inspire, includes support and connector reaction forces, instantaneous reaction time modelling of large PolyNURBS models, and improved geometry generation from optimisation.

The addition of advanced morphing of any geometry type to Inspire Studio is another feature, as is a major update to Altair Panopticon, a platform for user-driven monitoring of real-time data, which adds cloud-based deployment, enabling users to build, modify and share custom-designed functions and content easily via standard web browsers.

www.altair.com

Aurora Labs announces board and executive team changes

The board of Aurora Labs, headquartered in Bibra Lake, Australia, has announced that David Budge, the company's current Managing Director and CEO, will assume the new role of Chief Technical Officer, with Peter Snowsill, currently Chief Operations Officer, acting as interim CEO pending a new CEO's appointment.

To ensure the appropriate board makeup for a company at Aurora's size and development stage, Paul Kristensen, current board chairman, is to retire from the board. David Budge and Nathan Henry, the current Executive Directors, will also retire from their board positions to ensure the Aurora Board is majority non-executive in makeup, said to be in-line with best practice for ASX-listed companies. Two new non-executives have joined the board, Grant Mooney joins as non-executive chairman, and Ashley Zimpel joins as a Non-Executive Director.

Mooney is said to have significant experience in ASX-listed development companies across all stages and is the principal of Perth-based corporate advisory firm Mooney & Partners, which specialises in corporate compliance administration to public companies. He has gained extensive experience in the areas of corporate and project management since commencing Mooney & Partners in 1999, and his experience extends to advice on capital raisings, mergers and acquisitions and corporate governance. Mooney is chairman, director and company secretary of a number of ASX-listed companies in the resources and technology sectors.

Zimpel is described as a business developer, founder, entrepreneur, corporate financier, adviser and senior banker/investment banker, with broad financial markets experience. He is reported to have a strong record of capital raising in both equity, debt and structured financial products for start-ups, SMEs, ASX-listed public companies and government agencies both in Australia and internationally. His stockbroking and investment banking experience reportedly spans over thirty years across capital markets, corporate finance and public company businesses.

Outgoing board chairman Kristensen commented, "Aurora has received an increasing level of interest from several major international businesses for its 3D printing technology, so it's imperative we are able to capitalise on this by ensuring we have the optimal skillset at a board and Executive level for the next exciting phase of the company's evolution."

"As the company's founder, David has been an integral part of Aurora's development since its inception and his knowledge of 3D printing technology and the broader Aurora business is invaluable," he added. "This is why I'm delighted that David will continue at the company as CTO, which will enable him to focus on his primary expertise of cutting-edge research into 3D metal printing."

www.auroralabs3d.com

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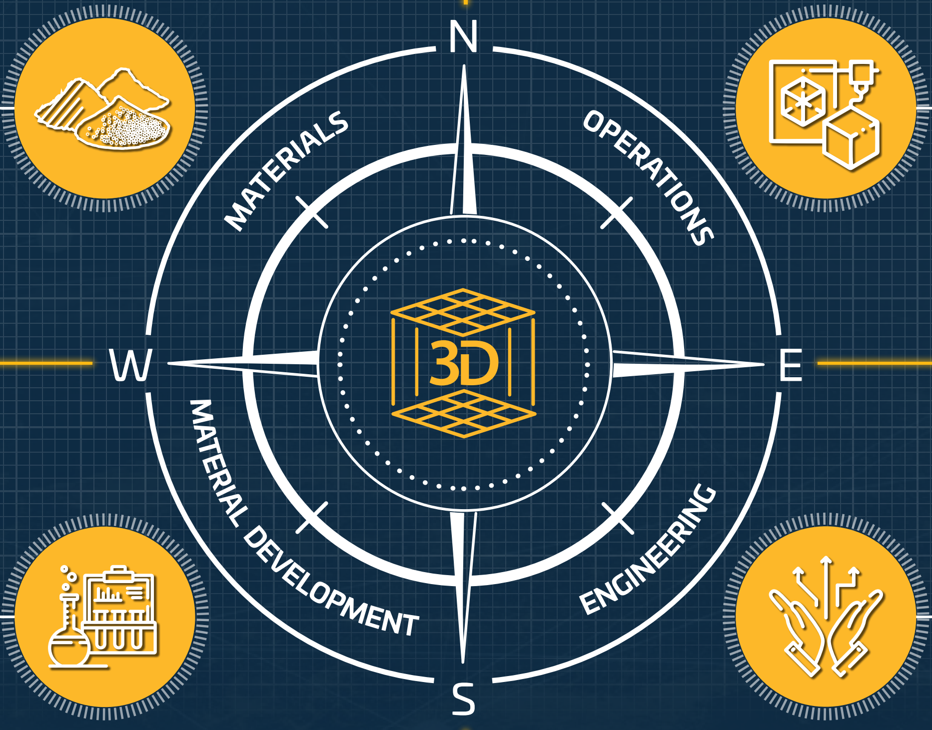

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- ASTM standardized methods to certify chemical composition

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- Application know-how
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MATERIALS → PART

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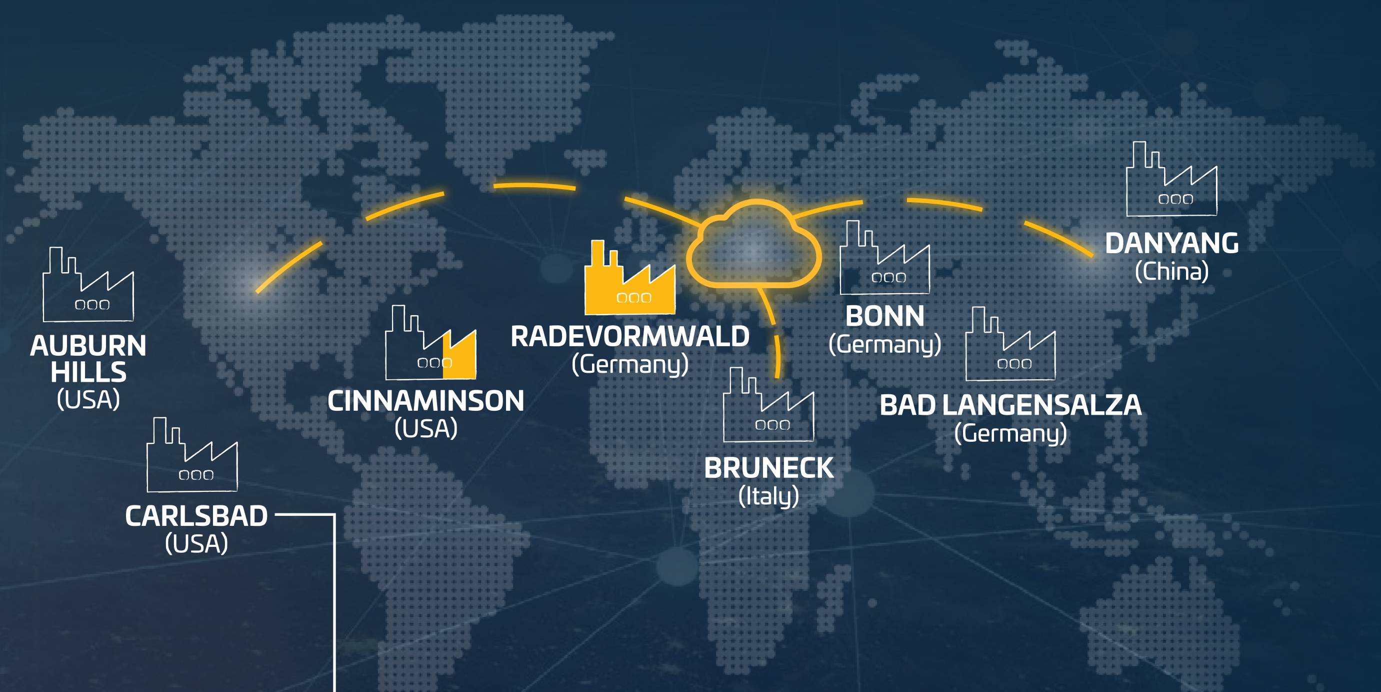
GKN ADDITIVE

GLOBAL PRINT NETWORK

R&D and manufacturing locations accross Europe, North America and Asia form our Global Print Network. It is part of GKN Additive's completely digitized value chain from powder to part.



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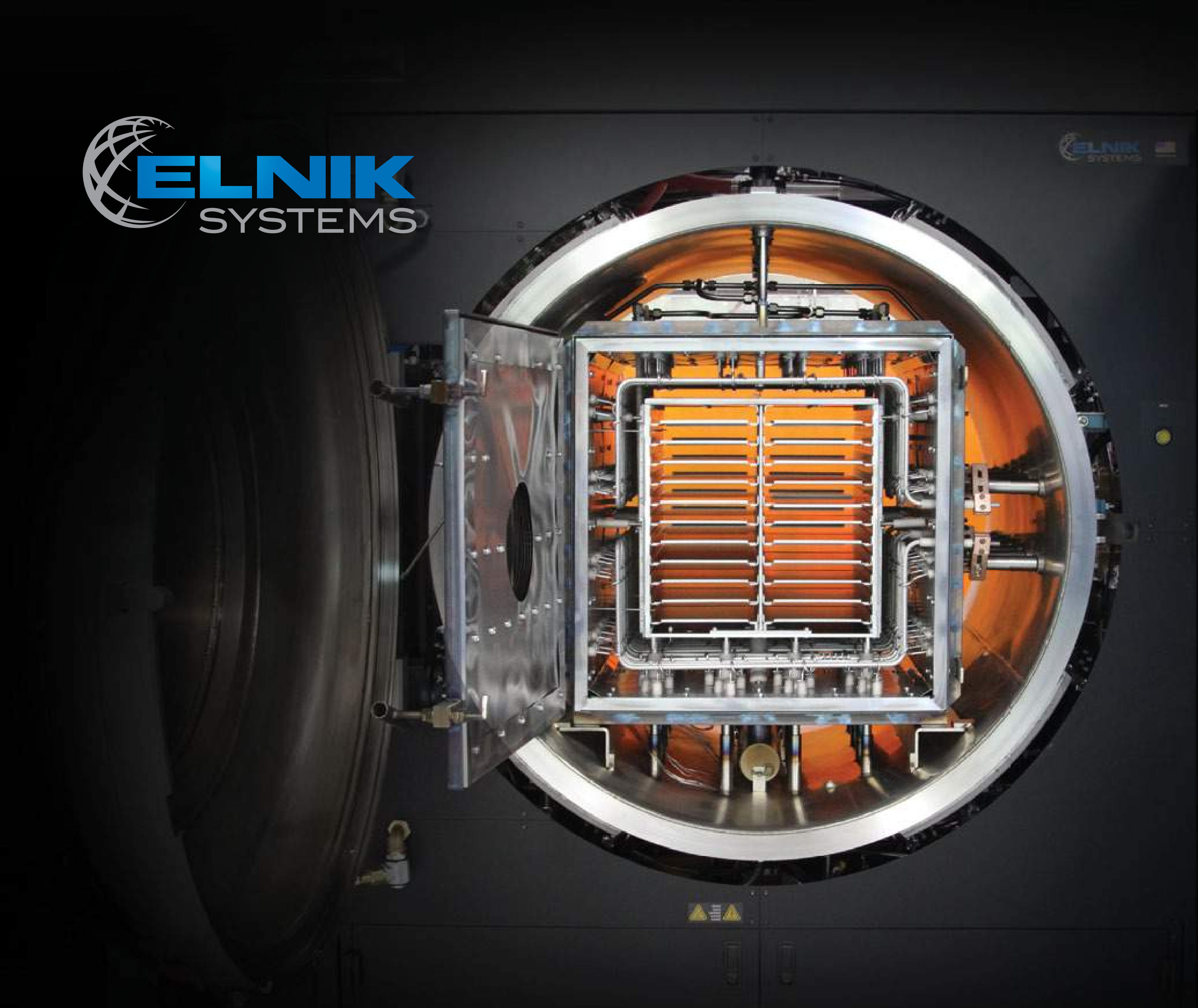
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Markforged publishes Trends Report and Additive Applications Library for AM

Markforged, Watertown, Massachusetts, USA, has released a new Trends Report and Additive Applications Library said to show how modern manufacturers are using Additive Manufacturing to drive supply chain optimisation and value in their organisations.

The company explains that the two new resources examine more than 100 applications within the aerospace and defence, automotive, education, electronics, medical and manufacturing industries, and applications across prototyping, tools and fixtures, end-use parts and maintenance parts.

Trends Report: The additive movement has arrived

Markforged analysed over 100 applications across six industries to understand how AM is being used currently. The report found an array of applications said to demonstrate a strong, growing movement toward Additive Manufacturing.

The applications centred around four major themes: accessibility, design freedom, physical strength and durability, and reliability – all of them were meant to improve or complement their conventional manufacturing processes and workstreams.

The report discusses how the applications are changing the way industries operate and showcases a range of AM applications that are changing manufacturing, from the ability to relieve skilled workers to focus on prototyping instead of tooling to producing critical experimental test nozzles in a matter of days instead of months. The scope of applications included reportedly offers a unique view into the manufacturing industry and how AM is driving business value.

The Additive Applications Library

Markforged explained that its new Additive Applications Library allows users to find real-world AM use cases and examples from Markforged customers globally. Users can filter by industry, application, and materials to help to identify similar Additive Manufacturing opportunities in their organisation and provide inspiration for new ways to improve their manufacturing processes.

"Many of our industry peers still believe that the value of Additive Manufacturing is ten to fifteen years away when you can 3D print houses, cars, and airplanes," stated Michael Papish, VP of Marketing at Markforged.

"But we're seeing real value with customers today. Applications we're featuring in our new Trends Report and Applications Library are already practical applications that manufacturers can use to save money, reduce downtime, and open up new revenue streams. Additive isn't future hype, it's already here, calling from inside the house," he concluded.

www.markforged.com

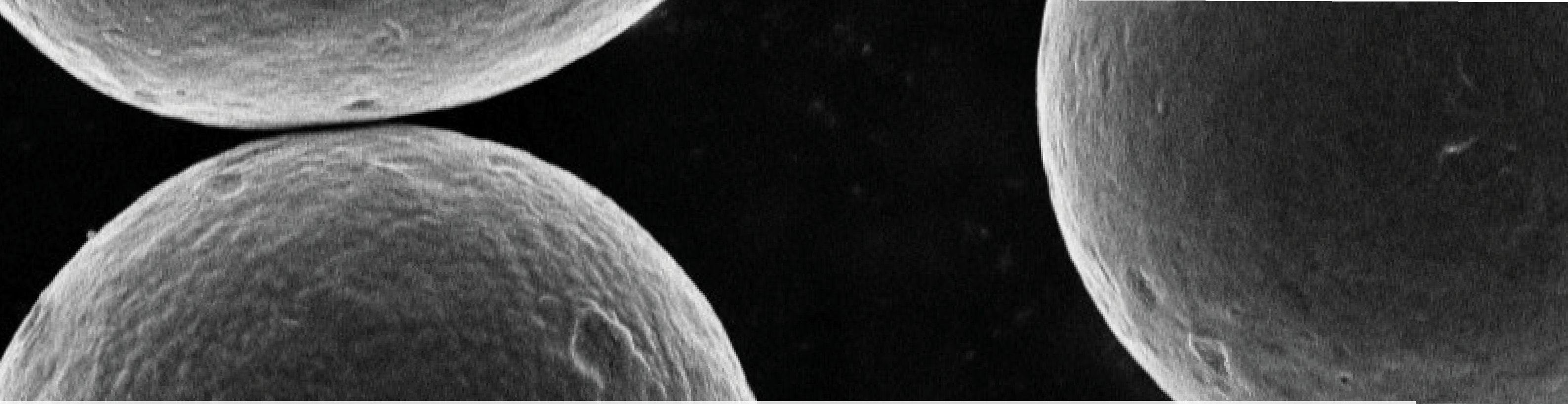
Rosswag qualifies Ni-base superalloy Waspaloy for Additive Manufacturing

Rosswag GmbH, Pfinztal, Germany, has qualified the nickel-base superalloy Waspaloy for Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing. Waspaloy is a registered trademark of United Technologies Corp that refers to an age-hardening austenitic nickel-base superalloy.

The alloy has a tensile strength of 1400 MPa, exceeding that of some of the nickel-base alloys most frequently used in the AM process, such as Inconel 718. Due to its good strength properties at temperatures up to approx 980ºC, it is typically used in high-temperature applications, particularly in gas turbines.

The company stated that its in-house process chain enables it to qualify materials for PBF-LB within a few weeks, using its small-scale atomisation plant and comprehensively equipped metallurgy laboratory. Drawing on these resources, the company has reportedly qualified more than thirty-five alloys for PBF-LB in recent years.

www.rosswag-engineering.de



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www.cnpcpowder.com

Aerojet Rocketdyne receives $1.79 billion NASA contract for additional moon mission engines

Aerojet Rocketdyne, Los Angeles, California, USA, has been awarded a $1.79 billion contract modification from NASA for the production of an additional eighteen RS-25 engines to support future deep space exploration missions, in support of NASA's Artemis Program to return America to the Moon.

The flight-proven, high-performance RS-25 engines are used to propel NASA's Space Launch System (SLS) rocket, a critical element of the Artemis program. As NASA looks to land the first woman and next man on the Moon with the Artemis programme, SLS is the super heavy-lift rocket that will carry the crew and cargo to the lunar vicinity.

There are currently sixteen RS-25 engines remaining from NASA's Space Shuttle Program that have been upgraded, tested, and are ready to support the first four SLS missions. Aerojet Rocketdyne is already building six new expendable RS-25 engines that target more than a 30% cost reduction on future production when compared to the versions that flew on the Space Shuttle. Delivery of these new engines will begin in 2023.

The additional eighteen engines continue to leverage supply chain optimisation and the incorporation of modern manufacturing techniques, like metal additive manufacturing, that were introduced in the initial SLS engine production.

The RS-25 engines used on the SLS are reported to contain multiple metal AM components. One is a vibration dampening device, the pogo accumulator assembly. The pogo accumulator assembly is a complex piece of hardware consisting of two components – the pogo accumulator and pogo-z baffle – and acts as a shock absorber to dampen oscillations caused by propellants as they flow between the vehicle and the engine. This is important component to ensuring a safe flight by stabilising these potential oscillations.

"The nation is returning to the Moon and moving forward with plans to explore other deep space destinations, including Mars," commented Eileen Drake, Aerojet Rocketdyne's CEO and president. "This contract ensures our flight proven RS-25 engines will be there every step of the way as NASA successfully and safely achieves these objectives."

The first four RS-25 engines for the Artemis I SLS flight have reportedly been integrated with the core stage, which is undergoing green run testing at NASA's Stennis Space Center. Later this year, all four engines will be fired simultaneously, as they will in flight, on the B-2 test stand.

The second set of four engines for Artemis II is said to be complete and is stored at Aerojet Rocketdyne's facility at Stennis. Once the Artemis II core stage that is being built at NASA's Michoud Assembly facility in New Orleans, Louisiana, USA, is complete, the engines will be ready for integration.

www.rocket.com
www.nasa.gov


Aerojet Rocketdyne is to produce an additional eighteen RS-25 engines for NASA's Artemis program (Courtesy Aerojet Rocketdyne)

Osseus Fusion Systems receives ISO 13485:2016 certification

Osseus Fusion Systems, Dallas, Texas, USA, reports that it has received ISO 13485:2016 certification with the Medical Device Single Audit Program (MDSAP), part of the US Food and Drug Administration (FDA), which will reportedly allow the company to accelerate growth of its spinal fusion and fixation products.

Osseus is a medical device company specialising in advanced technology products for minimally invasive surgery. ISO 13485:2016 specifies requirements for a quality management system where an organisation needs to demonstrate its ability to provide medical devices and related services that consistently meet customer and applicable regulatory requirements.

Derek Holland, VP Sales, Osseus Fusion Systems, commented, "We are excited to announce this ISO certification milestone and feel it exemplifies our drive for an impeccable level of quality and compliance. Additionally, with demand that already exists, we now have the opportunity to pursue international supply chains that give us incredible growth potential."

www.osseus.com

Carpenter announces restructuring efforts

Carpenter Technology Corporation, Philadelphia, Pennsylvania, USA, has announced a set of company-wide restructuring actions aimed at strengthening its performance. The plan includes reducing approximately 20% of Carpenter Technology's total global salaried positions, which is expected to generate approximately $30–35 million in annual cost savings. The company expects to record a pre-tax charge of approximately $10 million in the fourth quarter of the fiscal year 2020 as a result of implementing these reductions.

In addition, Carpenter Technology states that it has taken other significant actions to position itself to manage through the market disruption caused by COVID-19 and strengthen its foundation for sustainable long-term growth and value creation.

These measures include reviewing and prioritising capital investments to target existing and future growth markets as well as exiting the Amega West oil & gas business and the idling of powder facilities in Rhode Island and West Virginia. Collectively, the move is expected to generate $60 to $70 million of annual cost savings, in addition to the significant cash benefits expected to be realised.

"The COVID-19 pandemic has created challenges that we have met head on," stated Tony R Thene, president and CEO, Carpenter Technology Corporation. "Our business remains firmly on the foundation that has been built over 130 years as a recognised leader in high-performance speciality alloy-based materials and process solutions for critical applications. The actions we are announcing today, as well as those already deployed, are expected to make us even stronger."

"Although difficult, we have taken thoughtful and aggressive actions to combat the uncertainty in the near-term environment," he continued. "Our actions are focused on the future and are expected to have a significant impact on profitability and free cash flow in fiscal year 2021 and beyond."

"We have an impressive manufacturing footprint that includes unique assets capable of producing products that only a few in the world can match," he added. "Our facilities have been continuously operating during the crisis, as our safety culture provided a solid foundation for quickly adapting to the current challenges. The long-term outlook for our key end-use markets remains solid and we have significantly bolstered our position during these uncertain times by demonstrating our resilience in support of our customers' needs."

www.carpentertechnology.com

Amaero patent for high-performance titanium alloy enters final phase

Amaero International Limited, headquartered in Notting Hill, Victoria, Australia, reports that its international patent application for its high-performance titanium alloy Amalloy Beta Ti has entered its final approval stage, the national phase of the Patent Co-operation Treaty (PCT).

The PCT is an international treaty with more than 150 Contracting States, allowing patent protection for an invention simultaneously in a large number of countries by filing a single international patent application, instead of filing several separate national or regional patent applications. The granting of patents remains under the control of the national or regional patent offices, called the 'national phase', which Amalloy Beta Ti has now entered.

According to Amaero, the new high-performance titanium alloy, a heat treatable version of a beta titanium alloy, achieves ultra-high strength and fatigue performance via homogeneous precipitation and the removal of grain boundary alpha. Considered to be the highest strength-to-weight ratio of any structural metal, titanium is used in multiple applications across the aviation, defence and space industries, all markets which have been experiencing significant long-term growth in value, presenting a significant opportunity for the company.

The alloy was developed by researchers at Australia's Monash University, with which it collaborates for the development of Additive Manufacturing technology.

Amaero says it has exclusive global commercial license rights to the patented alloy, and believes it will form an important part of the company's offering to its aviation, defence and space clients in the future.

A second new high-performance alloy developed by Monash University for Amaero is also due to enter the national phase. Barrie Finnin, Amaero CEO, commented, "The team at Monash designed a heat treatable beta titanium alloy with a novel composition resulting in significant improvements to yield strength of around 30%, as well as enhancing Ultimate Tensile Strength (UTS), shear strength and fatigue life. In an aerospace context, being able to deliver improved durability, performance and saving weight makes a strong case for this new alloy to be used in place of the traditional options."

www.amaero.com.au

AMCM launches M 4K industrial metal AM machine for metre-high parts

AMCM has begun serial production of its AMCM M 4K-1 and AMCM M 4K-4 Additive Manufacturing machines (Courtesy AMCM)

Additive Manufacturing Customized Machines (AMCM), an EOS Group company based in Starnberg, Germany, has launched its AMCM M 4K-1 (single laser) and AMCM M 4K-4 (four laser) industrial Laser Beam Powder Bed Fusion (PBF-LB) metal Additive Manufacturing machines.

Built on the proven EOS M 400 platform, the AMCM M 4K is designed for the production of large components, with a build height of up to 1 m. Additional features include increased robustness of the frame design, a new filter system (RFS 2.0), and optional soft recoating. The AMCM M 4K can produce parts from a wide range of materials, including aluminium (AlSi10Mg), nickel alloy (IN718) and copper alloy (CuCr1Zr).

Martin Bullemer, Managing Director of AMCM, stated, "The AMCM M 4K is a wholly new offering that we have been perfecting for two years. What customers can appreciate is that its underpinnings are that of the EOS M 400 processes – which are the benchmark for metal 3D printing. Our team is extremely proud of this system now producing the biggest, highest quality metal powder bed 3D printing applications in the world."

Mission critical applications: Launcher combustion chamber

PBF-LB Additive Manufacturing is used for some of the most demanding applications – including high-performance and mission critical parts. Rocket developer Launcher was one of the AMCM M 4K's earliest adopters, using the technology to produce its copper alloy E-2 combustion chamber, a very large additively manufactured liquid rocket engine.

"The AMCM M 4K solved for both our desire to 3D print a tall combustion chamber in a single piece, and produce it in a copper material," explained Max Haot, Launcher CEO. "Printing in a single piece reduces cost and enables the highest-performance regenerative cooling design."

Launcher will be testing the E-2 at NASA Stennis as part of an Air Force Phase II SBIR later this year. The AMCM M 4K platform is a global offering and is available now, and several machines are currently in production at the company's dedicated new production facility in Starnberg. In addition to the AMCM M 4K platform, the company reports that it is producing further high-performance, customised industrial AM machines based on EOS technology.

https://www.amcm.com
https://www.eos.info/en

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ExOne announces five projects to advance binder jet AM

The ExOne Company, North Huntingdon, Pennsylvania, USA, has announced that five projects run by the company in partnership with Pennsylvania universities have received funding through the Manufacturing PA Innovation Program to advance metal Binder Jetting (BJT) Additive Manufacturing.

The award is part of a wider funding round in which Pennsylvania's Department of Community and Economic Development (DCED) awarded $2.8 million to Pennsylvania universities for forty-three projects on advanced manufacturing technologies

ExOne's Binder Jetting systems are currently able to additively manufacture parts in more than twenty metals, ceramics and composite materials, but important R&D work is still needed to further advance the production technology.

"The Manufacturing PA program is helping ExOne to expand our research and development efforts in important ways with the assistance of Pennsylvania's outstanding universities and other technology companies," stated John Hartner, ExOne CEO. "The projects funded by this program will help ExOne unlock the commercial and sustainability value that binder jet 3D printing has to offer, such as delivering lighter weight vehicles that are more fuel-efficient as well as all-new innovations."

ExOne's Additive Manufacturing machines are believed to be the most researched in the field of Binder Jetting, and this work has played an important role in advancing ExOne's BJT strategies, materials and processes.

"We strongly value our relationships with the academic R&D community, and we appreciate their support enhancing our competitiveness and advancing this important 3D printing field," Hartner added. "We congratulate our partners and all of the other universities and companies receiving Manufacturing PA Innovation funding."

The five projects funded by Manufacturing PA are expected to help ExOne resolve challenges related to the Binder Jetting of irregular and porous powders, as well as sintering and identifying parts that can best benefit from Binder Jetting, among other projects. The awards are as follows:

- Carnegie Mellon University: 'Binder Jet 3D Printing from Powder Produced by Metal Attrition.' This project will work to optimise BJT AM parameters and densification of irregularly shaped powders, such as those experiencing attrition.
- Carnegie Mellon University, with Kennametal and Ansys: 'Optimal Parts Consolidation and Structural Redesign for Additive Manufacturing to Reduce Weight, Production Costs, and Lifecycle Fuel Use.' This project aims to create a software tool that allows users to upload a CAD file of a large-scale system and automatically identify components and subsystems for consolidation and optimisation with BJT. This will allow manufacturers to minimise production costs and lightweight existing parts while preserving functionality.
- The Pennsylvania State University: 'Advanced Manufacturing of Ceramics for PA Industries.' This project aims to develop a new class of ceramic materials using Binder Jetting technology, which will provide a unique combination of high-temperature stability, corrosion resistance and toughness for a wide range of applications.
- University of Pittsburgh with Ansys: 'A Computational Tool for Simulating the Sintering Behavior in Binder Jet Additive Manufacturing.' This project aims to develop a computational tool for simulating the deformation and porosity resulting from the sintering of binder jet additively manufactured parts made of 316L stainless steel.
- Villanova University: 'Wetting of Binder Solution on Porous Bed of Microparticles.' This project will investigate how to best wet porous particles with binder and generate guidelines or parameters for this form of AM.

www.exone.com

ExOne's Additive Manufacturing machines are believed to be the most researched in the field of Binder Jetting (Courtesy The ExOne Company)

Velo3D raises $28 million in Series D funding round

Velo3D, Campbell, California, USA, has raised $28 million in a Series D funding round. New investors Piva and TNSC joined the round, along with existing investors Bessemer Venture Partners, Playground, and Khosla Ventures, bringing Velo3D's total funding to $138 million.

The company states that it plans to use the new capital to expand its product portfolio to include more machine options, compatible alloys, and enhanced software and hardware capabilities. It anticipates that the injection of fresh capital will help it to reach sustainable profitability by mid-2022.

Founded in 2015, Velo3 announced availability of its Sapphire AM machine in 2019. In its first year of commercialisation, the company reported nearly $30 million in sales and gained seven new customers, many of which have placed repeat orders.

Piva, which is said to be the largest investor in this new round of funding, has a strong heritage in industrial markets, as it is backed by Malaysia-based PETRONAS, one of the world's largest energy companies.

"With the Velo3D integrated solution of Flow™ advanced pre-print software, Sapphire™ printer, and Assure™ quality management software, companies can finally break free of the constraints of existing metal Additive Manufacturing processes," stated Benny Buller, Founder and CEO of Velo3D. "Customers in industries such as aerospace, oil & gas, and power generation are now able to achieve part quality for their mission-critical applications with performance levels that weren't possible before with 3D metal printing."

Ricardo Angel, CEO and Managing Partner at Piva, commented, "Velo3D is revolutionising the way we think about advanced manufacturing today. We have been impressed by Benny, the team and their breakthrough technology that will have a significant impact on the efficient design and manufacturing of more complex components, previously unattainable, with clear commercial traction already in the aerospace and aviation markets."

Angel added, "Velo3D will lead a new wave of more resilient, distributed manufacturing capabilities for its most critical components, which the world will need to ensure local product availability and timeliness, while mitigating potential future worldwide disruptions."

www.velo3d.com
www.piva.vc

Formnext 2020 remains on course for November event, with digital options if required

Mesago Messe Frankfurt GmbH, the organiser of Formnext, reports that it still expects the event, scheduled to take place in Frankfurt, Germany, from November 10–13, 2020, to go ahead. The organiser also states that it is working on a concept for safeguarding the health of attendees and a supplementary digital programme.

"We remain convinced of the unique value and advantages of a physical exhibition," explained Sascha F Wenzler, Vice President of Formnext, Mesago Messe Frankfurt GmbH. "And although digital interaction will never be able to replace face-to-face contact, it does offer more scope than previously thought possible only a few weeks ago."

It is for this reason that the organiser intends to consider digital options for Formnext, for example, exhibitors will also be given the opportunity to present products and solutions digitally to the international trade audience. Concepts and platforms are currently being developed for this purpose with further details to be released in the coming weeks.

According to the organiser, the rulings of the Federal Government and the Federal States of Germany, dated May 6 2020, stating that trade shows are no longer considered to fall under the category of major events that pose a particular health risk, also give cause for optimism for the event to run as planned in November.

Wenzler added, "This is great news not only for the trade show industry, but for the entire economy. Trade shows are an important driver of innovation and value creation in industry, especially after months of economic standstill in many industries and sectors."

The organiser explains that the health of exhibitors, visitors and employees remains a top priority. Therefore, concepts are currently being developed to ensure the highest standards of health protection. These include reducing visitor density, guaranteeing high hygiene standards and introducing contact tracing. These concepts are currently being coordinated with the responsible authorities and will be duly implemented in due course.

In addition to health protection, Formnext 2020 is reportedly being designed in consideration of a number of other important factors, such as the wider economic environment, the economic situation in the AM sector, and developments in the European and global travel industry.

"Ultimately, even in these challenging times, we want to organise a trade show that is as responsive as possible to the current situation and the needs of participants and the market," concluded Wenzler.

www.formnext.com


EOS M 290
EOS M 290

VBN Components accelerates growth with Swedish Scaleups

Ulrik Beste, Technical Manager (left) and Isabelle Bodén, Customer Relations at VBN Components (Courtesy VBN Components)

VBN Components, Uppsala, Sweden, has been adopted into the Swedish Scaleups programme, which helps innovative companies in Eastern Central Sweden to accelerate their growth. The company manufactures extremely abrasion- and heat-resistant metal components and tools for industrial use.

The company's finished metal alloys are marketed under the Vibenite® brand. Products are additively manufactured from Vibenite using the company's patented process, said to offer customers material savings of up to 87%, improved properties with integrated cooling channels, increased service life and lower weight.

Swedish Scaleups is aimed at mature companies that are ready to scale up seriously and invest in strong growth. The programme is completely industry independent and is said to be tailored to the needs of companies focusing on capital raising and internationalisation.

Together, through Swedish Scaleups, ten company incubators and science parks offer access to tailor-made support to scale up the companies' operations faster. VBN Components stated that the programme will offer it access to specialist knowledge in areas such as law, finance, marketing, leadership and technology. The goal is to move the company's products from early adopters to the mass market while maintaining the balance between growth, recruitment and cash flow.

Michael Camitz, Project Manager, Swedish Scaleups / Uppsala Innovation Centre, stated, "We are incredibly pleased that VBN Components sees the value of participating in Swedish Scaleups. It is an exciting company with a sustainable and innovative business concept as well as good conditions for rapid growth. We look forward to following their journey of success."

"Having been accepted to Swedish Scaleups is fully in line with our growth plan," added Ulrik Beste, Technical Manager at VBN Components. "The growth of a company can be described as a collection of geometric figures, that need to be placed in the market's previously different shaped holes. Swedish Scaleups helps with precision and how we can take shortcuts."

www.swedishscaleups.se
www.vbncomponents.se

Report expects high growth in aluminium powder market by 2023

A recently published report, by industry analyst IDC, sponsored by powder and material science company Equispheres, Ottawa, Ontario, Canada, predicts that the demand for aluminium powder in the Additive Manufacturing market will grow to over $695 million in 2023. Compared to the stated value of $147 million in 2018, this represents a compound annual growth rate of 36.5%.

The report, available to download from Equispheres' website, dissects and examines trends, technologies and challenges related to the metal AM market. It also discusses the challenges of introducing new technologies to the market and how Equispheres believes that it is positioned to help meet this market demand.

"The entire Additive Manufacturing industry has faced challenges surrounding the mechanical properties and reliability of their production powders for years," stated Kevin Nicholds, President and CEO of Equispheres. "Now recent events have permanently impacted existing supply chain approaches and there is immense market pressure on the Additive Manufacturing industry to improve process reliability and part mechanical properties so that supply chain gaps can be filled. With our unique powder, we have the ingredients to enable the industry to meet this challenge."

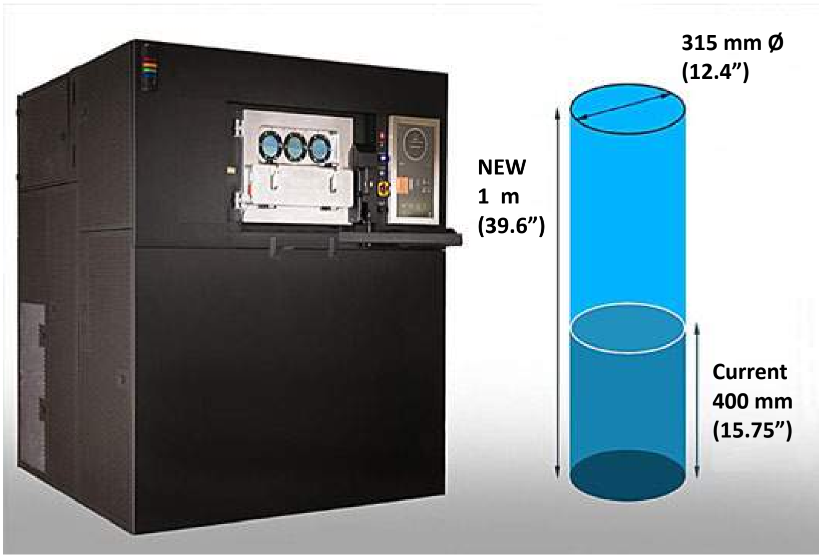
The IDC Technology Spotlight states that with the ability to use higher quality feedstock in production, metal AM, in certain applications, is now a much more appealing option.

www.equispheres.com

Velo3D launches metre-tall industrial metal AM machine, Knust-Godwin secures first order

Velo3D, Campbell, California, USA, reports that it plans to launch a next-generation Sapphire® industrial metal Additive Manufacturing machine with a vertical axis of 1 metre. The machine is scheduled to ship in Q4 2020, with precision-tool and component manufacturer Knust-Godwin having secured the first order to produce parts for an oil and gas application.

Technical features of the metre-tall Sapphire AM machine include a 315 mm diameter build plate, dual 1 kW lasers, in-situ optical calibration, as well as many of the same characteristics of the existing Sapphire machine. It is believed to be the world's tallest production metal Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing system, and is also compatible with nickel-based alloys.



Velo3D has launched a 1 m tall Sapphire metal AM machine (Courtesy Velo3D)

Knust-Godwin will utilise the new Sapphire machine to additively manufacture a part for oilfield drilling that is currently manufactured using more than five subtractive processes. Mike Corliss, VP of Technology at Knust-Godwin, stated, "There tends to be a trade-off between large-format additive machines and part quality; Velo3D is attractive to us because of their semi-conductor heritage and engineering disciplines around process control and metrology. We have confidence that we'll be able to build mission-critical industrial parts without compromises made to part quality."

"Our vision at Velo3D is to enable end-users to build whatever they want without the constraints of yesterday's standards," stated Benny Buller, Founder and CEO of Velo3D. "One of those constraints is the build envelope. A metre-tall system enables industrial applications that couldn't be built before, especially for oilfield service tools and flight hardware. Best of all, it will still utilise our highly patented Support-Free process, in-situ calibration, and process control for quality assurance."

www.velo3d.com
www.kgsbo.com

New hybrid AM process combines induction heating and low-pressure cold spray

Engineers from the University of Ottawa, Ontario, Canada, have designed a hybrid Additive Manufacturing technology that can help to prevent delamination of soft and ductile materials from hard substrates, reports ASM International.

According to the engineers, delamination is a challenge when using the cold spray process, and additional heat treatment processes have typically been used to address this problem. Unfortunately, to achieve significant improvements, long and extensive heat treatments are required.

As a potential solution to this issue, the engineers developed a tunable hybrid Additive Manufacturing process by coupling induction heating and low-pressure cold spray.

Pure aluminium was used as the soft feedstock powder, while Ti-6Al-4V was used for the hard substrate. Substrates were preheated at temperatures of 200°C, 400°C, and 600°C to accelerate the in-situ sintering process. Deposition efficiency, micro-hardness, adhesion strength, and tensile strength were evaluated to characterise the in-situ sintering effect.

The engineers observed that deposition efficiency was doubled with the hybrid process, compared to the traditional low-pressure cold spray process. Additionally, the resulting adhesion strength was increased by a factor of 70, while the coating micro-hardness was reduced by 20%.

Finally, the tensile strength specimens produced by the hybrid process reached a 2% total elongation, compared to 0.8% for the traditional process. The engineers believe that these results open up the possibility of using this hybrid technique as an Additive Manufacturing process for coatings and bulk parts production.

www.uottawa.ca

ArianeGroup tests entirely additively manufactured combustion chamber

ArianeGroup, headquartered in Issy-les-Moulineaux, near Paris, France, reports that it has successfully tested its first entirely additively manufactured combustion chamber.

Formerly Airbus Safran Launchers, ArianeGroup is a joint venture of the European aerospace company Airbus and the French group Safran. It consists of three core businesses which include aerospace (orbital propulsion systems and equipment), defence and security.

The additively manufactured combustion chamber, designed by ArianeGroup in Germany, was reportedly successfully fire tested fourteen times between May 26–June 2, on the P8 test bench of the DLR German Aerospace Center's Lampoldshausen testing facility.

The tests were conducted jointly by ArianeGroup and DLR and follow on from the hot fire test campaign conducted last year, which validated fourteen technological building blocks for future liquid-propellant rocket engines. The results are believed to represent a key step in the preparations for the future development of very-low-cost rocket engines.

The additively manufactured combustion chamber was produced and tested under ESA's Expander-Cycle Technology Integrated Demonstrator (ETID) project, part of ESA's Future Launchers Preparatory Programme (FLPP). It is a full-scale demonstrator for a launcher upper stage engine, which incorporates the latest propulsion technologies and is designed to validate innovative manufacturing technologies, materials and processes, such as AM, laser ignition, and the use of low-cost materials.

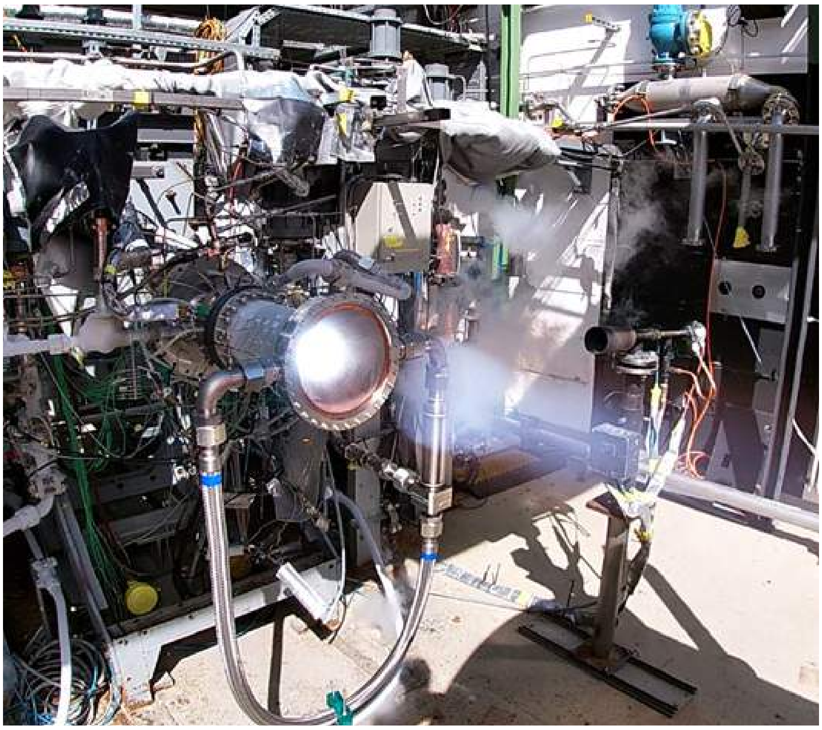
The combustion chamber features numerous innovations, such as low-cost copper alloy cooling channels and an outer jacket made by cold gas spraying. Additionally, the combustion chamber includes a single-piece injection head produced by Laser Beam Powder Bed Fusion (PBF-LB).

According to ArianeGroup, Additive Manufacturing will be adopted across the board going forward for all ArianeGroup liquid-propellant engines, for both upper stage engines (ETID) and high-thrust mainstage engines (Prometheus). The work on ETID and Prometheus is being carried out under ESA's FLPP which aims to enhance the competitiveness of future European launchers by creating mature technical solutions that are ready for rapid deployment, developing products with lower cost, effort, and risk.

The company says that these programmes enable ArianeGroup to develop its expertise in the field of AM for launcher propulsion systems, a technology which is reportedly revolutionising the design and production of future rocket engines.

ArianeGroup already uses Additive Manufacturing to produce components for Ariane 6 engines, and apart from significantly reducing costs and shortening production cycles, the use of AM has reportedly made it possible to integrate the Auxiliary Power Unit (APU) into Ariane 6, increasing the launcher's ability to adapt to the needs of different missions.

www.ariane.group
www.dlr.de
www.esa.int



ArianeGroup has successfully tested a completely additively manufactured combustion chamber (Courtesy ArianeGroup)

Submitting news..

Submitting news to *Metal AM* is free of charge. For more information contact Paul Whittaker: paul@inovar-communications.com

Phillips Corporation to provide AM expertise and support at US Army's Rock Island Arsenal

Phillips Corporation, Federal Division, Hannover, Maryland, USA, a leading service provider and distributor of machines and ancillary equipment to the United States Federal Government, has executed a Public Private Partnership Agreement (P3) to support the US Army Center of Excellence for Advanced Manufacturing at the Rock Island Arsenal-Joint Manufacturing and Technology Center.

The P3 calls for Phillips to be based at the CoE facility in Rock Island, where Phillips Federal applications engineers will collaborate with their army counterparts to exploit the potential of Additive Manufacturing in developing solutions to meet the army's current and future supply chain challenges. Phillips has exclusive partnerships with EOS, SPEE3D and others to provide additive and subtractive manufacturing support to the Federal Government.

At the ribbon-cutting for the Rock Island Arsenal CoE, Major General Daniel Mitchell, commanding general US Army Tank-Automotive and Armaments Command, stated, "I would have never dreamed that we would be able to print out parts. Advanced manufacturing technology holds the promise of greatly increased Army readiness rates so that we will be ready to spring into action whenever and wherever our nation calls upon us."

Alan M Phillips, Phillips CEO, commented, "Phillips Corporation sees substantial growth opportunities in Additive Manufacturing technologies (also known as 3D printing) that are rapidly advancing applications for forming unique metal and plastic industrial parts for the Defense Industrial Base."

"In order to increase awareness for these technologies, Phillips is pleased to reach an agreement with the Army's Rock Island CoE where we can collaborate on manufacturing unique parts using additive technology applications and processes," he continued. "This an exciting time in the evolution of Additive Manufacturing, and we are pleased to be involved with the CoE as a thought and application leader in the Additive Manufacturing segment of our industry."

https://phillipscorp.com
www.army.mil/ria

Stratasys to reduce global workforce by 10%

Stratasys Ltd, headquartered in Eden Prairie, Minnesota, USA, and Rehovot, Israel, has reported plans to reduce its global workforce as part of its strategic plan to accelerate growth with a leaner operating model.

The company states that this resizing, which it has advanced sooner than planned due to the impact of COVID-19, will affect approximately 10% of employees, and is designed to reduce operating expenses as part of a cost-realignment programme to focus on profitable growth. Stratasys expects the majority of the reduction to take place in the second quarter and completeduring the third quarter of this year.

In conjunction with other cost-mitigation measures, the resizing effort is expected to reduce annualised operating expenses by approximately $30 million. The company states that it will incur a charge of approximately $6 million in severance costs, primarily in the second quarter of this year.

"This reduction in force is a difficult but essential step in our ongoing strategic process, designed to better position the company for sustainable and profitable growth," commented Yoav Zeif, Chief Executive Officer of Stratasys. "I would like to express my appreciation to each of the employees impacted by this decision for their dedicated service."

"Current conditions make the job market even more challenging, and we have done our best to provide the departing employees globally with a respectable and fair separation," he continued. "This measure is not expected to affect the progress on our forthcoming product launch plans, which remain a top priority as we lead the industry to new heights with our best-in-class Additive Manufacturing solutions."

www.stratasys.com

Malvern Panalytical opens Shanghai application centre

Malvern Panalytical, a global supplier of analytical instrumentation and software, opened its APAC Application Center of Excellence in Shanghai on May 22, 2020, within its Shanghai offices. The new multi-functional application centre is said to showcase a large part of the Malvern Panalytical technology portfolio. Systems will be used for customer demonstrations, to provide expertise for current customers, and to develop new applications and solutions.

According to the company, the centre not only provides sample measurements for customers, but also enables corresponding measurement solution development and professional technical consulting services, including core service functions.

www.malvernpanalytical.com

Meltio makes its metal AM machine available on lease-to-own programme

Metal Additive Manufacturing company Meltio, based in Linares, Spain, and Las Vegas, Nevada, USA, has announced that its Meltio M450 metal Additive Manufacturing machine can now be acquired through a new lease-to-own programme, made available through HP Financial Services.

The company debuted its metal Additive Manufacturing technology at Formnext 2019, in Frankfurt, Germany, in November. Referred to as a '4D manufacturing' technology with '3E Metal Deposition', the Meltio M450 is capable of building fully-dense parts from wire and powder in the same machine, using a patented multi-laser deposition technology.

The scalable machine is said to offer a small footprint, and is reportedly 50% less expensive than current market systems, while using materials up to ten times cheaper than typically used in metal AM. It can be used for applications including the manufacturing of metal parts, part repairs, laser cladding, welding, texturing and more, and is said to offer easy integration with CNC systems, robots and gantry systems, as well as with hybrid manufacturing systems with AM capabilities.

The new lease-to-own programme is said to make financing the purchase of a Meltio metal AM machine more affordable by offering long-term finance plans ranging from thirty-six to sixty months. Finance plans start at €1,600 a month, depending on the configuration of the machine and terms of the agreement.

At the close of the lease period, the leaser will have the option to take ownership of the financed machine when paying the last instalment or renewing the lease and receiving a new system or model. The programme is available in more than fifty countries and territories.

www.meltio3d.com

The Meltio M450 is capable of building fully-dense parts from powder (left) and wire (right) in the same machine, using a patented multi-laser deposition technology (Courtesy Meltio)

Sandvik achieves AS9100D aerospace certification for titanium and nickel-base superalloy powders

Sandvik AB, headquartered in Stockholm, Sweden, reports that its new powder plant for titanium and nickel-base superalloys has received AS9100 Revision D certification for deliveries to the aerospace industry.

The powder plant for Osprey® titanium and nickel-base superalloys was officially opened at the end of 2019 in Sandviken, Sweden. Since then, extensive work has been ongoing to ramp up the highly automated plant, fine-tuning all processes and qualifying the powder to ensure the best possible consistency, morphology and quality. The first two titanium powders produced at the plant are Osprey Ti-6Al-4V Grade 5 and Osprey Ti-6Al-4V Grade 23. The nickel-base superalloys are Osprey Alloy 625 and Osprey Alloy 718.

"Having atomised fine metal powders for more than forty years, and supplying titanium to the aerospace industry since the 1980s, Sandvik is no stranger to powder atomisation or the requirements of the most demanding industries," stated Keith Murray, Vice President of Global Sales, Sandvik Additive Manufacturing.

"Now we are one of few companies that has the new and prestigious AS 9100D quality certification for our Osprey titanium powder and nickel-base superalloys used for Additive Manufacturing. It is a true milestone, which will facilitate many customer collaborations going forward." In addition to a shift towards sustainable manufacturing, Sandvik explains that traceability is of vital importance in the aerospace industry, the company can offer traceability for its titanium powder, which is made possible by having the full supply chain inhouse – from titanium sponge to finished powder.

The new titanium powder process uses advanced electrode inert gas atomisation technology to produce highly consistent and repeatable titanium powder with low oxygen and nitrogen levels. The automated production process is also supported by several industrial robots and a dedicated downstream sieving, blending and packing facility.

"Our highly automated manufacturing process ensures excellent consistency – and the powders demonstrate optimal particle size distribution," Murray concluded.

www.additive.sandvik

Additive Industries secures €14 million funding; Kersten to depart company

Additive Industries, Eindhoven, the Netherlands, has secured a €14 million investment from its shareholder Highlands Beheer BV, parent company of the Wintermans family. Additive Industries plans to use the capital contribution for the expansion of its product portfolio, the acceleration of its technological roadmap and strengthening of working capital.

Highlands has also acquired the shares owned by Daan Kersten, Additive Industries' co-founder and CEO, who left the company on June 30, 2020. Until a suitable successor is found, Mark Vaes, the company's current Chief Technology Officer, will assume the position of CEO.

In addition to Additive Industries' expansion plans, the company noted that the new funding will also provide cover for any possible impact of the coronavirus (COVID-19) that may affect the company's business in due course.

"This substantial investment confirms the long-term commitment of Highlands to the growth ambitions of the company and it allows Additive Industries to make yet another significant step on its mission to revolutionise the productivity for the AM of high quality metal parts," Kersten commented. "After eight intense years of fast growth I feel the time is right to make way and hand over the reins to new leadership."

Vaes added, "Since our inception in 2012 we have been working relentlessly on building a system that is unlike any other. A modular system with the largest symmetrical build volume commercially available, minimum operating interference and most of all, class leading productivity. I am convinced that with the continued support of our clients, our partners, our team and our shareholders we can now push our innovation roadmap even more."

www.additiveindustries.com

3DEO achieves ISO 9001:2015 certification

3DEO, Inc., a metal Additive Manufacturing technology company based in Los Angeles, California, USA, has received ISO 9001:2015 certification, which will enable it to further develop the commercialisation of its AM technology. ISO 9001 is the internationally recognised standard for a quality management system (QMS). The certification allows companies to operate more effectively on several different levels, including the ability to focus on customer requirements, ensure consistent production and continuously improve all aspects of the production process.

3DEO explained that the overall process of ISO 9001 certification has taken the company just three months, whereas the normal implementation time is six to twelve months. The company was able to achieve implementation within this timeframe because its factory and its systems were designed and built with process control and quality production methodology as a requirement.

"The ISO 9001 certification is a terrific milestone for 3DEO," commented Matt Petros, 3DEO's CEO. "A strong quality management system is the backbone of any world-class production line. The ISO certification marks an important step in realising 3DEO's long-term vision of leveraging next-generation technologies to build the world's highest quality, data-driven factory of the future. In the previous generation of manufacturing, spot checks and random sampling were best of class."

The 3DEO team celebrates achieving ISO 9001:2015 certification (Courtesy 3DEO, Inc)

Petros continued, "3DEO is building a dynamic production line with real-time streaming data that allows ongoing monitoring and end-to-end closed-loop feedback. For 3DEO, ISO is the starting point of what we expect to become the next generation of manufacturing."

Marty McGough, COO at 3DEO, stated, "We were very excited to implement ISO 9001 and achieve this world-class certification. Our starting point was a controlled process that provided us a stable base to work from. The certification has been very helpful in further accelerating our continuous improvement program throughout the entire organisation. We're looking forward to continuing our work in this area and excelling at our ISO and industry specific certification requirements in the coming years."

www.3deo.co

Farsoon introduces large-frame metal Additive Manufacturing machine

A spacecraft engine component measuring 590 mm in diameter, built by Falcontech on the Farsoon FS621M (Courtesy Farsoon Technologies)

Farsoon Technologies, Changsha, Hunan, China, has introduced a new large-frame Laser Beam Powder Bed Fusion (PBF-LB) machine, the FS621M. In developing the industrial-scale metal Additive Manufacturing machine, the company aimed to address some of the challenges faced by industry, including machine productivity, part size constraints, powder management, process control and factory layout.

Farsoon is a global manufacturer and supplier of industrial level polymer and metal Additive Manufacturing systems. It established Farsoon Technologies-Americas in Austin, Texas, USA, in 2017, and in 2018, Farsoon Europe GmbH was established in Stuttgart, Germany, to expand direct operations in Europe.

The company developed the FS621M in collaboration with industry partner Falcontech co., LTD., Wuxi City, Jiangsu, China, a leading manufacturing service provider in the aerospace industry, with a focus on extending the machine's build cylinder volume and increasing maximum productivity per laser. Being an important part of Falcontech's new Super AM Factory, the FS621M system is expected to give Falcontech an advantage in metal additively manufacturing components for large aerospace applications.

The new machine features a build platform size of 620 × 620 mm and vertical axis of 1.1 m. This build envelope offers new possibilities for large-scale metal production that, according to Farsoon, were not previously possible in industries such as aerospace, oil and gas, and many others.

The FS621M large-frame metal AM machine offers a build platform of 620 x 620 mm and a vertical axis of 1.1 m (Courtesy Farsoon Technologies)

The FS621M can be equipped with a single 1000 W laser or four 500 W lasers, allowing for higher rates of production. Like all Farsoon machines, it operates on an open platform which offers the user a high degree of control to tailor build parameters for cost-competitive metal AM. An advanced dynamic three-axis scanning system, powerful build process controls and real-time recoating monitoring are also said to help ensure build quality.

The machine also incorporates an integrated filter module, a secondary circulating system and a dual-station filter design, allowing for the exchanging of filters without disturbing the build process. The FS621M's powder handling processes share a common powder container design, which is used during loading, unloading and sieving procedures. These containers offer fully-sealed powder handling, easy transportation between stations and safe storage of powder.

The total installed base of FS621M machines currently numbers seven among aerospace and large-scale manufacturing customers which focus on large-volume AM, batch production, and process development for the AM of industrial powder materials including titanium and aluminium alloys, nickel-base superalloys and stainless steels. Falcontech reports that it has succeeded in supporting the development and series production of spacecraft components by AM in a number of aerospace projects.

http://en.farsoon.com

+GF+
CUT AM 500

3D Systems appoints Jeff Graves its new President and CEO

3D Systems, Rock Hill, South Carolina, USA, reports that its Board of Directors has named Dr Jeffrey A Graves as the company's new President and CEO, effective May 26, 2020. Graves brings seventeen years of CEO experience and replaces Vyomesh Joshi (VJ), who announced his retirement in February.

Graves joins 3D Systems from MTS Systems, a leading global supplier of high-performance test, simulation and measurement systems, where he served as CEO for the past eight years. During his time at MTS, Graves reportedly led a company transformation to clearly define and deploy a focused business strategy and streamlined operating model.

Prior to MTS, Graves was CEO of C&D Technologies, a global provider of energy storage products for seven years, and served as CEO of KEMET Electronics, a manufacturer of high-performance capacitor solutions, for three years.

He currently serves on the Board of Directors of Hexcel, a leading global manufacturer of advanced composite materials, and Faro, a company that develops and manufactures solutions that enable high-precision 3D capture, measurement and analysis across a variety of industries. He holds a Bachelor of Science, Master of Science and Doctorate in Metallurgical Engineering and Materials Science.

"I am incredibly excited about the opportunity at 3D Systems," stated Graves. "Digital manufacturing will play a key role in the transformation of manufacturing, and 3D Systems is uniquely positioned with its portfolio of additive manufacturing systems, material science, software and domain expertise to help companies benefit from this transformation."

Jeff Graves has been appointed as 3D Systems' new President and CEO (Courtesy 3D Systems)

Charles (Chip) McClure, chairman of the board of directors, commented, "Jeff's financial and operational discipline and precision is a core reason we chose him for this role, has shown that he knows how to organise and focus a business portfolio and streamline an operating model to deliver differentiated solutions to markets."

www.3dsystems.com

Protolabs invests £10.5 million to increase AM capability

Protolabs, Maple Plain, Minnesota, USA, has begun work on a £10.5 million facility that is expected to increase its Additive Manufacturing capability by 50%, in order to meet growing demand.

The company is building a new 5,000 m^2 production facility in Putzbrunn, Germany, that will provide customers with greater access to its automated manufacturing processes and quality systems. Despite the coronavirus (COVID-19) pandemic impacting economies across Europe, construction of the new building has started, with the initial shell scheduled to be completed by the end of December 2020, and the fit-out and machinery due to be installed in several stages beginning in May 2021.

Additionally, up to twenty-five further machines and additional equipment will be added to the existing technology, whilst a CNC machining centre, with a 5-axis milling machine, will be installed to support the finishing of additively manufactured parts for high-end applications. Automated finishing, colouring and painting systems will also be part of the expansion, along with additional AM technologies in the future.

Protolabs explains that this is the latest investment by the company in supporting its global customer base across automotive, aerospace, medical, electronics and heavy industry, and follows a £5 million extension currently being finalised at its European Headquarters in Telford, Shropshire, UK.

"We are the world's fastest digital manufacturer, but a major goal for us is to produce 3D printed parts even faster," stated Bjoern Klaas, Vice President and Managing Director of Protolabs Europe. "When a finished design enters our online ordering platform it goes through a short feasibility check by our expert design team and then on to be printed. The new facility will give us the capacity to speed this process up even more to real time."

Klass added, "We will be able to move all departments from the current building in Feldkirchen near Munich to Putzbrunn and, importantly, with the larger production area and 50% more capacity, we'll be able to deliver even more projects in as little as one day. With optimised work processes and additional employees, the new location will support our activity in the UK, especially our ability to produce certified medical devices under ISO 13485."

He concluded, "Our expansion plans in the UK and Germany show that our concept of digitalisation and automated processes is in line with the spirit of the times and the requirement to support our customers in bringing products to market in the shortest possible time."

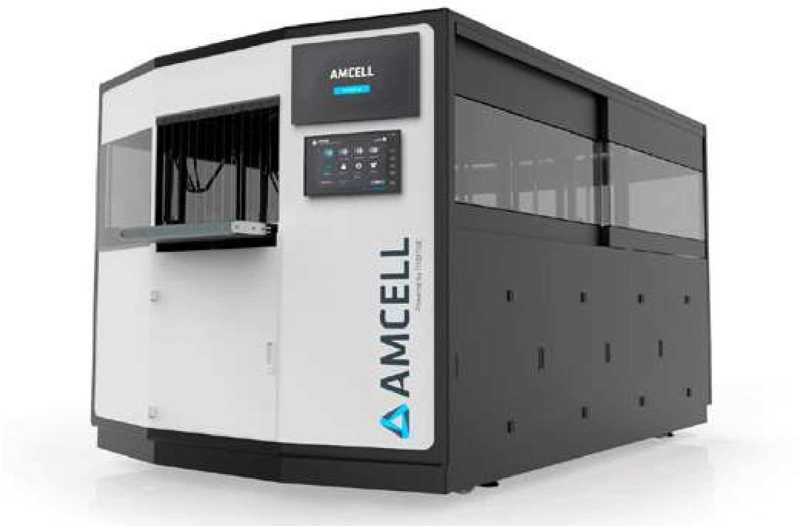
www.protolabs.com

Triditive plans 1,700 m² factory for production of its AM machines

Triditive, Gijón, Spain, has announced plans to open a 1,700 m² factory in Siero, Spain, for the production of its AMCell Additive Manufacturing machines. The move comes after the company received an investment from US-based Stanley Ventures, the venture capital team of Stanley Black & Decker, Inc., and Sadim Inversiones, an economic promotion company based in Ujo, Spain, enabling plans for the facility to go ahead.

AMCell is described by Triditive as the first automated '3D Factory in a Box' and integrated with EVAM, a software platform for remote control and automatic production optimisation, to automate and manage the entire Additive Manufacturing workflow in a single platform.

The machine is powered by Automated Multimaterial Deposition (AMD) Technology® and uses a process similar to Metal Injection Moulding to produce green parts, with the advantages of the Material Extrusion (MEX) AM processes (also referred to as Fused Deposition Modelling and Fused Filament Fabrication). The result is said to be a process with the highest throughput of cost-efficient metal parts. The modular AMCell series is composed of an Additive Manufacturing module, quality control and automatic storage modules, and customers can configure it depending on their needs, adding as many modules as they need to scale up production capacity.



AMCell is described by Triditive as the first automated '3D Factory in a Box' (Courtesy Triditive)

The company has already sold several of its AMCell machines to the Spanish Army and to Stanley Black & Decker for its USA factories. Stanley Ventures delivers access to breakthrough technologies and innovation partnerships across Stanley Black & Decker's businesses as a strategic investor that accelerates growth and collaboration around the globe through a diverse portfolio of companies.

The investment from Stanley Ventures follows Triditive's presentation of the AMCell at the Stanley + Techstars Accelerator Demo Day in Hartford, Connecticut, USA, in October 2019. Triditive is said to be the first Spanish company in which Stanley Ventures has invested. Mariel Diaz, Triditive's Founder and CEO, stated, "We will create the largest AM Factory in Spain! 20,000 ft² to create technology, employment, and add value to our customers. Thanks to our investors Stanley Ventures, Sadim Inversiones and Techstars for the support!"

www.triditive.com
www.stanleyventures.com
www.sadiminversiones.es

Osaka Titanium Technologies receives AS9100 certification for spherical Ti alloy powder

Osaka Titanium Technologies Co., Ltd., Amagasaki, Hyōgo Prefecture, Japan, has been awarded JIS Q 9100 (AS9100) certification for its TILOP (Pre-Alloy) spherical titanium alloy powder. AS9100 is a widely adopted and standardised quality management system for the aerospace industry and defence sector.

TILOP (Titanium Low Oxygen Powder) is the brand name given by Osaka Titanium Technologies to its method of producing titanium powder by gas atomisation for Additive Manufacturing and Metal Injection Moulding. OTC produces several titanium powders under the TILOP brand name, including commercial pure (CP) titanium powder, Ti-6Al-4V pre-alloyed powder, both with ranges of powder particle size distribution tailored to the customer's specific applications.

The product's AS9100 certification recognises it as meeting the requirements imposed by the standard for the manufacturing and sale of high-performance materials. Certification was awarded by the Japan Quality Assurance Organization (JQA).

www.osaka-ti.co.jp

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Elementum 3D granted patents for its Reactive AM

Elementum 3D, Erie, Colorado, USA, has been awarded patents in the USA, Canada, and Australia for its Reactive Additive Manufacturing (RAM) technology. The company states that its RAM process significantly expands the potential AM materials library by enabling the Additive Manufacturing of previously unviable materials.

Through RAM, Elementum 3D explains that it has introduced a family of new Laser Beam Powder Bed Fusion (PBF-LB) AM materials with superior properties compared to previously available AM materials and corresponding wrought alloys. This success in AM with new materials and previously unsuitable traditional manufacturing materials is expected to enable the introduction of new AM applications.

The company's RAM technology is used to create additively manufacturable, high-performance alloy powders based on established wrought alloys, including aluminium 1000, 2024, 6061, 7050 and 7075. These popular high-strength wrought aluminium alloys could not previously be additively manufactured because they are prone to hot tearing (solidification cracking), resulting in parts with poor mechanical properties.

The RAM process forms sub-micron inoculants in the melt pool that nucleate aluminium grains to produce a fine equiaxed microstructure for good buildability and performance. By making AM versions of these alloys widely available, Elementum 3D states that it eliminates material compromises.

An unmodified 'standard' 6061 aluminium alloy is shown in Fig. 1 after Additive Manufacturing and polishing. The left-hand micrograph shows a low-magnification image of the polished and unetched growth plane with the large grain structure and the network of intergranular cracking clearly visible. The right-hand image shows a higher magnification micrograph of the same material etched with weck's reagent showing the cracking network.

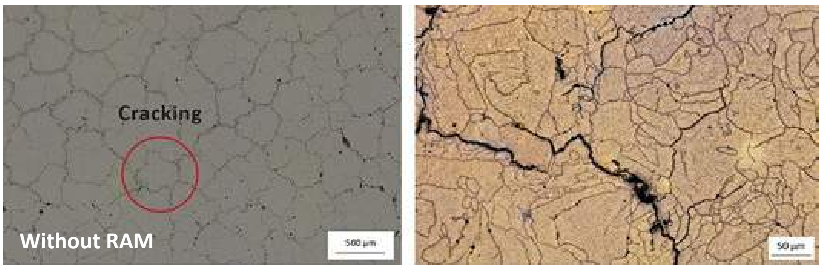


Fig. 1 Unmodified 'standard' 6061 aluminium alloy after Additive Manufacturing by PBF-LB showing large grains and an extensive network of intergranular cracking. The left-hand image is unetched and the right-hand micrograph is etched with weck's reagent and taken at higher magnification (Courtesy Elementum 3D)

Elementum 3D's A6061-RAM2 additively manufactured material is shown in Fig. 2, with the left-hand image showing a crack-free microstructure with a dispersion of nucleating and reinforcing particulates. The right-hand image shows a higher magnification view of the same material etched by weck's reagent revealing the fine equiaxed aluminium grain structure that gives the A6061-RAM2 material its properties.

"Our revolutionary technology advances metals development for Additive Manufacturing at an unprecedented pace," stated Dr Jacob Nuechterlein, President and founder of Elementum 3D. "It gives engineers the extra degree of freedom they have never experienced, inspiring them to bring into existence new and innovative applications."

www.elementum3d.com

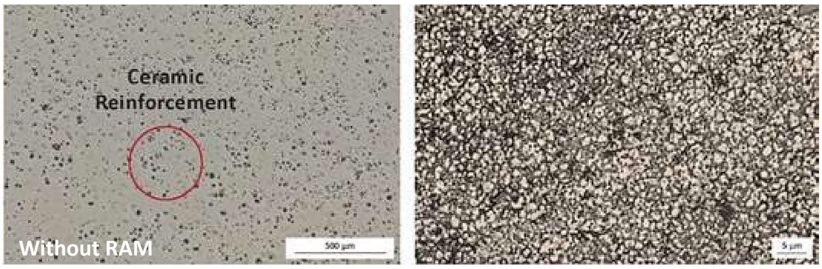


Fig. 2 Elementum 3D's A6061-RAM2 aluminium alloy showing a crack-free microstructure with the darker phase comprising reinforcing particles and the very fine (1–2 μm) aluminium grains revealed after etching with weck's reagent in the higher magnification image on the right (Courtesy Elementum 3D)

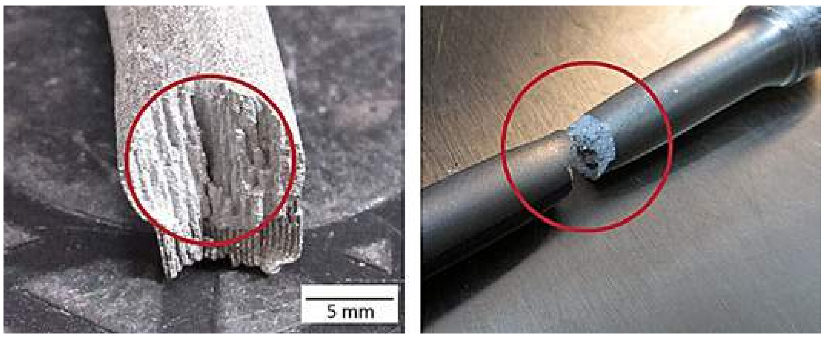


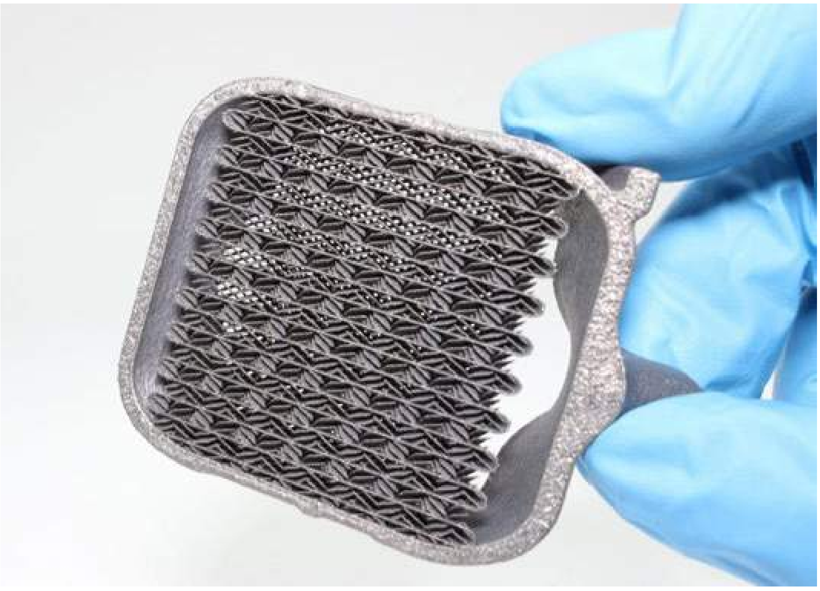
Fig. 3 Left; Unmodified 'standard' 2024 aluminium alloy without RAM addition exhibits columnar grain growth. Right; Elementum 3D's A6061-RAM2 aluminium alloy with RAM addition exhibits ductal behaviour (Courtesy Elementum 3D)

Velo3D develops process for Additive Manufacturing of Al F357

Velo3D, Campbell, California, USA, has announced the commercial release of a manufacturing process for additively manufactured parts in aluminium F357 on its Sapphire® metal Additive Manufacturing system for thin-walled heat transfer applications.

According to the company, F357, a foundry-grade aluminium alloy, is suitable for the Laser Beam Powder Bed Fusion (PBF-LB) process and enables the metal Additive Manufacturing of parts that have traditionally only been manufactured using casting practices. There are other aluminium alloys that are more commonly used in metal AM, such as AlSi10Mg, but aluminium F357 can be anodised and shares characteristics with A356, a widely-used casting alloy.

"Aluminium F357 has already been certified for mission-critical applications – unlike some exotic alloys – so it was a logical addition to our materials portfolio," explained Benny Buller, Founder and CEO of Velo3D. "We will continue to add more compatible materials that enable customers to print parts they couldn't before, yet with even better material properties than traditional manufacturing."



Additively manufactured aluminium F357 part produced on Velo3D's Sapphire metal AM machine (Courtesy Velo3D)

The manufacturing process was developed jointly with PWR, a global supplier of advanced cooling solutions to Formula 1, NASCAR and other racing series, along with the automotive, military and aerospace industries. Matthew Bryson, General Manager for PWR, commented, "We chose aluminium F357 due to its ideal material properties to suit thermal performance, machining and weldability."

"Our ability to print free-form and lightweight structures for heat transfer applications with our Sapphire system from Velo3D will further enhance performance and packaging optimization opportunities for our product range and provide significant value to our customers," he explained.

Further to this new F357 manufacturing process, Velo3D's patented SupportFree AM process eliminates the need for support structures for the production of complex passageways, steep overhangs and low angles. Coupled with its non-contact recoater, the company explains that its Additive Manufacturing process can produce the ultra-thin wall structures and high aspect ratios that are essential for a variety of flight-critical applications.

www.velo3d.com

DP Technology releases powder bed AM software

DP Technology, Camarillo, California, USA, the parent company of the ESPRIT CAM system, has enhanced its support for Additive Manufacturing with the release of a new software package designed specifically for the Powder Bed Fusion market. The new software, ESPRIT Additive for Powder Bed, is an add-in application for CAD program SolidWorks®.

ESPRIT Additive for Powder Bed Fusion is compatible with any file supported by SolidWorks and features its patented Part-to-Build™ capability. When preparing a part for manufacturing, the program automatically assigns exposure strategies based on simple inputs from the user.

DP Technology stated that the new software also introduces a slicer with what it describes as unparalleled accuracy, achievable thanks to a parametric workflow model. Once the part is ready to slice, it may be imported to the job environment as many times as required.

"This optimised workflow saves our users even more time by eliminating the need to repeatedly define the manufacturing information," stated Clement Girard, Product Manager for Additive Solutions for DP Technology. "Additive for Powder Bed Fusion improves consistency by ensuring a part is built the same way each time and maintains traceability by recording each step from the original 3D CAD file."

www.espritcam.com

SBI International to supply Multistation with its metal AM machine M3DP

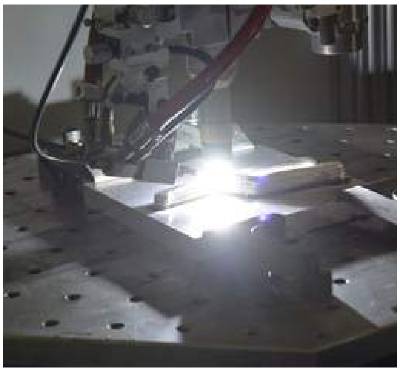
SBI International, Hollabrunn, Austria, and Multistation SAS, Paris, France, have entered into an exclusive partnership to deliver Plasma Arc metal Additive Manufacturing to the French market. As part of the partnership, SBI will supply its metal wire and arc Additive Manufacturing M3DP technology.

The M3DP features a modular and compact design, with a broad application range suited for plasma arc metal Additive Manufacturing in industries such as aerospace, oil & gas, marine & shipbuilding, tool making, service and maintenance applications. It is said to be capable of achieving high deposition rates, which benefits the manufacturing of large parts. Its optional gas-tight working chamber offers the possibility to process also sensitive materials like titanium and nickel-base alloys.

"We are very happy that we can introduce our new M3DP product range to the French market, which is particularly dedicated for Additive Manufacturing in aerospace applications," stated Dr Martin Peruzzi, CEO of SBI. "The experience of Multistation in the field of Additive Manufacturing will support the introduction of our M3DP product range into the French industry."

Yannick Loisance, CEO of Multistation, commented, "With the M3DP line of SBI, we complete our offer of metal Additive Manufacturing processes with a very powerful process, complementary to our different offerings in laser or electron beam bed melting, supersonic or Binder Jetting and DED (WAAM, laser wire, LMD). Having SBI as our partner we can now offer a complete portfolio of solutions along the value chain of metal Additive Manufacturing."

www.sbi.at
www.multistation.com



SBI International will supply its M3DP metal AM machine to Multistation (Courtesy SBI International)

Open Mind Technologies introduces latest update for its hyperMill software

Open Mind Technologies AG, headquartered in Wessling, Germany, a developer of CAD/CAM software solutions, has released hyperMILL® 2020.2, an updated version of its CAD/CAM software suite which offers users new and enhanced features for efficient 3D and 5-axis machining.

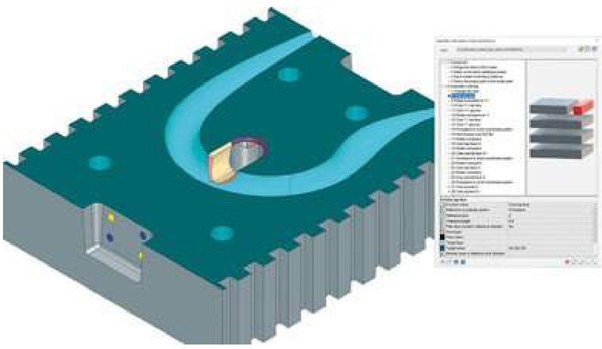
A key strategy in the latest hyperMILL CAM software releases is the ADDITIVE Manufacturing process which reportedly supports additive and subtractive machining on one machine tool. Open Mind states that its hyperMILL ADDITIVE Manufacturing technology offers flexible strategies for additive material applications, including filling strategies for both planes and free-form shapes, and in 2D and 3D sections. Applications also include hybrid machining to fix damaged parts and additive machining of an existing component.

"We continue to improve the hyperMILL user experience with new, optimised strategies, as well as provide easier to use interfaces and even more efficient filtering and feature management functions," stated Alan Levine, Managing Director of Open Mind Technologies USA, Inc. "Also, enhanced functionality in our Mill-Turn, hyperCAD® -S and AUTOMATION Center modules are all key to continually improving the user experience and increasing machining productivity."

According to the software company, a hyperMILL AUTOMATION Center Advanced option offers numerous additional features and extensive templates to the software's automation capabilities. Templates allow the user to define and standardise complex processes independent of the specific geometry from any one CAD model.

Components can now be modelled parametrically directly in hyperCAD® -S, especially helpful for fast, production-related designs. Parametric geometry data used in hyperMILL is associatively linked, and when there are any changes, is automatically updated.

www.openmind-tech.com



The 'hyperMILL® AUTOMATION Center Advanced' as part of the latest updated, offers comprehensive template functions (Courtesy Open Mind Technologies AG)

ASTM International debuts strategic guide to Additive Manufacturing data

ASTM International's Additive Manufacturing Center of Excellence (AM CoE), Conshohocken, Pennsylvania, USA, in collaboration with America Makes, the USA's national accelerator for AM, have debuted a strategic guide said to identify gaps, challenges, solutions and action plans for Additive Manufacturing data.

The strategic guide follows a workshop on AM data management and schema, jointly organised by ASTM International and America Makes and held in Washington DC, USA, in December 2019. The workshop brought more than 100 experts from government, industry, academia together for a series of technical talks, panel discussions and brainstorming sessions related to data in AM.

Recent developments in digital data acquisition, analysis, modelling, machine learning and artificial intelligence, could quickly accelerate the AM development timeline. However, this growth has yet to be observed, stated the partners.

"A key and large gap in the development of an AM data ecosystem is how to easily and securely generate, store, analyse and share critical and vital data," explained Mohsen Seifi, PhD, ASTM International's Director of Global Additive Manufacturing Programs. "A sub-gap is the consistency of the data that is gathered across multiple groups."

"This strategic guide attempts to address series of gaps and provide solutions and potential action plans to address the gaps," added Mahdi Jamshidinia, PhD, ASTM International's AM R&D Project Manager. "The guide provides a summary of discussions during the workshop and can be used by all industry stakeholders and AM experts who want to participate in the development of an AM data ecosystem and contribute to standardisation."

Brandon Ribic, Technology Director of America Makes, stated, "The guide highlights the importance of data management and data principles which will benefit the broader AM supply chain, and will serve as a resource to strengthen collaboration and ease the challenges common to AM data sharing. We are grateful to all who worked on this effort and believe this guide complements the efforts of the AMSC and America Makes' technology maturation strategic objectives."

www.astm.org
www.americamakes.us

Additively manufactured fuel component installed in commercial nuclear reactor

A thimble plugging device produced by metal Additive Manufacturing was successfully installed in Exelon Generation's Byron Unit 1 nuclear plant during its spring refuelling outage, according to Westinghouse Electric Company LLC, Cranberry Township, Pennsylvania, USA, a supplier of nuclear power plant products. The installation is believed to be a first for the nuclear industry.

Ken Canavan, Westinghouse's Chief Technology Officer, stated, "Westinghouse continues to lead the way with the development of the most advanced technologies to help the world meet growing electricity demand with safe, clean and reliable energy. Our Additive Manufacturing programme offers customers enhanced component designs that help increase performance and reduce costs, as well as provide access to components that may not be available using traditional manufacturing methods."

Ken Petersen, Exelon Generation's Vice President of nuclear fuels, commented, "Additive Manufacturing is an exciting new solution for the nuclear industry. The simplified approach helps meet the industry's need for a wide variety of low-volume, highly-critical plant components. We are proud to have Westinghouse as a partner on this industry milestone and to help further demonstrate the viability of this technology."

www.westinghousenuclear.com
www.exeloncorp.com

The metal additively manufactured fuel component has been installed in a nuclear reactor (Courtesy Westinghouse Electric Company LLC)

NanoAL's Addalloy aluminium powder wins gold 2020 Edison Award

NanoAL, LLC, Boston, Massachusetts, USA, recently won a Gold Edison Award for 3-D Printing Enhancements for its proprietary Addalloy® Aluminum Powders. NanoAL is a subsidiary of Braidy Industries and serves as its research and development division, developing new aluminium alloys; the Addalloy family of high-strength aluminium alloy powders is specifically designed and developed for metal Additive Manufacturing.

The Edison Awards have been recognising and honouring the best in innovation and innovators worldwide since 1987. Addalloy Aluminum Powder was chosen as the 2020 Gold Award winner by an international panel of over 3,000 leading business executives.

"This award confirms the industry-wide need for NanoAL's customer-centric approach when designing alloys for Additive Manufacturing. We fully utilise the process advantages of Additive Manufacturing without forgetting that customers need solutions that are cost-effective and easy to implement," stated Dr Nhon Vo, NanoAL CEO.

The composition of alloys within the Addalloy family takes advantage of the atomisation and Laser Beam Powder Bed Fusion (PBF-LB) processes to create advanced microstructures with non-traditional strengthening mechanisms said to greatly enhance the performance of metal AM components.

Because Addalloy alloys, unlike some other next-generation aluminium powders on the market, are designed without expensive rare earth elements or complicated powder blends, they are reported to be both cost-effective and easy to use.

NanoAL is currently in the process of commercialising the Addalloy family of alloys. The current product line includes Addalloy 5T for structural components, Addalloy 7S for ultra-strong lightweighting applications, and Addalloy HX for thermal management.

Frank Bonafilia, Executive Director of the Edison Awards, commented on the Gold Award, "After a thorough review, the Edison Awards Judges recognise NanoAL Addalloy Powder as a game-changing innovation standing out among the best new products and services launched in their category."

www.nanoal.com
www.edisonawards.com

Digital Metal launches software upgrade said to triple its AM build speeds

Digital Metal, part of Sweden's Höganäs Group and a developer of metal binder jet Additive Manufacturing machines, has launched a new software upgrade which it states triples the build speed of its DM P2500 machines. The upgrade reportedly enables significantly larger production volume per time unit while maintaining high component quality. The new software is now standard on all new units, and upgrade kits are available for installed machines.

According to, Digital Metal, its new DM P2500 metal binder jetting machine has been made to be as accurate as possible, with all moving parts having an accuracy down to single microns, said to enable excellent repeatability in serial production. In addition, a 160 mm thick custom-made diabase stone is now incorporated to heighten stability and ensure no vibrations affect the Additive Manufacturing process.

"We constantly work to improve the performance of our printers so that our customers can work as cost-effectively as possible," stated Alexander Sakratidis, Sales & Marketing Manager at Digital Metal. "This important upgrade makes it possible to reach even greater production volumes without sacrificing component quality. We plan to continue introducing similar significant upgrades twice a year."

www.digitalmetal.tech

Digital Metal has launched a software upgrade said to triple the Additive Manufacturing speed of its DM P2500 machine (Courtesy Digital Metal)

Kingsbury becomes exclusive supplier of Gefertec's WAAM machines in the UK, Ireland and Gulf

Kingsbury, a supplier of metal cutting systems to the UK and Irish manufacturing industry, based in Gosport, Hampshire, UK, has signed a distribution contract with Gefertec GmbH, Berlin, Germany, to become the exclusive supplier of its Wire Arc Additive Manufacturing (WAAM) machines in the UK, Ireland and the Gulf.

Gefertec's 3DMP® technology is based on modern arc welding and CAD for metal part production. The company's software uses CAD data and converts it into individual digital build 'layers' before the blank part is additively manufactured, followed by a 3D scan for quality control and subsequent milling to net shape. In comparison to conventional subtractive machining, 3DMP® is believed to be an economic and efficient AM method, with possible savings in production costs of up to 60%.

Richard Kingsbury, Managing Director of Kingsbury, stated, "Gefertec's metal AM technology fits perfectly with our existing French agency lines of AddUp Laser Beam Powder Bed Fusion (PBF-LB) machines and production lines, and direct energy deposition equipment from its BeAM subsidiary. There are tremendous advantages with WAAM. Chief amongst these is that standard MIG/MAG welding wire is used as the raw feedstock to create parts rapidly within a large build envelope. Such wire is relatively inexpensive and readily available in a wide range of metals."

"Gefertec's proprietary 3DMP technology, which is a CAD to layer-by-layer arc welding process on a machine platform controlled by the familiar Siemens 840D CNC, transforms our offering to customers," he concluded.

Tobias Röhrich, CEO of Gefertec, commented, "With more than sixty years of experience in the relevant markets and industries, Kingsbury is a perfect partner for us. We share with them the same vision of a long-term cooperation and of offering our customers more than just hardware but efficient production solutions for quantities down to a batch size of one."

Röhrich added, "With Kingsbury's expertise and passion for manufacturing, we will make the benefits of our award-winning 3DMP technology a success for customers in the UK, Ireland and the Gulf."

www.kingsburyuk.com
www.gefertec.de

Dunlee increases output of additively manufactured tungsten anti-scatter grids for CT systems

Dunlee's AM facility (Courtesy Dunlee)

Dunlee, a distributor of products, solutions and services for the third-party imaging business, headquartered in Hamburg, Germany, reports that it is increasing its output of additively manufactured tungsten anti-scatter grids used in CT systems, to support patient access during the coronavirus (COVID-19) pandemic.

Dunlee is a brand of the Philips Company Group and specialises in medical imaging components including CT, MR and X-ray solutions for OEMs, CT replacement tubes and additively manufactured tungsten products.

The company explains that CT examinations are used to assess respiratory conditions as well as monitor severe COVID-19 cases, making it an important component of COVID-19 diagnosis and assessment. The pure tungsten anti-scatter grids, which are manufactured in Best, the Netherlands, absorb unwanted scatter radiation to improve the quality of CT images. Within Cone Beam CT, Dunlee's 2D anti-scatter grids are said to provide an improvement in signal-to-noise ratio up to a factor of 1.7 compared to previous solutions.

"As a result of the COVID-19 pandemic, we are in operation around the clock, so we are working closely with our long-term partner EOS to obtain new printers while also fine-tuning our existing printers to increase output," stated Jan Laheij, Global Head of Commerce – Imaging Components, Dunlee. "We are fortunate that we can count on quick response from the EOS maintenance and service team to keep our machines running 24/7."

Dunlee states that it is also hiring more operators and engineers, and has re-prioritised projects so it can provide anti-scatter grids as quickly as possible to CT system manufacturers. Laheij added, "While the pandemic is impacting our lives and our way of working, our customers remain the focus of everything we do."

www.dunlee.com

Metal AM enables NZ Defence Force veteran to compete in Invictus Games

The titanium additively manufactured spacer and cleat in position on Creeggan's bike (Courtesy Zenith Tecnica)

Zenith Tecnica, Auckland, New Zealand, recently used GE Additive Arcam EBM technology to produce a titanium part that will enable New Zealand Defence Force (NZDF) veteran, Stevin Creeggan, to compete in the cycling events at the 2021 Invictus Games. The part, a titanium spacer, compensates for a difference in the length of Creeggan's legs by raising the surface height of one bicycle pedal.

Creeggan was sole survivor of a helicopter crash in 2010 which left him with multiple injuries, including self-fused vertebrae in his neck and lower back, and severe damage to his right leg, which was reconstructed with plates, screws and rods to hold his femur and lower femur together – leaving it shorter than his left leg by 2.5 cm. Maintaining his fitness became a challenge after his accident, leading him to take up cycling and later put his name forward to complete in The Invictus Games. The games were founded in 2014 by Prince Harry for current and former armed service personnel who have been wounded or injured. Next year, Creeggan will compete in the archery, wheelchair basketball, and cycling events.

Ewan Conaghan and Martin Campbell, New Zealand Defence Force mechanical engineers, took on the project. While Campbell stated that he has a long history with bicycles and "jumped at the chance" to produce the spacer, Conaghan noted that the design brief was out of the ordinary for a design engineering team more accustomed to designing parts for military vehicles.

"We are mechanical engineers, but people will knock on our door with all sorts of ideas," he stated. "As soon as we saw David's request, we knew immediately that 3D printing was the way to go."

The team initially designed and additively manufactured a test run of carbon fibre prototypes, working with Creeggan to perfect the design. "With GE's additive technology, using titanium we were able to reduce the weight to 50 g which was just great for Stev and the design is specific to his shoe," Campbell continued.

Zenith Tecnica was contracted to make the final piece in titanium using GE Additive Arcam EBM Q10plus machine, which uses Electron Beam Powder Bed Fusion (PBF-EB) technology. The company's Technical Manager, Peter Sefont, stated that the design was highly effective, noting, "we only had to suggest a few small tweaks to get to the final design and it allowed us to get the most out of the additive technology."

Zenith Tecnica primarily delivers parts for the aerospace, motorsports, marine and medical sectors, and so the production of the bicycle spacer and cleat was a new challenge. "Our GE Additive EBM machines are certified to 3D print titanium aerospace and medical parts," explained Sefont.

"We make quite a few customised patient-specific implants and prosthetics, as mass customisation is one of the key benefits to 3D printing, but the pedal spacer and cleat is not something we have manufactured before so it was great to be a part of it," he stated.

www.zenithtecnica.com

Martin Campbell and Ewan Conaghan, NZDF engineers, with a printed prototype (Courtesy Zenith Tecnica)

Amaero adds AmPro SP500 and SP100 machines at new USA facility

Amaero International Limited, headquartered in Notting Hill, Victoria, Australia, has commissioned its first AmPro SP500 and SP100 machines at its new facility in El Segundo, California, USA. Amaero is reported to have exclusive distribution rights for the sale of AmPro machines in North America, and is now offering the SP500 and SP100, as well as their ancillaries.

The AmPro SP500 is said to be particularly suited to the Additive Manufacturing of steel tooling and has a build area of 500 x 250 x 250 mm with minimal factory floor impact compared to traditional machine tool options. The machine features removable build cartridges, enabling fast build changeovers.

The AmPro SP100 is reportedly simple to use, easy to maintain, and ideal for R&D, academia, teaching, and low volume production. It has a smaller Laser Beam Powder Bed Fusion (PBF-LB) platform with a build envelope of 100 mm diameter and 80 mm in build height.

"I was particularly impressed by the safety, efficiency, and capital costs of the machines and look forward to putting them to use," commented Shawn Zindroski, General Manager of US operations, Amaero International Limited. "The SP100 technology gives us the ability to test, validate, and develop our internal parameters set for our existing powder alloys. Importantly, as the metal powder market continues to evolve we will have a platform to test new alloys easily to scale for our customer production runs."

Barrie Finnin, CEO, Amaero International Limited, stated, "This is a significant milestone in our company's overall growth strategy as we are now able to really accelerate our sales strategy. Having the AmPro SP500 and SP100 operational for the first time marked the start of our machine sales in the United States. "Machine sales form an important part of our business plan and strategy and through our exclusive distribution rights for the AmPro machines in the United States we are now able to offer the SP500, SP100, and their ancillaries for sale as of today."

www.amaero.com.au
www.amprogroup.com.au

Amaero installed its first AmPro SP500 and SP100 machines at its new facility in El Segundo, California, USA (Courtesy Amaero)

Optomec expands capabilities with aluminium AM using LENS DED

Optomec, headquartered in Albuquerque, New Mexico, USA, has announced an advancement in capability for its LENS Directed Energy Deposition (DED) Additive Manufacturing machines and the repair of aluminium alloys. The advancement reportedly enables LENS DED machines to be used to deposit any aluminium alloy, including those developed specifically for their improved properties for AM processing.

This development helps open up the transportation and aerospace industries to Additive Manufacturing and the repair of complex aluminium alloy parts using powder-based DED. Additionally, the use of Optomec's LENS simultaneous 5-axis system is said to enable the processing of aluminium alloy parts with complex geometries without the need for support structures. The company explains that the deposition of aluminium alloys in a controlled atmosphere glove-box with very low levels of oxygen and moisture ensures the achievement of components with superior mechanical properties.

David Otazu, LENS Applications Engineer at Optomec, commented, "Our engineers have developed process parameters for aluminium alloys to provide an excellent surface finish, high deposition rates and a density of ~99.9%."

With this advancement, the company believes that its Optomec LENS systems can now successfully process all common materials used for Additive Manufacturing, which as well as aluminium include steels, titanium, nickel and copper.

www.optomec.com

Chiron develops first AM machine

The Chiron Group, Tuttlingen, Germany, a specialist in the field of CNC-controlled vertical milling and turning machining centres, has developed its first Additive Manufacturing machine, the AM Cube, for the production of large and complex components.

According to the group, the AM Cube is based on a conventional cartesian coordinate system, similar to a CNC machining centre. The system is programmed using either a standardised DIN ISO code or, for complex components, using a CAD/CAM software tool. All aspects of the system can be controlled using tried-and-tested Siemens components, from hardware to the HMI through to programming of the AM Cube.

Chiron explains that the deposition head of the AM Cube can be changed during an active Additive Manufacturing/coating process. This option enables the AM Cube to be used to combine different process requirements; for example, one deposition head could be used to achieve a high surface quality, and another could be used to achieve a high deposition rate. The automatic head change function enables these properties to be combined in a single workpiece.

The AM Cube is equipped with a total of three deposition heads, and both wire and powder can be applied as deposition materials within a single manufacturing process in different production phases. By designing an AM machine for the two commonly used deposition materials – wire and powder – the group states that it has also patented a "completely new technology."

The AM Cube offers both powder and wire AM options (Courtesy Chiron)

The AM Cube system can reportedly be reconfigured from 4-axis to 5-axis machining with relatively little effort. It is equipped with cutting-edge sensors and is said to meet all relevant safety requirements for operation without operator monitoring. Chiron explains that where the AM Cube is used to machine particularly reactive materials such as titanium, the entire system can be flooded with protective gas to reduce oxidation, enabling manufacturing to be performed under a protective gas atmosphere for several hours.

Chiron introduced the AM Cube to the public during a virtual Open House, held online from May 14–15, 2020, due to the coronavirus (COVID-19). During the digital event, Axel Boi, the company's Head of AM, presented the AM Cube in detail, and external 'visitors' numbering around 1,000 were given the chance to learn more about the company's AM developments.

"The Additive Manufacturing department is a start-up within our own business group," stated Axel Boi, Head of Additive Manufacturing at the Chiron Group. "With this 3D metal printer, made by Chiron, we are creating a facility for manufacturing larger components with long procurement times and high material prices. This technology can be used effectively in the mechanical engineering, tool manufacturing, energy production and aerospace sectors. These are all important target sectors for the Chiron Group."

www.chiron-group.com

Open Additive awarded contract to develop multi-laser AM technology

Open Additive, LLC, Beavercreek, Ohio, USA, has been awarded a $2.94 million Air Force Commercial Readiness Program (CRP) contract to advance its metal Additive Manufacturing technology and product line to industrial scale.

The 'Open Systems Platform for Multi-Laser Additive Manufacturing' contract reportedly builds on the company's Small Business Innovative Research (SBIR) portfolio and independent research to develop open-architecture Laser Beam Powder Bed Fusion (PBF-LB) systems with advanced processing and in-situ monitoring capabilities.

According to the company, the programme seeks to develop and demonstrate a prototype quad-laser PBF-LB platform with full user control of standard and advanced processing parameters, multi-sensor monitoring and feedback control, and integrated heated build plate with 600 mm x 600 mm build area, all configured within a versatile form factor.

The contract was awarded in February of this year, completing its first technical review this April. Dr Thomas Spears, Open Additive's Chief Scientist, serves as the project's Principal Investigator, having joined the team in September 2019 after spending six years at GE Aviation and GE Additive, where he led technology and product development in metal Additive Manufacturing.

www.openadditive.com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www.materials-solutions.com

Sintavia achieves Nadcap accreditation for heat treatment

Sintavia achieves Nadcap approval for heat treatment at both its Hollywood, Florida, USA, and Davie, Florida, USA, locations (Courtesy Sintavia, LLC)

Sintavia, LLC, Hollywood, Florida, USA, has achieved National Aerospace and Defense Contractors Accreditation Program (Nadcap) approval for heat treatment at both its Hollywood, Florida, and Davie, Florida, locations. It is reportedly the only company in the world with Nadcap approvals for laser and electron beam Additive Manufacturing, as well as in-house heat treatment.

The Nadcap accreditation for heat treatment includes nickel and aluminium alloys, and the initial approval is good through July 31, 2021. In addition to Nadcap approvals for heat treatment and AM, Sintavia also holds Nadcap approvals for non-destructive testing and chemical processing through its wholly-owned subsidiary, QC Laboratories, Inc.

The company states that it also plans to pursue Nadcap approval for its in-house metallurgical and mechanical testing laboratory, located in Davie, Florida, which is already ISO 17025-certified.

"Since its founding, Sintavia has always defined itself as the quality leader for aerospace & defence Additive Manufacturing," states Brian Neff, Sintavia's Chief Executive Officer.

"Nadcap approval for our internal heat treatment capabilities is not only a continuation of this focus, but also will allow Sintavia to provide higher quality production parts more quickly to its customers. Moreover, we are proud of the fact that we are the first manufacturer anywhere in the world to achieve these quality accreditations."

www.sintavia.com

DoE grants $28 million funding for R&D on ultra-high temperature materials

The U.S. Department of Energy (DoE) has announced up to $28 million in funding for a new Advanced Research Projects Agency-Energy (ARPA-E) programme called ULtrahigh Temperature Impervious Materials Advancing Turbine Efficiency (ULTIMATE), reports the Metal Powder Industries Federation (MPIF). The programme will reportedly develop and demonstrate ultra-high temperature materials that can operate in the high-temperature and high-stress environments of a gas turbine blade. Projects will specifically target gas turbine applications in the power generation and aviation industries.

According to the DoE, gas turbines are used for a variety of applications, from aerospace engines to industrial power generation, and natural gas turbines currently produce an estimated 35% of the electricity generated across the USA. Improving turbine efficiency is expected to create opportunities to generate more energy savings, lower carbon emissions, and benefit the economy in these sectors as well as across a range of other sectors.

The ULTIMATE programme aims to improve the efficiency of gas turbines by increasing the temperature capability of the materials used in the most demanding environments, such as the turbine blade. The temperature capability of current state-of-the-art blade materials has improved steadily over the last few decades to 1,100°C, through incremental microstructure and chemistry refinement.

However, there exists a new opportunity to discover, develop, and implement novel materials that work at temperatures significantly higher than industry standard superalloys, to further increase efficiency and economic gains.

ULTIMATE projects will address this need by developing novel ultra-high temperature metal alloys and coatings integrated with advanced manufacturing processes. The ULTIMATE programme will target enabling gas turbines blades to operate continuously at 1,300°C in a material test environment or with coatings, with turbine inlet temperatures of 1,800°C or higher.

"Gas turbines are a major generator of electricity, and have significantly contributed to the cleaner generation of electricity over the past several years," stated Mark W Menezes, Under Secretary of Energy. "Developing new, innovative technologies under the ULTIMATE programme will allow us to better utilise gas turbines across multiple power sectors, from electricity generation to transportation and aviation, making all of these industries more efficient."

Lane Genatowski, ARPA-E Director, commented, "The development of novel ultra-high temperature alloys in conjunction with coatings and advanced manufacturing will help to increase the efficiency of our nation's power generation and aviation industries. Enabling turbines to operate at higher temperatures for longer sustained periods will result in significant reductions of both wasted energy and carbon emissions across many crucial power generation applications."

www.energy.gov
www.arpa-e.energy.gov

Autodesk launches Netfabb 2021 with improved support for metal AM

Autodesk, San Rafael, California, USA, has revealed the latest release of its Netfabb® Additive Manufacturing software. The new release, Netfabb 2021, offers a number of new features, including improved build controls and greater support for metal Powder Bed Fusion (PBF) and Directed Energy Deposition (DED).The use of new 3D packing methods in Netfabb 2021 has reportedly been made possible with two new algorithms, which increase packing density for processes that don't require support structures, such as Binder Jetting (BJT).

Using these new 3D packing methods, a size sorting algorithm prioritises large parts for the centre of the build platform while filling the remaining volume with smaller objects, while a gravity algorithm uses a physics-based engine to simulate gravity and packs parts more closely. Netfabb 2021 also offers advanced toolpath features. New hexagonal hatch patterns are said to help balance thermal input and build quality, and smoke simulation of slice data from SLM Solutions and Renishaw helps identify areas where the smoke plume may interfere with the laser path, causing deflections that jeopardise build quality. The new release allows users to control toolpath vectors based on an external input, such as process simulation results.

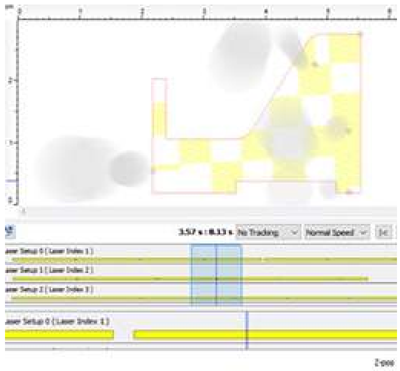
Increased mesh limits have been made possible using simulation Utility LT (included with Netfabb Ultimate), which simulates metal PBF technology to identify and remediate common build failures, including distortion, recoater blade interference, hotspots, lack of fusion zones and support structure failure. With the 2021 version, Autodesk stated that it has relaxed the limits significantly to enable this utility to simulate even more complex geometries.

Two new features have been added to Netfabb 2021's Simulation Utility which are said to offer enhanced process simulation for metal PBF processes. Validated parameter files for Inconel 718 have been added, with machine vendor defaults for the EOS M290 and the Additive Industries MetalFAB1 machines, to enable the generation of accurate simulations without the need to generate new parameter files.

In addition, the ability to offset the geometry preform in the new release is expected to enable users to compensate for predicted distortion in a DED simulation and mitigate distortion in DED parts.

The new release also offers improved AM machine integrations and the ability to quickly establish build setting customisations, and create, save and load build profiles for a given material directly from Netfabb.

A number of new features and functions have been added to improve user experience. For example, users can now clone supports between similar parts, and taper supports to minimise their footprint and the effort required to remove them. Users can also automatically create bar supports that recognise thin walls and generate a single path of bars, overriding the global contour offset to wall setting.



Smoke simulation of slice data in Netfabb 2021 (Courtesy Autodesk)

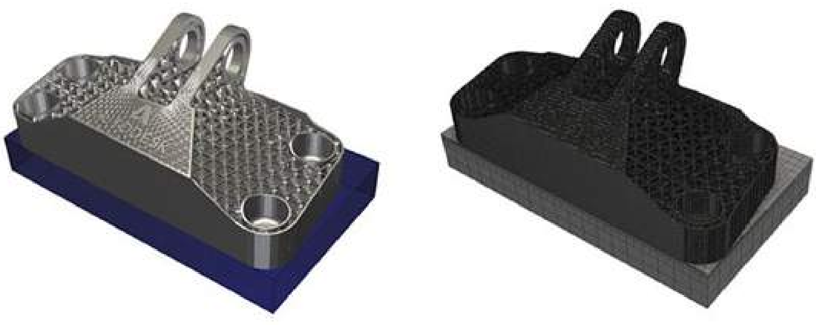
The Custom Part Library in Netfabb 2021 can now be populated with a user's own designs, offering quick access to the most often-used parts such as custom test specimens used to fill up build platforms, and common objects such as giveaway parts.

Parts can also be duplicated easily with a newly redesigned rectangular pattern dialogue, and build volumes can be filled with selected parts and slices simultaneously, minimising guesswork and task repetition. All parts inside or outside the platform can be automatically selected, making it easier to move them to a different platform or delete them entirely.

The new release is said to make it possible to automate common workflows. A new scripting example allows users to compare two similar meshes automatically, and helps to identify differences using colours and graphs.

In addition, automatic support separation is said to allow users to separate open and solid supports into two parts with one click, giving increased control over objects when assigning toolpath parameters. The ability to clone any workspace is expected to allow for faster duplication of a build platfrom, making it possible to experiment with different packing, slicing or toolpathing strategies easily.

www.autodesk.com



Autodesk's Netfabb 2021 offers improved simulation support for metal PBF (Courtesy Autodesk)

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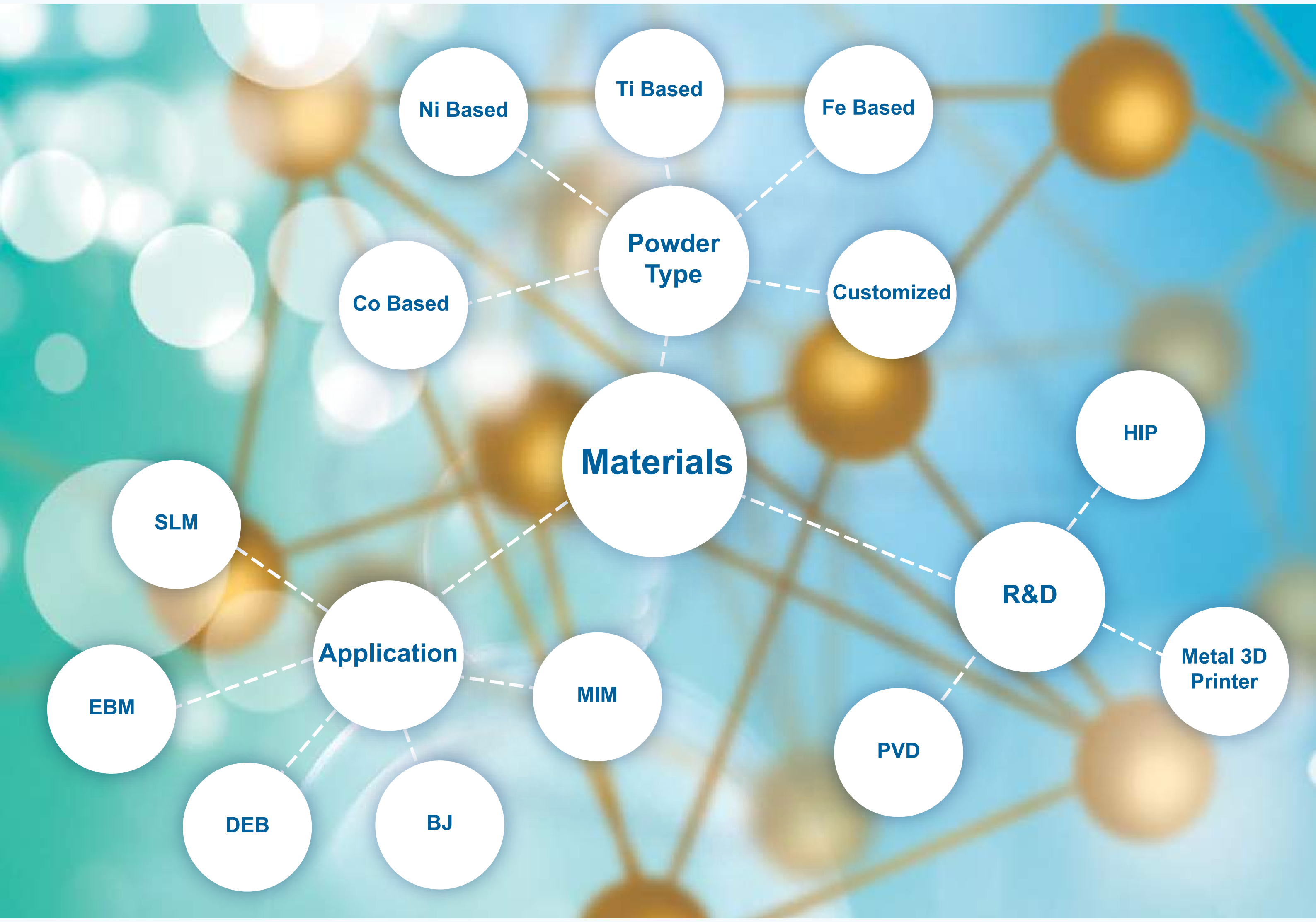
Material Technology Innovations Co., Ltd. 纳联材料

MTI

Specialized in AM metal materials



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Haute Fabrication to build 'world's largest' PBF-LB AM machine

Haute Fabrication, a start-up located in Fort Dodge, Iowa, USA, reports it is launching as an independent supply chain provider and intends to utilise fabrication technology, automation, artificial intelligence, and cross-reality integration, with a focus on lowering the cost of creation and provide a sustainable global supply chain. The company is reported to be bringing its patent-pending technology to a worldwide audience as it enters into the global value-added manufacturing market.

The start-up explains that high-quality conventional manufacturing techniques are faced with prohibitive difficulties such as minimum order sizes, material waste, structural flaws and inconsistencies. Other Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing machines are also hampered in numerous ways, explains Haute Fabrication, such as by limited build size, limited mass manufacturing capability, thermal stress cracking, and additional thermal processing follow-up being required.

Haute Fabrication plans to leverage its mass- manufacturing capability to launch a series of new PBF-LB AM machines which it believes may be the key to providing a reliable solution to these problems, starting with the HDLS 250 – Minotaur, a hybrid PBF-LB machine for customers such as creators, machine shops and labs.

According to Haute Fabrication, the cornerstone of its new technology suite is its development of a series of what are said to be the world's largest artificial intelligence-controlled 'Fully Automated Very Large Format Direct Metal Laser Sintering' AM machines, with built-in high-temp auto-clave. These large AM machines and robotic processes would reportedly be capable of making a single piece or thousands of pieces of on-demand objects which would otherwise require a large fleet of competitors' equipment.

The HDLS 250 – Minotaur has a targeted build area of 600 mm x 600 mm x 1000 mm, all of the advanced features of the larger machines, and aims to lower machine costs by 30–50%. In part, this cost reduction will be achieved by removing the need for expensive, proprietary, vendor-locked materials.

The largest AM machine planned by Haute Fabrication will be capable of creating objects up to 27 m^2 in size, said to be fifty-two times larger than can be produced by any existing PBF-LB machine. The high-temperature autoclave enables annealing process temperature stability in order to provide thermal processing, prevent stress cracking, voids, micro-fractures and other temperature-based flaws, enabling the highest quality and most durable fabricated products available.

By integrating the company's PBF-LB technology with automation and VR programming for robotics engineering, Haute Fabrication is able to bring its value proposition on the basics of manufacturing down to material costs and energy utilisation and remove direct manual labour costs from the equation.

The start-up states that its primary goal is to leverage the competitive advantage created by its automated technology suite and robotisation to provide cost-effective and worry-free on-demand contract fabrication for prototyping, small run and mass-manufacturing, while reducing the need to purchase expensive machines and employ highly specialised support staff.

By using distributed on-demand hybrid Additive mass-Manufacturing and conventional mass-manufacturing techniques, customers are not tied to a set production size or quantity. This is expected to allow inventors, artists, entrepreneurs and large companies to innovate and compete more effectively in today's global market.

www.hautefabrication.com

Farsoon and Siemens accelerate software integration for industrial AM

China's Farsoon Technologies, Changsha, and Siemens China, Beijing, have announced that the first Farsoon Additive Manufacturing machine installed with Siemens NX software has now started beta-testing at a customer site.

After establishing a framework for integrated industrial solutions for Additive Manufacturing last September during the 21st China International Industry Fair (CIIF), Siemens and Farsoon's R&D teams have been working to push the technology integration.

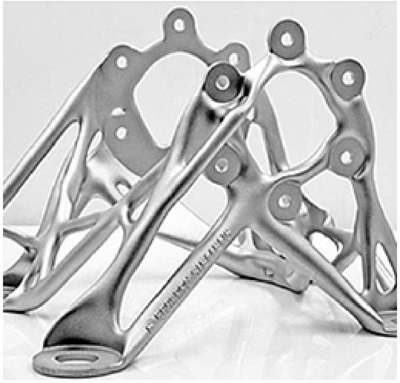
The goal of this collaboration was the implementation of Siemens' end-to-end software and 'Digital Twin' solutions on all Farsoon metal and plastic open platform industrial AM systems.

Siemens NX software integrates key functions including design, topology optimisation, CAE verification, process simulation, build evaluation and scan-path planning. With clear focus on industrial AM and 'Open for industry' philosophy, Farsoon is reported to have established an increasing industrial customer base amongst aerospace, automotive, tooling, and large-scale manufacturing users.

Hope Hou, General Manager of Farsoon Technologies, announced the first hardware integration during his presentation at the Siemens booth during Formnext 2019. "The industrial control components from Siemens Digital Factory Solution have been applied to Farsoon's latest metal laser sintering system FS301M, offering high-quality AM solutions to industrial users," stated Hou.

https://new.siemens.com

http://en.farsoon.com



An aluminium gearbox mount from a Siemens sponsored Formula Racing car was the first collaboration. The part is designed by Siemens NX software and fabricated on a Farsoon FS301M (Courtesy Farsoon)

H.C. Starck Tantalum & Niobium changes name to Taniobis

As of July 1, 2020, H.C. Starck Tantalum & Niobium has announced that it is operating under the Taniobis brand name. Taniobis will continue to offer a wide range of materials, powders, and alloys based on tantalum and niobium.

Taniobis uses these rare ores and refractory metals to produce high-performance powders on an individual basis for its customers. These materials are important in a range if industries, including automotive, energy, aviation, electronics, the chemical industry and the medical technology industry.

The supply and development of Ta and Nb materials also supports global trends in areas including the Internet of Things (IoT), big data, smart cities, and connectivity, where current developments are heavily dependent on tantalum and niobium.

For example, in data communication, the goal is to filter and set transmission frequencies on an exact basis: this takes place via surface acoustic wave (SAW) filters based on niobium oxide and tantalum oxide. For processing data using high-performance processors, an ultrathin layer containing tantalum ensures ongoing disruption-free operation.

Taniobis also processes tantalum for tantalum electrolytic capacitors. These items are essential to advanced microelectronics, as they have extremely high energy density. This makes it possible to design ultra-small components with high conductivity, which is important in the IoT segment in particular. That makes them interesting for the connected driving and connected cars segment as well. Capacitor powders form the basis for mobile and security-related applications in connected cars.

In the IoT context, a thin layer based on tantalum is essential when it comes to making copper an option as a conductor material for high-speed processors. Without this layer, Cu ions would destroy the processors' semiconducting properties. The tantalum layers are not only necessary for logical data chips; they are also needed for storage chips such as flash memory and SSDs.

These advantages are also critical when it comes to big data, a topic which has become increasingly relevant since the rapid rise of global wireless data access has made high-speed data processing even more crucial. It also takes on special importance in light of the growing trend toward assisted driving and even autonomous driving.

Additive Manufacturing is another important area of application. Taniobis is a leader in the development of biocompatible alloys for the production of patient-specific implants made using AM. The Taniobis development known as AMtrinsic is of particular interest in this context; these pre-alloyed high-performance powders were developed specifically for AM.

Thanks to the unique intrinsic properties of tantalum and niobium, such as high melting points, high resistance to corrosion, extremely high resistance to chemicals, and high thermal and electrical conductivity, Ta and Nb and alloys containing these elements are suitable for a wide range of high-tech applications in fields such as the chemical industry, the energy segment, in superconductors and in high-temperature environments.

www.taniobis.com

Protolabs UK adds cobalt chrome to its AM materials offering

Protolabs UK, Telford, Shropshire, has added cobalt chrome to its materials offering for metal Additive Manufacturing. Cobalt chrome has a high strength-to-weight ratio, is resistant to heat, wear and corrosion, and has applications in multiple sectors including aerospace, oil & gas and medical.

Andrea Landoni, 3D Printing Product Manager for Protolabs, stated, "Cobalt chrome is one of the toughest materials known and can be polished to an extremely smooth surface. The advantage of 3D printing is that we can produce any shape that you want, whether it is for an unusual geometry or to save weight."

Cobalt chrome can reportedly withstand temperatures of up to 600°C, and its low nickel content gives it excellent biocompatibility, making it ideal for orthopaedic and dental applications. Using Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing, Protolabs UK states that it can produce very fine resolution parts, down to a minimum feature size and wall thickness of 1 mm.

Landoni added, "One of the problems of cobalt chrome is that it is so hard wearing that it is very difficult to produce parts from it using other processes such as CNC machining. The properties of parts produced by DMLS [PBF-LB] are also equal to or better than those of wrought materials and the process is ideal when the geometry or structure of a part is simply not possible using any other process."

Cobalt chrome parts produced by Protolabs UK, with a resolution of 20 µm (Courtesy Protolabs UK)

www.protolabs.co.uk

Wayland Additive's NeuBeam process to open up further industrial applications

Wayland Additive, Huddersfield, UK, has announced the development of a new metal Additive Manufacturing method it calls the NeuBeam® process. Said to be an entirely new Powder Bed Fusion (PBF) process, it is claimed that NeuBeam offers the best of both laser and electron beam PBF systems, opening up Additive Manufacturing to a wider range of industrial applications.

Will Richardson, CEO of Wayland, explained that the new technique is an electron beam process that effectively neutralises the charge accumulation generated by the electron beam. This offers greater flexibility than PBF-LB while overcoming any stability issues associated with PBF-EB. In addition, this means that the NeuBeam process enables metallurgical requirements to be tailored to application requirements rather than to maintain the print process within the narrow bounds permitted by the process.

"At Wayland Additive, we have been working on the development of an entirely new PBF process for metal Additive Manufacturing that minimises the existing limitations that current users have to work around. When considering the existing two PBF technologies, NeuBeam offers a new way, a third way," stated Richardson.

Although PBF-EB and NeuBeam are both PBF processes, using an electron beam as the heat source to melt the metal powder, it is stated that PBF-EB and NeuBeam are fundamentally different. Unlike the traditional PBF-EB process, the charging issues that can make PBF-EB unstable have been fully neutralised with NeuBeam using core physics principles developed in the demanding semi-conductor industry. Moreover, NeuBeam is a hot part process rather than a hot bed process. This efficiently creates parts that are free of residual stresses because the high temperatures are only applied to the part and not the bed, ensuring free-flowing powder post-build (no sinter cake) and stress-free parts with reduced energy consumption.

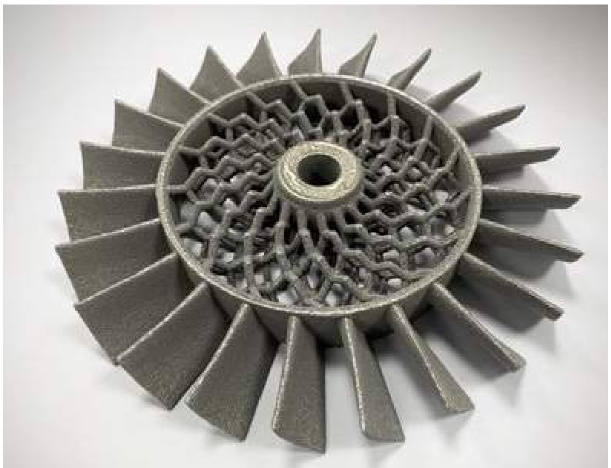
Furthermore, the process is reported to overcome many of the limitations for additively manufacturing large components – no residual thermal stresses, no gas cross-flow, and a much simplified powder removal process than existing eBeam systems.

The NeuBeam process is capable of producing fully dense parts in a wide range of materials, many of which are not compatible with traditional PBF-EB or PBF-LB processes such as refractory metals and highly reflective alloys.

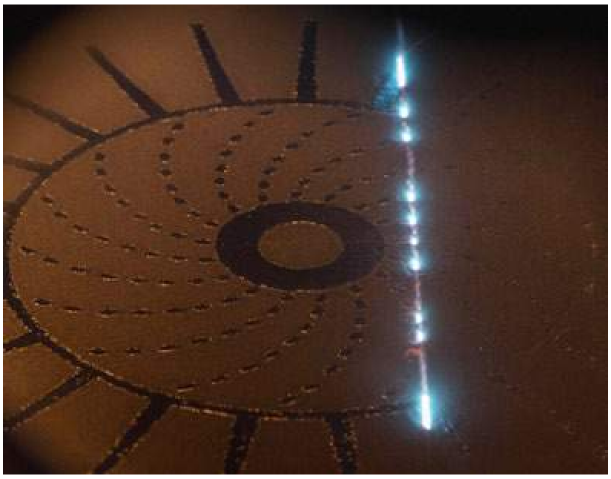
NeuBeam also offers built-in real-time in-process monitoring, allowing for rapid material development or tuning of microstructures by adapting the solidification during manufacture. With NeuBeam the process temperature is not constrained by sintering the powder bed, allowing the process temperature to be optimised to the material microstructure and/or the application.

The level of in-process monitoring is achieved through a combination of advanced technologies, including structured light scanning, electron imaging and high speed infra-red cameras. Each of these different monitoring approaches are calibrated to the same reference points in the machine, with managed adjustments, to ensure optimum results and output. Being a true thermal process, everything in the build chamber is able to be monitored, and it is possible to see the true temperature of the whole powder bed in-process as a build takes place. The thermal history of the material being processed can also be seen, as can the topography of the surface so that defects can be detected, and reported, as they occur.

www.waylandadditive.com



An impeller part produced using the NeuBeam process with no post-processing (Courtesy Wayland Additive)



In process view of the NeuBeam process, producing impeller part (Courtesy Wayland Additive)

PyroGenesis' QMS approved by major aerospace company

PyroGenesis Canada Inc., has announced that its Quality Management System (QMS) for the production of metal powders for the Additive Manufacturing industry has been approved by one of the leading non-European aerospace companies.

"Although this does not guarantee any future orders and, on the face of it, may seem to be a minor and expected development, it is in reality very significant as it complements the cutting-edge improvements we have made with our NexGen™ technology which we have announced in previous press releases, and is a key and fundamental step forward," stated Peter Pascali, CEO and president of PyroGenesis.

PyroGenesis' NexGen™ Plasma Atomization System, which produces metal powder at over 25 kg/hour, was unveiled in 2019 after having fulfilled a specialty metal powder order for a non-aerospace client, while maintaining all the characteristics demanded by the AM Industry (such as oxygen content, flowability, density, etc.).

At the time, Massimo Dattilo, vice president of PyroGenesis Additive noted that, "a limiting factor in titanium adoption in the marketplace has been its cost. By lowering the cost of a typically expensive product, NexGen™ has opened the door to other opportunities (both markets and applications) which, until now, found titanium to be too expensive to adopt. We expect that price reductions now permitted by the NexGen™ technology will drive an increased adoption of PyroGenesis' powders by new markets and applications where the higher cost of plasma atomised powders was typically prohibitive."

"This relationship outside of Europe expands, builds upon and complements that which we have developed with Aubert & Duval in Europe," added Pascali. "It has taken a bit more time than expected, but we now have in place one of the best quality systems which, combined with our gamechanging NexGen™ technology, positions us well to service the AM Industry."

www.pyrogenesis.com

Equispheres secures C$30 million investment round

Equispheres, Ottawa, Ontario, Canada, has raised Series B investment and a new round of funding totalling C$30 million. The funding was led by HG Ventures, with participation from Sustainable Development Technology Canada (SDTC), BDC and other undisclosed contributors.

Within the last year, Equispheres has released two major reports on the results of testing on its unique metal powders. One outlined how its powder outperformed in Additive Manufacturing aerospace-ready quality tests, and another revealed that the company had been successful in developing an aluminium alloy powder suitable for binder jet Additive Manufacturing, which was previously unfeasible.

According to the company, this new funding will largely be used to scale up production capacity and facilitate R&D efforts with strategic industry partners

Kevin Nicholds, President and CEO of Equispheres, stated, "We are extremely excited to have HG Ventures as a partner; their extraordinary combination of research capability and venture capital experience made them an ideal partner to understand both the technical and market potential of our product across the transportation industry."

www.equispheres.com

Würth Industry North America signs distribution agreement with Markforged

Würth Industry North America (WINA), a division of the Würth group and an industrial distributor of supply chain solutions for fasteners, MRO and safety equipment, has signed a national agreement with Markforged, Watertown, Massachusetts, USA, in order to better serve the needs of Würth's Industry's customers in the general manufacturing market, as well as oil & gas, heavy equipment, and transportation.

According to the companies, the agreement to distribute Markforged's Additive Manufacturing solutions complements Würth Industry's strength of providing innovative supply chain solutions for original equipment manufacturers (OEMs). Würth Industry states that it now provides several additional cost-saving options to its customers, including metal additively manufactured parts and tools, rapid prototyping, and full service digital Kanban solutions to better manage inventory.

The range of additively manufactured inventory solutions are believed to be limitless due to Markforged's wide rang of metals — from high-conductivity copper to industrial tool steel to superalloys like Inconel — all in a safe, fast, and easy-to-use platform. In addition, its composite platform can additively manufacture in continuous carbon fiber, Kevlar®, and more, creating functional parts that rival aluminium in terms of strength and stiffness, but at a fraction of the weight.

"We are thrilled to bring innovative digital supply chain solutions to our customers," stated Dan Hill, CEO of Würth Industry North America. "By integrating Markforged 3D Printing technology with our existing Kanban programs, we are able to offer quicker time to market and lower inventory costs. We're able to cut out the sourcing, purchasing, and transportation costs and deliver the value directly to the customer."

Greg Mark, CEO and founder of Markforged, commented, "We're excited to expand the global reach of our solutions with Würth and continue to push the bounds of what's possible in Additive Manufacturing. This partnership truly opens up valuable potential for us, and for the industry. Markforged makes it easy to build anything you can imagine, and that capability will allow industrial manufacturers to lower inventory costs by printing production tools and parts – quickly and reliably."

www.wurthindustry.com/en/wina/startseite/index.php

www.markforged.com

AML3D commences trading, delivers its first Arcemy AM machine

AML3D Limited, an Australian startup established to commercialise its Wire Additive Manufacturing (WAM) technology, has commenced trading on the Australian Securities Exchange (ASX) after successfully raising AUD $9 million. Funds from its IPO are expected to enable AML3D establish an additional manufacturing centre and build sales capacity of its Arcemy® AM machines.

AML3D's Arcemy large-format metal AM machine has been delivered to ST Engineering (Courtesy AML3D)

AML3D also announced delivery of its first Arcemy metal AM machine, to ST Engineering in Singapore. Once fully commissioned, the stand-alone module will provide enhanced manufacturing capabilities, said to be capable of delivering custom components promptly with and superior strength.

"The delivery of our first Arcemy module is a significant milestone in the commercialisation pathway of AML3D," stated Andrew Sales, AML3D's Managing Director. "Partnering with ST Engineering after successfully passing their due-diligence process provides a high degree of industry validation for our technology and allows us to demonstrate our capacity to quickly provide commercial outcomes in 'off site' environments outside our own manufacturing facility."

The 'rent to buy' agreement with ST is reported to give AML3D the right to use 50% of the Arcemy module's capacity through the 'rent' period. AML3D's access to the module provides the capability to manufacture components for its own customers throughout Asia, before the establishment of the company's planned Singapore facility.

The WAM process is a type of wire-based AM developed by AML3D, allowing savings of up to 80% of material waste, making it more sustainable than casting and forging methods. AML3D states that its WAM process also provides the opportunity for design optimisation of parts, providing weight reductions of up to 30% without compromising in-service loads of up to 250 tonnes.

www.aml3d.com

PostProcess Technologies adds Z-axis and 3D Alliances to its partnership network

PostProcess Technologies Inc., Buffalo, New York, USA, a provider of automated post-production solutions for industrial Additive Manufacturing, has announced a channel partnership with Russia-based Additive Manufacturing distributor Z-axis and a collaboration with 3D Alliances, based in Herzliya, Israel.

As part of the partnership, Z-axis will expand PostProcess Technologies' reach throughout Russia, Belarus, Kazakhstan, Kirgizia, and Armenia. 3D Alliances who specialise in the deployment and management of global channel networks for AM companies, will support PostProcess Technologies' recruitment of new European sales partners as part of the collaboration.

"It's been exhilarating to see the speed at which customers across the globe are seeking our automated and intelligent post-print solutions," stated Bruno Bourguet, Managing Director of PostProcess Technologies International. "To better service this expanding market and help us identify strong partners, we are pleased to have the opportunity to work with 3D Alliances. Already, they have helped us secure a strategic agreement with Z-axis. Together with our channel partners, we continue to aim at achieving our objective of moving forward in automating the post-print step of the Additive Manufacturing workflow in Industry 4.0."

Sergeï Kulakov, Director, International Division at Z-axis, commented, "Just between 2010 to 2018, we have seen a ten-fold increase in the value of the Russian Additive Manufacturing market. The revolutionary solutions offered by PostProcess Technologies will be increasingly valuable as this customer base continues to expand. We are thrilled at this partnership, which is enabling us with the opportunity to offer digitised end-to-end workflow solutions."

Gil Lavi, Founder and CEO of 3D Alliances, reported, "In the past year, and specifically at Formnext 2019, I could see the industry shift from prototyping solutions towards the integration of 3D printing technologies in manufacturing. This is the vision of many leading manufacturers who are looking to set their own tailor-made end-to-end digital workflow."

"Automated post-processing solutions are opening the bottleneck of handling large amounts of parts with minimum manual labour and maximum consistency, efficiency, and repeatability. We are thrilled to join forces with PostProcess Technologies, who is the leading player in this solution segment."

www.postprocess.com

Fraunhofer ILT, MTU Aero Engines, Airbus and Mercedes-Benz collaborate on hybrid AM

The Fraunhofer Institute for Laser Technology (ILT), Aachen, Germany, is collaborating with MTU Aero Engines, Airbus and Mercedes-Benz on the ProLMD research project. Established in 2016 and funded by the German Federal Ministry for Education and Research (BMBF), the project's aim is to develop new hybrid processes that combine conventional production methods with Laser Material Deposition (LMD) to develop a new manufacturing approach.

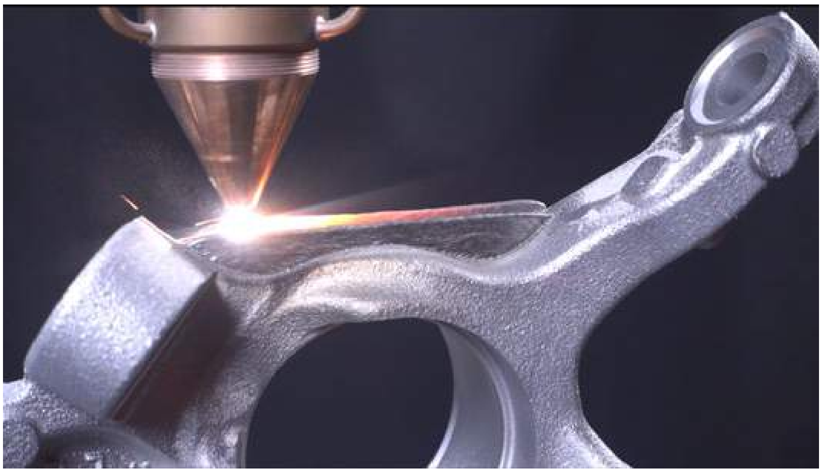
Fraunhofer ILT, together with a total of seven industrial partners, will collaborate on the development of a highly efficient, modular LMD cell that can be integrated into an existing process chain with little effort. To take advantage of maximum application flexibility, the partners are developing processes using both wire and powder materials.

Additionally, Fraunhofer ILT has developed a processing optic for generating a ring beam for coaxial laser material deposition, which is being further developed and used in the joint ProLMD project. This optic generates a ring with a uniform intensity distribution, thus offering directional independence during welding. In the project, processes with deposition rates in the range of 1 to 2 kg/h at high geometric resolution are being developed.

"The aim was to develop economical and robust system technology for the LMD process, based on a jointed-arm robot, and to integrate it into a process chain for hybrid manufacturing," stated Jan Bremer, a scientist at Fraunhofer ILT. "We are moving along the process chain for robot-based hybrid Additive Manufacturing and researching various technologies required for this. The spectrum of content covers everything – from processing heads, robot and shielding gas systems to welding processes, quality assurance and software."

Fraunhofer ILT explained that what hybrid actually means in practice can be demonstrated by three applications from the project partners – MTU Aero Engines (the addition of functional elements on an engine component), Airbus (component reinforcement by the addition of AM ribbing) and Mercedes-Benz (the adaptation of a press tool in body production). The project focuses on locally reinforcing or modifying conventionally manufactured components, but the technologies developed also make repair applications possible.

Bremer added, "These examples show what we understand by hybrid manufacturing. It is the flexible combination of advantages from different manufacturing processes, as it combines any conventional manufacturing process with LMD to form a continuous process chain."



Example of the hybrid Additive Manufacturing process to be developed as part of the project (Courtesy Fraunhofer ILT)

Turbine housing of a GEnx engine (Courtesy MTU Aero Engines AG)

Hybrid manufacturing also provides a good example of how complex variant diversity can be simplified in production, Bremer explained: "For example, you always start by punching and trimming a basic part in the same way. The variants are then later produced using LMD. The user can, therefore, continue to use his punching machine, but then additively apply reinforcements to the component, for example."

"Thanks to the LMD process and the technologies developed in ProLMD, we can act flexibly and use automation to a great extent. This is in line with our guiding principle: Additive Manufacturing – but only in those parts of the process chain where it results in added value," he concluded.

The division of tasks among the other project partners sees the Lasertec business unit of the KUKA site in Würselen responsible for project management and cell integration of the robot, while Laserline GmbH from Mülheim-Kärlich is in charge of the design and development of the beam source and optics. M. Braun Inertgas-Systeme GmbH, Garching, is responsible for the construction of a shielding gas cell, while Dortmund-based BCT Steuerungs- und DV-Systeme GmbH is developing the software and machine-integrated measuring technology.

While KUKA has its robot weld materials sensitive to oxidation, such as titanium, in a flexible shielding gas cell reliably, the Aachen-based engineers are using another robot system to weld nickel- and iron-based materials without a shielding gas cell, but with shielding gas flowing locally from the nozzle. If the deposition rate is higher, an additional shielding gas nozzle of a few centimetres in size is used as required.

Fraunhofer ILT states that, at its Aachen base, there is one large and one more compact robotic cell for Additive Manufacturing. With additional financial support from the BMBF, they are creating a less expensive version of the ProLMD robot system for small- and medium-sized enterprises (SMEs).

"We have scaled down the solution from a 3.1 m long robot arm with 90 kg load capacity to about 2 m and 60 kg load capacity," Bremer further added. "On the large robot, we can demonstrate a flexible changing system with wire- and powder-based processing heads, while the small cell is all about powder-based LMD, machine-integrated geometry measurement and the new CAM module."

www.prolmd.de

Heraeus AMLOY and Trumpf to work on the Additive Manufacturing of amorphous metals

An amorphous expansion sleeve is one part that can be improved by the Additive Manufacturing of amorphous metals (Courtesy Heraeus AMLOY)

Heraeus AMLOY, a division of Heraeus, Hanau, Germany, and Trumpf, Ditzingen, Germany, have joined together to collaborate on the Additive Manufacturing of amorphous metals, also known as metallic glasses. The aim of the collaboration is to establish the Additive Manufacturing of amorphous parts as a standard production method on the shop floor by improving process and cost efficiencies.

According to the companies, amorphous metals are twice as strong as steel, yet significantly lighter and more elastic. They exhibit isotropic behaviour, which means their material properties remain identical, regardless of the direction in which the AM machine builds up the workpiece.

Heraeus AMLOY and Trumpf believe that a number of areas could benefit from the Additive Manufacturing of amorphous metals, and key examples of this include parts that are subject to significant stresses, as well as where lightweight design is required, in sectors such as aerospace and mechanical engineering. These materials are also believed to be an excellent choice for medical devices due to their biocompatibility.

Combining the advantages of amorphous metals and Additive Manufacturing

Amorphous metals are formed by cooling molten metal extremely quickly. An Additive Manufacturing machine can then build them into larger, more complex parts – something that other methods are unable to do, according to the two companies.

This opens the door to new industrial applications for amorphous metals. Additive Manufacturing also exploits the considerable potential that amorphous metals hold for lightweight design, as an AM machine only builds structures that actually help a part fulfil its function, so material use and weight are kept to a minimum.

Amorphous metals are very light by nature, so the combination of Additve Manufacturing and amorphous metals can reduce weight in a range of applications. AM makes the production of amorphous parts faster and simpler in a wide range of contexts, and enables users to build parts in one piece instead of making components one-by-one and then assembling them into a finished part.

Tailoring amorphous alloys for Trumpf's TruPrint machines

As part of this collaboration, Heraeus AMLOY will combine its expertise in the production and processing of amorphous metals with Trumpf's experience in Additive Manufacturing. Heraeus AMLOY states that it has optimised its amorphous alloys for Additive Manufacturing and tailored the material for use with Trumpf's TruPrint systems.

The latest-generation TruPrint 2000 machine is believed to be a particularly good choice for additively manufacturing amorphous metals, as the machine is designed to enable excess powder to be prepared in an inert gas environment for the subsequent build. This protects the powder from any adverse influences, which is a key for amorphous metals because they react so quickly with oxygen.

Customers that already have a Trumpf AM machine can now reportedly use it to process zirconium-based alloys from Heraeus AMLOY, and it is also possible to order additively manufactured amorphous parts directly from Heraeus. The two partners hope to make copper- and titanium-based alloys available for Additive Manufacturing in the future.

Klaus Parey, Managing Director Trumpf Additive Manufacturing, commented, "Amorphous metals hold potential for numerous industries. For example, they can be used in medical devices – one of the most important industries for Additive Manufacturing. That's why we believe this collaboration is such a great opportunity to make even more inroads into this key market with our industrial 3D printing systems."

www.heraeus.com
www.trumpf.com

Intech Additive Solutions launches new range of metal AM machines

Intech Additive Solutions Pvt. Ltd., Bangalore, India, formerly known as Intech DMLS Pvt. Ltd., has launched a new range of metal Additive Manufacturing machines. The iFusion machine series includes the iFusion SF1 and iFusion LFMulti, designed and constructed at Intech Additive Solutions' Bangalore facility.

Established in 2012, Intech Additive Solutions has been offering metal AM services to both the domestic and global markets for some time, providing solutions from concept design to fully-functional production parts for industries including aerospace, automotive, general engineering and medical. The company has business offices in the USA and Europe and has previously received strategic investment from DMG Mori.

On the launch of the company's range of metal AM machines, Sridhar Balaram, MD & CEO of Intech Additive Solutions, stated, "The iFusion series of metal 3D printers, based on the Selective Laser Melting technology and the first of its kind in India, are designed for high precision, stability, reliability and to deliver unmatched performance with higher build rates."

"These cost-effective machines are part of Intech's 3D eco system, with softwares bundled in for machine parameter optimisation and build process being sold as a package," he continued. "The overall target of Intech is to reduce the cost of acquisition, cost of operations and first time right with a quick go to market."

The iFusion SF1 is a smaller-format machine designed for use in R&D laboratories, universities and other small-scale production environments. The iFusion LFMulti is a large-format multi-laser machine said to offer extensive features, designed for use in large-scale industrial metal AM.

"These machines are a culmination of more than 30,000 man hours of research, development and innovation spread over the past thirty-six months," explained Balaram. "We have 3D printed more than 800 parts for variety of industries in different materials. Along with our in-house developed Software AMOptoMet and the upcoming AMBuilder, we aim to create a full-fledged eco system for Additive Manufacturing, fuelling the industrialisation of AM in India."

www.intechadditive.com

The Intech Additive Solutions team poses in front of the newly-released iFusion SF1 and iFusion LFMulti (Courtesy Intech Additive Solutions Pvt. Ltd.)

MN3D network established for Additive Manufacturing in maritime industry

A new network, MN3D, has been established by the Maritime Cluster Northern Germany (MCN) to drive the adoption of Additive Manufacturing in the maritime industry. Funded by the Central Innovation Program for SMEs (ZIM) of the Federal Ministry of Economics and Energy, the network aims to develop improved, alternative manufacturing methods and products for the maritime sector. In doing so, its special needs and requirements will be taken into account. These concerns include the size and exposure of the objects to low-frequency vibrations, seawater resistance, durability of objects and associated reliability, accessibility of the objects, environmental requirements and economic efficiency. The implementation of AM in the maritime industry and marketing strategies will also be jointly driven by the network partners.

Global sales in Additive Manufacturing, including software, hardware and materials, reportedly rose by 18% in 2018 to over €8 billion. The AM market is expected to continue to grow rapidly in the coming years.

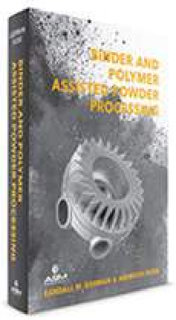
All activities of the MN3D network partners will be directed towards the joint development of concrete research and development projects to promote innovations in AM for the maritime industry. To this end, applications will be submitted to the ZIM program for further funding. Currently, R&D projects are being planned on surface quality, materials, integration of sensor technology, component sizes and tool life.

The MN3D partners can be found on the network's website.

www.maritimes-cluster.de
www.mn3d.de

ASM International publishes new book on binder and polymer assisted powder processing

ASM International has published a new book, *Binder and Polymer Assisted Powder Processing*, co-authored by Randall M German and Animesh Bose.



Binder and Polymer Assisted Powder Processing has been published by ASM International (Courtesy ASM International)

The 273-page book focuses on the basic principles and options available for the application of polymers and natural organics to powder processing. It links materials, powder characteristics, forming processes and product attributes together to give what the authors believe to be the first unified treatment on polymer-assisted powder processing.

The processes discussed include injection moulding, sinter-based Additive Manufacturing, uniaxial die compaction, tape casting, extrusion, slip casting and slurry casting. In each process, the technical requirements are outlined and polymer candidates are identified.

ASM International explains that the book bridges the practical aspects of cost, availability and safety with fundamental structure, properties, processing and tests. Each chapter concludes with a review of current industrial standards and examples of practices.

The book covers the following topics as dedicated chapters:

- Engineering powders
- Binder constituents
- Binder formulation
- Powder-binder feedstock mixing and testing
- Shaping processes
- Binder removal
- Sintering densification
- Component mechanical properties
- Case studies of powder-binding processing practices
- Opportunities for powder-binder forming technologies

The book is available to purchase via the company's website.

www.asminternational.org

Titomic and Triton Systems to deliver AM to US Department of Defense

Titomic Limited, Melbourne, Australia, has partnered with product development and technology company Triton Systems Inc, headquartered in Chelmsford, Massachusetts, USA, to implement Titomic's Kinetic Fusion (TKF) capabilities for validation through R&D projects with the US Department of Defense (DoD).

Established in 1992, Triton has introduced many products used by the defence and healthcare sectors. The company specialises in bringing specific products to a validation stage where DoD approval leads to product manufacturing, and as part of the Defense Industrial Base, develops and delivers critical solutions to address complex challenges that support the DoD through applied research and development, including the design, development and supply of products, subsystems, and components to meet US military requirements.

The focus of the partnership will be to enable products made with Titomic's TKF technology meet stringent military requirements, including performance in temperature extremes, robustness, and durability under very demanding operating environments. Current metal AM production processes and materials have reportedly not been able to satisfy the requirements of the DoD for certain mission-critical applications.

Utilising Triton's existing DoD network, Triton will execute programmes to deliver prototypes using the unique capabilities of Titomic TKF metal AM systems. The parties will collaborate on a technology transfer program to 'upskill' their respective technical teams with manufacturing capabilities only achievable using the TKF process.

"The signing of this agreement with Triton Systems, a successful US technology venture company, represents a strong pathway to explore commercial opportunities within the US Department of Defense," stated Jeff Lang, Titomic Managing Director.

Titomic and Triton will also explore opportunities for the acquisition of one or more TKF systems within Triton's facilities in the USA for further research and OEM production. In the interim, Titomic will provide sample and prototyping fabrication services for existing development efforts from its Melbourne bureau.

David Model, Chief Operating Officer of Triton Systems, added, "We are excited to bring Titomic's cutting edge cold spray technology to our DoD customer base. The defence community has been looking for the capability to quickly and flexibly manufacture large scale parts using additive technology. We believe the TKF solution will allow Triton and Titomic to closely work with our DoD end users and prime partners to facilitate the qualification and adoption of critical additively manufactured parts for military platforms."

www.titomic.com
www.tritonsystems.com

AM 4 Industry project publishes cost-benefit tool to identify suitable AM components

The Ecoplus Plastics and Mechatronics Cluster, based in Lower Austria, has reported that researchers Tobias Schröer and Sören Münker from the Research Institute for Rationalization (FIR) at RWTH Aachen University and part of the of the Collective Research Network (CORNET) project 'AM 4 Industry' led by Ecoplus Plastics and Mechatronics Clusters, have developed a practical cost-benefit tool that helps companies identify components suitable for Additive Manufacturing.

The researchers explained that deciding on the use of Additive Manufacturing processes in a company can be very challenging, and is often based on incomplete information and time-consuming trial-and-error tests. Practice shows that competitive advantage is often created only through deep integration of AM into the value chain. For example, the cost advantages of lightweight components manufactured using AM are achieved through reduced fuel consumption over the part's whole lifetime.

Thus, a classic comparison of manufacturing costs is often insufficient for obtaining a realistic assessment of the economic advantage. The researchers believe that what is needed is a holistic model that can compare not only the costs but also the technological advantages at a very early stage to help identify new benefits and accelerate decision-making processes. With this goal in mind, Schröer and Münker have developed an advanced cost-benefit tool as part of the 'AM 4 Industry' project.

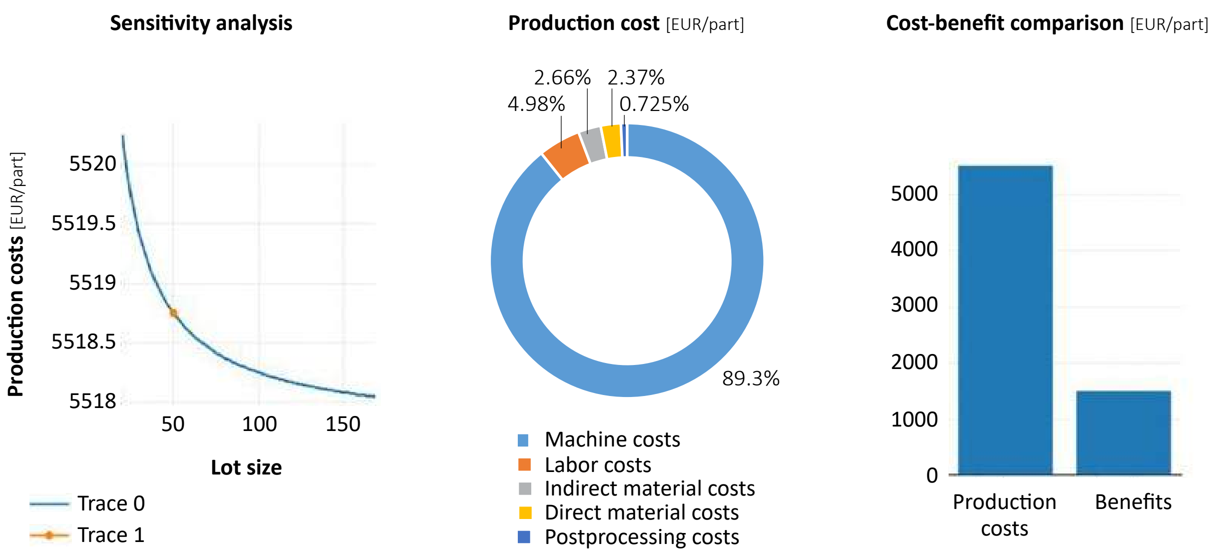
The model reportedly helps to assess the individual cost-benefit ratio in a structured way by acknowledging specific product characteristics and already known advantages of the AM technologies. It takes into account the entire life cycle of product design/engineering, production/quality and service/after-sales in order to determine the most economically-promising applications out of the totality of the potential applications. As a result, the practicable model enables industrial users to compare different production methods for specific parts and supports well-founded and accelerated decision-making.

"Capturing the potential of Additive Manufacturing and exploiting it is a major practical challenge," stated Tobias Schröer, Head of Production Management at the RWTH Aachen and co-developer of the cost-benefit model. "The cost-benefit tool clearly shows how to identify possible business cases by comparing costs and benefits at an early stage."

The 'AM 4 Industry' project comprises eight renowned research partners and fifty-one companies from Austria, Germany, and Belgium, who have spent two years researching the successful industrial use of Additive Manufacturing processes. The primary goal of the project was to develop models to support companies in successfully integrating AM in production technologies. In contrast to existing approaches, the newly developed cost-benefit model allows the identification and evaluation of Additive Manufacturing not only in terms of costs but also of generated benefits.

The cost-benefit model can be downloaded via network's website.

www.am4industry.com



Researchers from RWTH Aachen University and have published a cost-benefit tool for AM as part of the 'AM 4 Industry' project (Courtesy 'AM 4 Industry')

Elementum 3D and Masten Space complete hot fire testing of fuel injector

Elementum 3D, Erie, Colorado, USA, and Masten Space Systems, Mojave, California, USA, have completed successful hot fire testing of their jointly-developed PermiAM metal additively manufactured fuel injector, part of the NASA Phase I SBIR project.

The patent-pending PermiAM Laser Beam Powder Bed Fusion (PBF-LB) process, is reported to enable material agnostic transpiration cooling, which enables complex rocket engine injectors, with face cooling, to be built using Additive Manufacturing. The technology is said to enable design simplification and cost savings by combining regions of controlled permeability with fully-dense structures within the same injector component. As well as space-going engines, this technology could also be applied to other fields, including commercial jet engines or automotive fuel injection.

A key benefit of PermiAM, compared to traditional porosity creation methods, is its ability to form micron-scale porosity, Elementum 3D told *Metal AM* magazine. This enables high-fluid resistivity and controllable pressure drops, enabling optimised injector performance. With the ability to vary material density, structural and flow performance may be fine-tuned across the part, enabling novel injector geometries with structural members embedded in porous transpiration-cooled faces or small-scale porous flow paths integrated into structural elements.

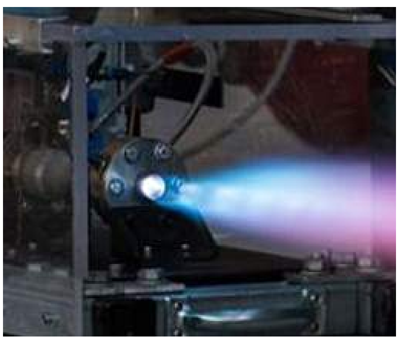
Varying the density across the part enables lightweight, yet stiff and strong, parts that can increase engine thrust-to-weight ratio. Cost and schedule savings are realised through the capability to manufacture single parts with varying material properties where, in the past, multiple components needed to be manufactured separately and assembled with a high touch time, long lead times and higher operations costs.

Through work with industry partners, as well as direct quotes from manufacturers for hardware, Masten has determined that the cost savings provided by PermiAM will meet or exceed the 60% mark, which is the criterion used in business to determine when a technology or process is game changing. Time savings of over 90% are possible when compared to a traditional Rigimesh rocket injector face, and weight savings of 50–70% can be achieved for the hot structure, as PermiAM cooling could allow aluminium to replace Inconel parts.

"This exciting work with Masten is leading us to new and exciting technologies only possible with 3D printing," Dr Jacob Nuechterlein, Elementum 3D's President and Founder, told *Metal AM*. "We see PermiAM making a significant impact on all sorts of industries, from diesel engines to complex heat exchangers to carbon sequestration. Like many space innovations, we are applying our joint technology to a wide variety of terrestrial applications as well."

Sean Mahoney, CEO of Masten Space Systems, added, "The value of this technology is unlocked where it turns into applications – and that is precisely what Elementum and Masten are doing. This partnership is already helping improve systems here on Earth, and unlocking the Moon for our future."

www.elementum3D.com
www.masten.aero



Elementum and Masten Space's PermiAM fuel injector (Courtesy Masten Space Systems)

M. Holland adds BASF metal filament to its offering

M. Holland Company, Northbrook, Illinois, USA, a distributor of thermoplastic resins, has announced an expanded distribution agreement with BASF 3D Printing Solutions, Heidelberg, Germany. Adding to its portfolio of AM products and services, M. Holland is now distributing Ultrafuse® 316L, BASF's stainless steel composite filament. This filament can be processed using standard Fused Filament Fabrication (FFF) machines and debinding and sintering processes.

"We are excited to broaden our existing relationship with BASF and are fortunate to be among the select organisations authorised to distribute Ultrafuse® 316L," stated Haleyanne Freedman, Market Manager, 3D Printing at M. Holland. "This metal polymer composite filament is a groundbreaking and industry-changing product that is also cost-effective. Our clients can leverage this distinct material to complement existing plastic injection moulding opportunities and a wide array of other applications."

"By expanding our distribution partnership with M. Holland to now include our Ultrafuse® 316L metal filament for Additive Manufacturing, we are able to make the printing of metal parts more accessible and affordable to manufacturers," added Firat Hizal, Head of Metal Systems, BASF 3D Printing Solutions. "As we expand our presence in North America, customers can quickly and reliably create stainless steel parts, utilising their existing printers and an established debinding and sintering network."

This distribution arrangement follows a prior agreement with BASF, and enhances a growing portfolio of AM materials from suppliers Henkel, Owens Corning and 3DXTech.

www.mholland.com

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ADDITIVE MANUFACTURING

24-28 August 2020 Dresden, Germany

For those wishing to gain profound insights into the current state of Additive Manufacturing technologies for metal and ceramic parts, including non-beam methods like binder jetting and fused filament fabrication, this is the perfect place to be. The unique abundance of dedicated AM labs of four Fraunhofer institutes, as well as the strong industry presence, ensures that this intense course is up-to-date and of practical relevance. The program includes plant and lab visits as well as practical hands-on exercises.

REGISTRATION DEADLINE: 10 August 2020


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POWDER AND HARD METAL

12-16 October 2020 Gothenburg, Sweden

Hosted by Chalmers University, this module covers both fundamental aspects as well as industrial practise given by experts from academia, research institutes and industry. The module includes state-of-the-art lectures on metal powder fabrication and properties for Additive Manufacturing, Hot Isostatic Pressing and Press & Sinter. The week in Gothenburg also includes a study visit to a powder fabrication plant, that will include a lab and plant tour and onsite presentations.

REGISTRATION DEADLINE: 12 August 2020

PRESS AND SINTER

2-6 November 2020 Grenoble, France

Hosted by Grenoble's INP, National Institute of Technology, the Press and Sinter module will cover both fundamental and practical facets of conventional powder processing, pressing and sintering operations. The participants will get an understanding of the physical, chemical and mechanical mechanisms that operate during powder pressing and sintering operations, which will improve understanding of the industrial process.

REGISTRATION DEADLINE: 15 October 2020


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eit RawMaterials ACADEMY

EPMA european powder metallurgy association

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

Empa uses novel AM process to alter properties in magnetic parts

Empa, the Swiss Federal Laboratories for Materials Science and Technology based in Dübendorf, Switzerland, has published its results from a recent research study, creating new alloys with novel properties and embedding them in additively manufactured metal workpieces with micrometre precision.

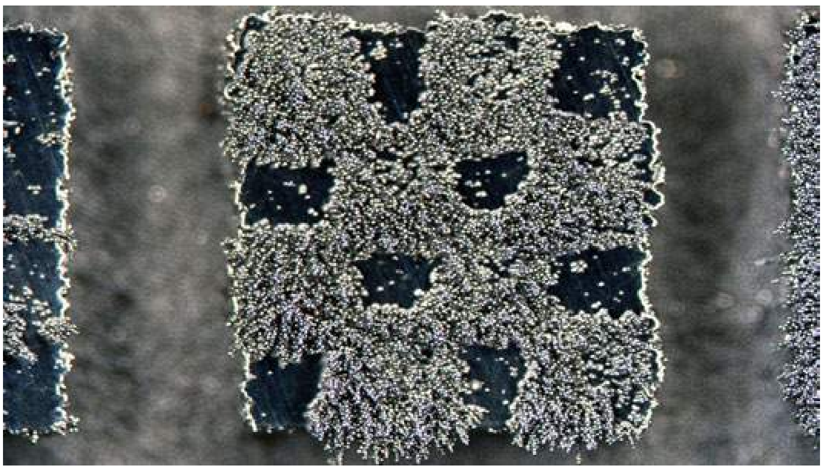
During metal Additive Manufacturing in Laser Beam Powder Bed Fusion (PBF-LB) machines, temperatures of more than 2,500°C are reached within milliseconds, causing some components of the alloys to evaporate. Widely considered a problem inherent to the process, Empa researchers explain that they have transformed this problem into an opportunity..

Empa states that the material sample, which it describes as a small metallic chessboard 4 mm long on either side, shows that Additive Manufacturing is not only suitable for creating new geometric shapes, but also for producing new materials with completely new functionalities. The small chessboard is a particularly obvious example, with its eight magnetic squares, and eight non-magnetic squares. The entire piece has reportedly been additively manufactured from a single grade of metal powder with only the power and duration of the laser beam varied.

At the beginning of the study, the Empa team, led by Aryan Arabi-Hashemi and Christian Leinenbach, used a special type of stainless steel which was developed twenty years ago by Hempel Special Metals in Dübendorf, among others. The so-called P2000 steel does not contain nickel, but around 1% of nitrogen. P2000 steel is said to not cause allergies and is well suited for medical applications. However, it is particularly hard, which makes conventional milling more difficult.

Initially, it seems unsuitable as a base material for AM, state the team. In the melting zone of the laser beam, the temperature quickly peaks and a large part of the nitrogen within the metal normally evaporates, changing the properties of the P2000 steel.

Arabi-Hashemi and Leinenbach are reported to have turned this drawback into an advantage. They modified the scanning speed of the laser and the intensity of the laser beam, which melts the particles in the metal powder bed, and thus varied the size and lifetime of the liquid melt pool in a specified manner.



Precisely magnetised iron filings stick to this mini chessboard with 4 mm edge length (Courtesy Empa)

In the smallest case, the pool was 200 microns in diameter and 50 microns deep, in the largest case 350 microns wide and 200 microns deep. The larger melt pool allows much more nitrogen to evaporate from the alloy; the solidifying steel crystallises with a high proportion of magnetisable ferrite. In the case of the smallest melt pool, the melted steel solidifies much faster. The nitrogen remains in the alloy; the steel crystallises mainly in the form of non-magnetic austenite.

During the experiment, the researchers had to determine the nitrogen content in tiny, millimetre-sized metal samples very precisely and measure the local magnetisation to within a few micrometres, as well as the volume ratio of austenitic and ferritic steel.

According to Empa, the experiment could soon add a key tool to the methodology of metal production and processing. The method is said to be not limited to stainless steels, but can also be useful for many other alloys.

"In 3D laser printing, we can easily reach temperatures of more than 2500°C locally," stated Leinenbach. "This allows us to vaporise various components of an alloy in a targeted manner – e.g. manganese, aluminium, zinc, carbon and many more – and thus locally change the chemical composition of the alloy."

Leinenbach considers certain nickel-titanium alloys known as shape memory alloys and at what temperature the alloy "remembers" its programmed shape depends on just 0.1% more or less nickel in the mixture. By using AM, structural components could be made that react locally and in a staggered manner to different temperatures.

The ability to produce different alloy compositions with micrometre precision in a single component could also be helpful in the design of more efficient electric motors, explains the Empa. It is now possible to build the stator and the rotor of the electric motor and make better use of the geometry of the magnetic fields.

www.empa.ch

Texas A&M researchers develop method for Additive Manufacturing martensitic hard steels

Researchers at Texas A&M University, USA, in collaboration with scientists at the US Air Force Research Laboratory, have reportedly developed a process that allows the Additive Manufacturing of martensitic steels into sturdy, defect-free objects of nearly any shape.

Martensitic steels naturally lend themselves to applications in the aerospace, automotive and defence industries, among others, where high-strength, lightweight parts need to be manufactured without adding to part cost. However, for these and other applications, the metals must to be able to be built into complex structures with minimal loss of strength and durability.

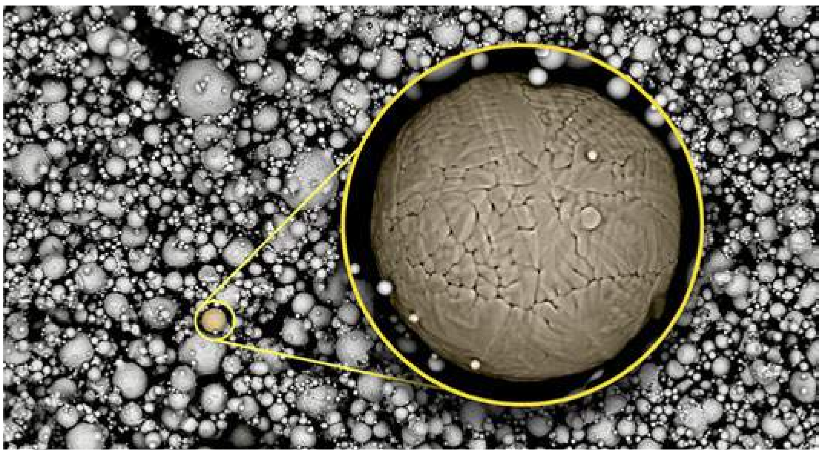
"Strong and tough steels have tremendous applications but the strongest ones are usually expensive – the one exception being martensitic steels that are relatively inexpensive, costing less than a dollar per pound," stated Ibrahim Karaman, Chevron Professor I and head of the Department of Materials Science and Engineering. "We have developed a framework so that 3D printing of these hard steels is possible into any desired geometry and the final object will be virtually defect-free."

Although the procedure developed was initially for martensitic steels, researchers from the Texas A&M said they have made their guidelines general enough so that the same AM pipeline can be used to build intricate objects from other metals and alloys. The findings of the study were reported in the December issue of Acta Materialia.

Martensite steels and metal Additive Manufacturing

Martensite steels are formed when steels are heated to extremely high temperatures before being rapidly cooled. The sudden cooling unnaturally confines carbon atoms within iron crystals, giving martensitic steel its signature strength. To meet the needs of a diverse field of applications, martensitic steels, particularly low-alloy martensitic steels, must be capable of being formed into a wide range of shapes and sizes depending on requirements.

Additive Manufacturing is the ideal solution for the production of complex-shaped components, but the AM of martensitic steels using laser-based processes such as Laser Beam Powder Bed Fusion (PBF-LB) can introduce defects such as pores within the material.



Martensite steel powder used for AM (Courtesy Raiyan Seede, Microstructural Engineering of Structural and Active Materials Group, Texas A&M)

"Porosities are tiny holes that can sharply reduce the strength of the final 3D printed object, even if the raw material used for the 3D printing is very strong," explained Karaman. "To find practical applications for the new martensitic steel, we needed to go back to the drawing board and investigate which laser settings could prevent these defects."

Predicting and preventing defects in additively manufactured martensitic steels

For their experiments, Karaman and the Texas A&M team first used an existing mathematical model inspired by one used in welding to predict how a single layer of martensitic steel powder would melt at different laser speed and power settings. By comparing the type and number of defects they observed in a single track of melted powder with the model's predictions, they were able to change their existing framework slightly so that subsequent predictions improved.

After a few such iterations, it was stated that their framework could correctly forecast – without additional experiments – whether a new, untested set of laser settings would lead to defects in the martensitic steel builds. This procedure is more time-efficient, the researchers explained:

"By combining experiments and modelling, we were able to develop a simple, quick, step-by-step procedure that can be used to determine which setting would work best for 3D printing of martensitic steels," stated Raiyan Seede, a graduate student in the College of Engineering and the primary author of the study.

Further contributors to the study included Austin Whitt and Raymundo Arróyave from the Department of Materials Science and Engineering; David Shoukr, Bing Zhang and Alaa Elwany from the Department of Industrial and Systems Engineering; and Sean Gibbons and Philip Flater from the Air Force Research Laboratory, Florida. The research was funded by the Army Research Office and the Air Force Research Laboratory.

https://engineering.tamu.edu/

3T-am cuts part setup time from five hours to ten minutes with Renishaw and MSP

3T Additive Manufacturing Ltd (3T-am), Newbury, Berkshire, UK, has achieved a reduction in its part setup time from five hours to ten minutes with the adoption of technology from Renishaw PLC, Wotton-under-Edge, Gloucestershire, UK, and Renishaw associate company MSP, Alnwick, Northumberland, UK.

3T-am, formerly 3T RPD, offers metal and polymer Additive Manufacturing services to a wide range of industries, primarily using Laser Beam Powder Bed Fusion (PBF-LB). It offers supply chain solutions providing parts that reduce volume weight, cost and lead time whilst maintaining safety through prototype, development and serial production.

3T-am has experienced strong growth in recent years, and while originally known for its prototyping capabilities, has more recently become established as a serial production company. As a result, the company is looking to expand its capability and capacity to meet customer demand.

Though it has always delivered orders on time, due to its meticulous and lengthy setup processes, operators were often required to work unplanned overtime shifts in order to fulfil urgent customer orders and meet quick turnaround times. To ease this pressure, the company made significant investments in two 5-axis mills and a CMM, but despite this extra capacity, each part still required manual setup, and, therefore, created additional demand on their manufacturing personnel to deliver parts on schedule.

By automating 3T-am's processes, MSP has made it possible for the company to complete setup and alignment for a full batch of parts in the machine during the day and leave the machine to run overnight with full confidence. This has enabled 24/7 lights-out production, allowing the company to maximise its machine utilisation and produce a whole batch of parts in one day, compared to only one part previously.

3T-am's part setup time was reduced from five hours to ten minutes (Courtesy MSP)

The need for automation at 3T-am

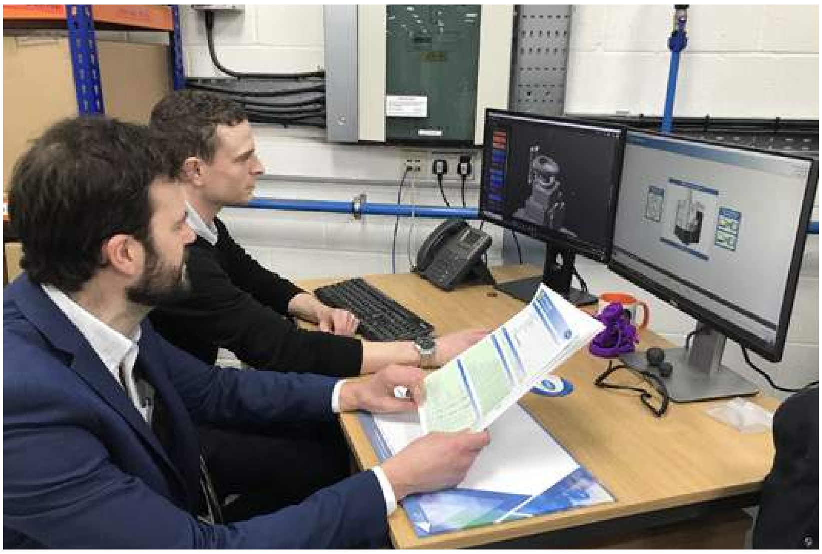
3T-am's ambition was to produce right-first-time parts, but the company found that this would be impossible without automation due to the inherent challenges posed by Additive Manufacturing. Their production to near-net shape means there is little material to work with, giving no margin of error, and they are usually complex shapes with no orthogonal surfaces to locate on, making it difficult to achieve accurate alignments. Furthermore, the AM build process can cause parts to distort, meaning their final shape may be marginally different to the initial CAD model.

Before introducing MSP's products, 3T-am manually located each part in the fixture. This was a highly skilled and very time consuming process to ensure the alignment was accurate. Test spotting cuts were made to visually identify positional error, and the part was then either manually adjusted again or updates to the machining program were made. This manual setup process took, on average, five hours per part, but for more complex parts could sometimes take a day.

Once the initial part had been machined, a first article inspection on the CMM was performed before the rest of the batch could be manufactured. For a complex part, this inspection process could check in excess of sixty features, and it would only be at this stage that errors were discovered, meaning that the setup process needed adjustments and causing delay in the manufacture of the other parts. Even if the part passed inspection, the machine tool had in the meantime sat unused waiting for the inspection result.

Furthermore, the length of the process meant jobs were passed between operators and engineers changing shifts, which resulted in extensive technical handovers to safeguard the alignments needed on each job. For more complex parts, a 'one job, one man' method was used to avoid key information being missed; however, this made part manufacture solely dependent on one person and their working shifts, potentially resulting in excessive overtime and pressure for this engineer.

Martin Jarvis, Production Engineer at 3T-am, stated, "Our manual setup was high risk and we had low confidence. We would be nervous when the finished part was taken to inspection as our day's work could be written off and we would need to do an expensive single part rebuild and fast track it through production to ensure it was delivered on time – that was a problem."



3T-am invested in NC-Inspect MODUS (left) and NC-PerfectPart (right) (Courtesy MSP)

Solving the problem with Renishaw and MSP

3T-am turned to Renishaw and MSP to help reduce setup times, improve quality and automate their processes in order to make full use of their pallet changing system for lights-out production and maximise machining capacity.

The use of Renishaw's OMP600 high-accuracy machine tool probe and MSP's NC-PerfectPart software allows 3T-am to identify and correct errors in part positioning and machine performance prior to machining. The OMP600 offers all the benefits of automated job setup, as well as the ability to measure complex 3D part geometries and, in combination with MSP's software, automate machining processes and eliminate the potential for human error.

NC-PerfectPart's initial step is to assess the machine tool's geometric performance to ensure it is calibrated and correct in 5-axis movement. This confirms every aspect of the probe and machine performance is within set tolerances prior to part setup and machining, to ensure that parts can be finished accurately.

The part is securely loaded into the machine and the software then measures it to calculate an accurate best fit alignment in 6° of freedom. The controller is automatically updated to compensate for the discrepancy between the physical part location and the nominal machining program, to ensure the machining path takes place where the real part is.

This eliminates the need to carefully fixture and adjust the part manually. Crucially, any misalignment errors are automatically removed and the time taken to align or locate the part is significantly reduced.

The same measurements are then used by the software to check the part's condition of supply. It produces a Pre-Machining Inspection Report, which notes if there is too much distortion or not enough material to create a 'good part' or 'clean up' in the areas which are to be machined. This is generated before any machining begins, so the part process can be stopped from the outset if any condition of supply errors are present.

NC-PerfectPart's ability to automate part alignment and take measurements at any tool orientation, in any direction, also allows for simple, generic work holding to be used, as the fixture is only required to securely hold the part. This removes the need for expensive bespoke location fixtures and allows the same fixture to be used for multiple parts (where applicable).

At the end of the process, using NC-PerfectPart, the part can be inspected on the machine before it is removed from the fixture and a Post-Machining Verification report is produced which verifies the part has been machined within tolerance. This reduces reliance on the CMM, eradicating CMM bottlenecks and gives the ability to automate the inspection process.

"I challenged MSP to prove their claims in real time as it all seemed too good to be true," stated Jarvis. "I attended Renishaw's Innovation Centre in Gloucester and presented the MSP engineer with a completely blind test. I turned up with a part which they had no advance knowledge of, and they programmed the part and delivered the promised results before my eyes. When MSP's products were installed at 3T-am, the MSP guarantee also meant we were making right-first-time parts before their engineer even left site."

Operator and Programmer at 3T-am, Jon Saunders, added, "As well as the great results, we have been very pleasantly surprised by how straightforward MSP's software has been for us to use day to day. The automation gives us the certainty we always wanted that the parts are going to be right."

"The impact has been huge for us in terms of our working practices and the confidence we now have in delivering what we do," commenced Jarvis. "It has almost made me want to get back out working on the shop floor."

www.3t-am.com
www.renishaw.com
www.mspltd.com

3D Systems releases enhanced reverse engineering software for AM

3D Systems, Rock Hill, South Carolina, USA, has announced two new versions of its Geomagic® Design X™ and Geomagic Wrap® software, which include first-to-market capabilities that are said to streamline workflows and offer digital tools to achieve greater precision. These enhancements to its reverse engineering solutions have been developed to help manufacturers maintain a competitive advantage by accelerating product development cycles, enabling faster time to market.

3D Systems explains that its Geomagic Design X software combines robust 3D scan processing and complete CAD design functionality to achieve faster, more accurate and reliable reverse engineering than is possible with other methods. Using the software's newest features, engineers are expected to benefit from streamlined modelling workflows as well as expanded modelling pathways for complex, revolved parts.

The newest Geomagic Design X release includes an Unroll/Reroll function that enables a new modelling workflow to tackle these complex, revolved parts. Revolved parts with features have historically been very cumbersome to model, as CAD software uses a two-dimensional environment to create three-dimensional, rotating parts with multi-axis features. The process often requires a great deal of trial and rework to get to a final part – often sacrificing precision. Using a comprehensive suite of mesh processing tools, an engineer using Geomagic Design X can now unroll the mesh to automatically extract a 2D sketch, make the modifications needed, and then reroll the sketch for additional engineering. This feature reduces the need for multiple rounds of trial and re-work, dramatically improving part precision, efficiency and downstream usability.

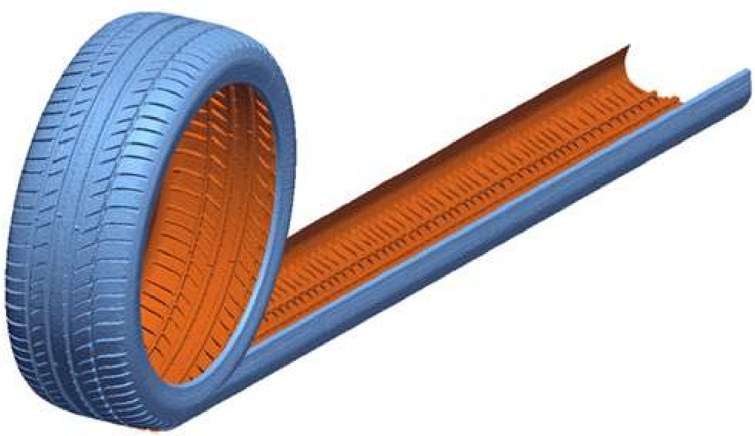
The new Selective Surfacing features in Geomagic Design X 2020 simplify the hybrid modelling process, providing easy workflows for traditionally difficult parts with both organic and prismatic features. Topology optimised parts and castings with precision features present unique challenges for repatriating a generative mesh or 3D scan into CAD with intelligence. Selective Surfacing combines fast organic surfacing with high precision feature modelling methods.

Also available will be Geomagic Wrap 2021, providing a toolset to transform 3D scan data and imported files into 3D models for immediate use in downstream engineering applications across a variety of industries. General availability of Geomagic Wrap 2021 is planned for late July 2020, and includes scripting automation said to enable engineers to work more efficiently. It includes a new scripting editor that allows engineers to customise their workflow for their unique applications. The editor uses Python – an open-source, widely-used programming language with which many engineers are familiar – to interact with the custom Geomagic Wrap accessible features. This has enabled a much simpler experience with new tools such as 'autocomplete' and 'contextual highlighting' that accelerate the design of accurate, 3D surfaced models. These new features are complemented by enhanced API Documentation that will be live-hosted on the company's support site providing customers access to continuously updated documentation

It also includes new texture manipulation tools to streamline workflows involving colour and texture scans. When an engineer scans an object that includes colours, logos or other complex visual elements in a scan-to-web workflow or digital asset creation, an additional software program is generally required to edit and retouch these files prior to manipulating the surface textures. The latest release includes a more robust set of texture map manipulation tools to deal with complex geometries directly within Geomagic Wrap. Having these advanced capabilities included in the same program streamlines the workflow – enabling creation of higher quality and more logical texture maps for improved downstream usability – helping improve efficiencies and reduce design time.

A new HD Mesh Construction method provides a powerful way to construct 3D data from point clouds. This can be a particularly challenging operation when dealing with a scan that is missing information, or for those that result in large data sets. HD Mesh Construction is designed to overcome these challenges, enabling engineers to create watertight meshes.

www.3dsystems.com



Unrolling of a 3D scan of a tyre for mould modelling in Geomagic Design X (Courtesy 3D Systems)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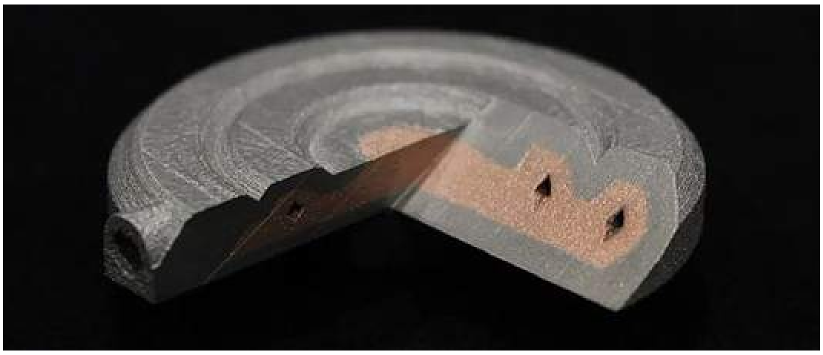
Aerosint additively manufactures its first dual metal part

Aerosint, Liège, Belgium, reports that it has additively manufactured its first dual metal part, produced on the Aconity Midi + machine. The machine was designed by the company's partner Aconity 3D GmbH, Herzogenrath, Germany, to enable Aerosint's multi-material powder deposition technology to be integrated.

According to Aerosint, this is a major breakthrough for Additive Manufacturing, as multi-metal AM gives designers and engineers the degree of freedom to make better parts; no other technology is thought to currently be capable of producing such dual-metal parts.

The integration of Aerosint's dual-metal recoater in Aconity3D's Midi + Laser Beam Powder Bed Fusion (PBF-LB) machine enabled the use of 316L and CuCrZr to build the test part. Consisting of 174 layers of 40 µm each, the part has a height of 6.9 mm and diameter of 55 mm. An integral 1.7 mm channel is featured within the CuCrZr portion. The part build time was said to be around 5.4 hours.

www.aerosint.com
www.aconity3d.com



Aerosint has additively manufactured a dual metal part for the first time (Courtesy Aerosint)

TU Graz develops LED-based metal Additive Manufacturing machine

Researchers at the Institute for Manufacturing Technology at Graz University of Technology (TU Graz), Austria, have developed a new technology for metal Additive Manufacturing called Selective LED-based Melting (SLEDM), involving the targeted melting of metal powder using LED light sources. The researchers have applied for a patent on the new process.

The technology is similar to Laser Beam Powder Bed Fusion (PBF-LB) or Electron Beam Powder Bed Fusion (PBF-EB), but reportedly eliminates two central problems of powder bed-based AM; the time-consuming production of large-volume metal components, and the time-consuming manual reworking required.

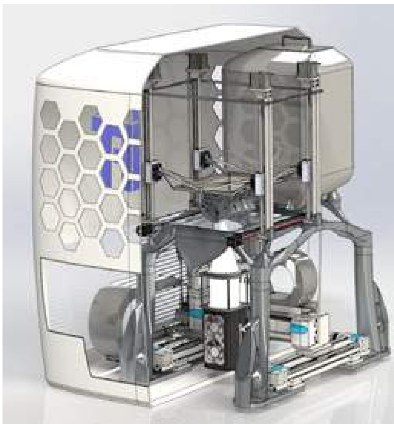
According to Franz Haas, head of the Institute for Manufacturing Technology at TU Graz, in SLEDM metal powder is melted using a high-performance LED beam. The light-emitting diodes used for this were specially adapted by lighting specialist Preworks and equipped with a complex lens system with which the diameter of the LED focus can be easily changed between 0.05 and 20 mm during the melting process. This enables larger volumes to be melted per unit of time, without having to do without filigree internal structures, and thus reduces the production time of components, for example for fuel cell or medical technology, by a factor of twenty.

This technology is combined with a newly designed production system, which – in contrast to other AM systems – assembles the component from top to bottom. This is said to reduce the amount of powder required and enable the necessary post-processing to be carried out during the AM process.

The demonstrator of the SLEDM process is included in the K project CAMed of the Medical University of Graz, where the first laboratory for medical AM was opened in October 2019. Here, SLEDM will be used to produce bioresorbable metal implants – primarily screws that are made of magnesium alloys and used in the repair of broken bones. These implants dissolve in the body after the fracture has grown together, meaning that a second operation is unnecessary. The researchers believe that, using SLEDM, it may be possible to produce such implants directly in the operating room, as an LED light is less dangerous to use in the operating theatre than a powerful laser.

The second focus for the SLEDM process is on sustainable mobility, namely in the manufacture of components such as bipolar plates for fuel cells or components for battery systems. Haas plans to produce a marketable prototype of the metal AM machine in the next development step.

www.tugraz.at



The metal AM machine developed at TU Graz melts metal powder using high-performance LED light sources (Courtesy TU Graz)

Innovation and differentiation: Precious metal Additive Manufacturing in the jewellery sector

Rich in creativity and rooted in a long artisanal manufacturing heritage, one would imagine that there can be few sectors as perfectly suited to embrace the potential of metal Additive Manufacturing than the jewellery industry. In reality, however, the sector continues to hold back on the full-scale adoption of AM, despite numerous successes. In this article, Michela Ferraro-Cuda considers progress to date in the adoption of precious metal AM in the jewellery industry, and showcases a number of leading designers who have leveraged the technology's potential for innovation and differentiation.

Jewellery is a multifaceted and complex sector which is almost impossible to consider as a single industry. This is in part because of cultural influences that play a significant role in differentiating the types of jewellery produced, and in part because of how jewellery is manufactured. Based on a particular culture, nationality and market, bespoke, small series or large series collections might be more likely. Considering the evident differences between the type of jewellery made by a skilful artisan or an artist, and jewellery produced on a large or even medium scale, it appears clear that the processes and technologies involved will differ – sometimes substantially. It is essential to comprehend these aspects of the jewellery industry in order to understand how precious metal Additive Manufacturing, based mainly on Laser Beam Powder Bed Fusion (PBF-LB) technology, has challenged the sector to find its own niche.

Given the value of the materials used, the added value of jewellery manufactured by an artisan is based on the fact that it is handmade (with the support of tooling), whereas for a piece of jewellery manufactured with faster, technology-based processes, the added value is based on the perfect replication of the same design, in small or large scale, at a lower cost than if it had been handmade. Regarding the artisan aspect of production, further discussion is needed on whether the value is different when AM is involved for part of the production process, or the entire process is based on the hand-modelling skills of an artist or artisan. This is a discussion that will not find an easy conclusion, if any.

Fig. 1 A bracelet from the 'Embrace' collection by Marie Boltenstern consisting of rows of colourful 4 mm gemstones woven into additively manufactured protective geometric spheres (Photo courtesy www.loupiosity.com)

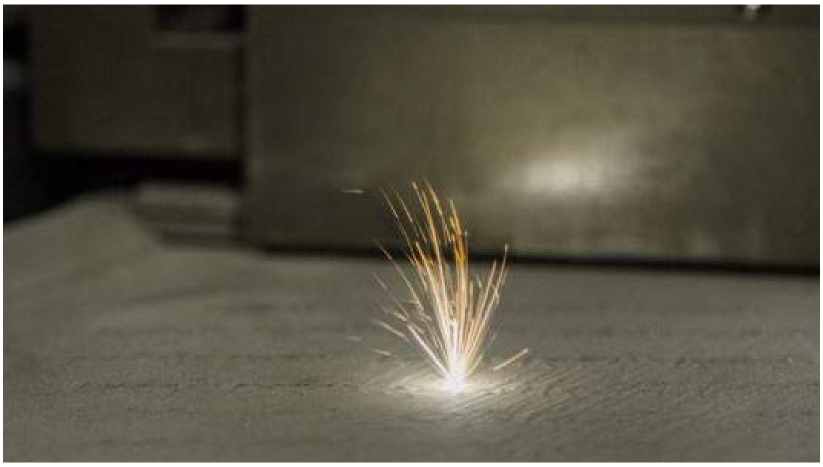


Fig. 2 Inside the build chamber of a Laser Beam Powder Bed Fusion (PBF-LB) machine at Progol3D® Internal Projects, Titanium (Courtesy Progold S.p.A.)

Fig. 3 PBF-LB build plates showing the support structures that are required during manufacture. Multiple items can be 'nested' on such build plates, but designers need to consider carefully the locations of removable support structures in order to minimise post-processing. Build by Progol3D® Internal Projects, Titanium (Courtesy Progold S.p.A.)

The backstory of AM in the jewellery industry

Wax model makers were in high demand until around fifteen to eighteen years ago; their ability to produce, for example, a mirrored model for a pair of earrings, was particularly highly valued. These sculptural skills were not widely available in the market, but the models they produced were the foundation for any casting production run. Thus, it was important for companies to reserve their 'spot' with model makers for each new collection from one season to another.

The advent of Computer Aided Design (CAD) software and the associated rapid prototyping processes – in essence the first examples of Additive Manufacturing – had a great impact on this aspect of the jewellery industry. Faster and more efficient prototyping ensured that, first, larger companies (which could afford to invest in this new technology) and, later, medium and even small companies (via a growing number of service bureaux) were able to maximise their production lines, speed up collection launches and optimise their related investments.

Reactions to the arrival of this new technology varied: some complained that designers no longer used their creative talents, instead merely exploiting the design features offered by CAD, while others focused on the new, unexploited potential of CAD and rapid prototyping technologies. The advent of new innovations in design and manufacturing always challenges the status quo, and the jewellery sector – perhaps due to its traditional heritage – is among the most suspicious of new technologies.

Despite this initial suspicion, fast prototyping processes had a very successful evolution in the industry and, in the years that followed, the range and types of equipment available to produce wax or resin models for casting greatly increased. For some jewellery collections, it is preferable to additively manufacture a wax or resin 'tree' with the models attached ready for casting. This offers

Fig. 4 An additively manufactured 18 Kt necklace by Nuovi Gioielli from the 'Sound of Wings' collection (Courtesy Nuovi Gioielli S.R.L.)

significant advantages for volume production, eliminating some process steps, saving time and keeping costs low.

It goes without saying, of course, that over the years the jewellery industry has fully adopted other processes such as stamping, electroforming and CNC machining for medium to large production runs or to provide semi-finished/finished parts. However, these processes require higher upfront investments and must be used to manufacture very high numbers of a product to amortise the cost. These production processes, therefore, are preferred for collections where consistent and large scale production is planned, or for collections with a higher mark-up, such as those by luxury brands.

So where in this landscape does precious metal Additive Manufacturing fit?

The arrival of precious metal AM in the jewellery market was met with curiosity and enthusiasm, especially among production departments and product developers. The immediate question was how both AM manufacturers and potential adopters could evaluate the potential of this new technology. The immediate approach was to make a comparison against pieces of jewellery already manufactured using other technologies. I remember reading with great curiosity the papers published on successful trials carried out in the aerospace industry, where metal AM could reduce the weight of some parts, or enable mechanical parts to be manufactured in one piece rather than several assembled pieces. In the jewellery industry, the same exercises did not yield such positive results. It is true that reducing weight in jewellery is one crucial factor, given the price of precious metal, but it is not the only one. In fact, the same comparison exercise, investigating how a piece of jewellery currently produced by casting or CNC would perform if produced by metal AM, could be very misleading.

A 2016 study carried out by Bulgari [1] reported on several trials undertaken by the company. The company's team compared parts of their jewellery collection, in precious and non-precious metal, made by

Fig. 5 These 18 Kt gold 'Ojo' pendants were created as part of a research project into the AM of complex jewellery designs, with a particular focus on surface finish and polishing processes (Courtesy Frank Cooper, Birmingham School of Jewellery, UK / Cooksongold)

the direct casting of an additively manufactured resin model, against pieces made by metal AM. The main aspects analysed by this study were density and conformity. The study is thorough and detailed, taking into consideration several metals and alloys, and represents a huge and extensive analysis comparing elements made using the two different techniques. However, from the beginning, precious metal AM has had a disadvantage, which made it challenging for jewellery making: the surface quality of as-built parts. Even if using the right combination of parameters (scan speed, laser power, etc) might offer the desired quality, Bulgari's team found that the process time required to produce the piece to the necessary quality would be too extensive, defeating the original purpose.

However, having talked recently with Ivano Torresan, CEO of Italian jewellery producer Nuovi Gioielli and an early adopter of AM for precious metals, his approach is simple: if a product already performs well when manufactured using a selected technique, why should we consider switching the production method to Additive Manufacturing? The answer, of course, is that we shouldn't. Or at least – we more than likely shouldn't.

The investment involved in adopting a manufacturing method such as precious metal AM should not be considered for those pieces of jewellery that can already be produced perfectly well using their current production method; where it should be considered is where the use of AM enables designers to challenge the norm and produce jewellery designs, which would be impossible to make by any other available manufacturing technique. This is the key.

Damiano Zito, CEO of Progold S.p.A., makes almost the same argument – he states that precious metal AM should be adopted where it enables the creation of new production paths, such as the production of a piece of jewellery in an alloy that would be problematic to process using casting, such as platinum or titanium. In particular, he highlights how titanium Additive Manufacturing has opened up new opportunities for jewellery brands and emerging designers. Titanium is much lighter than the traditional precious metals used in jewellery, and thus offers the advantage of creating large, statement pieces without affecting wearability. Precious metal AM has offered the opportunity for designers to think about jewellery production in a different way.

This seems to be the key point of precious metal AM: that it allows manufacturers and designers to think in a way that was not possible before. Frank Cooper, Senior Lecturer and Centre Manager at the Centre for Digital Design and Manufacturing, within Birmingham City University's

Institute of Jewellery, Fashion and Textile, agreed, underlining how this technology offers the unique possibility "to produce items of absolute complex geometry," as long as designers understand the principles behind the precious metal AM design process, such as what can be additively manufactured without compromising the finishing process.

This takes us back to surface finishing, which, along with build quality, remains fundamental for any product to be appreciated and accepted in the jewellery industry. Back in 2017, when I was completing my MBA dissertation on the adoption of precious metal AM in the jewellery industry, surface quality was confirmed as the most common barrier. While surface quality may not have a significant impact on a mechanical part's performance (and, in most cases, aesthetics for mechanical parts are not a high priority), surface quality and aesthetics are crucial considerations when deciding whether to pursue Additive Manufacturing in the jewellery industry.

Other interviewees from the aerospace and automotive industries were surprised to find that this element was such a key factor in our industry; but the reality is that this has been the foremost issue that has kept precious metal AM on the sidelines for some time. There are, of course, many common requirements between a high performance mechanical application in, for example, the aerospace industry and a high quality piece of AM jewellery. Both require flawless manufacturing to full density, totally free from porosity, in order to, in the one industry, deliver the necessary mechanical performance and, in the other industry, to be polishable to the required level of an international jewellery label.

Additionally, the difficulty of adequately eliminating surface defects left by the supports needed during a product's build and, at the same time, obtaining a smooth and homogeneous surface has undermined the decisions of potential adopters. In the jewellery world, the potential of precious metal AM is met with great enthusiasm by makers and designers, but, when the time comes to invest capital in the technology, decision makers have remained dubious. In some of the conversations I had with professionals three years ago, a common idea was that, if this issue was not resolved, the major players in the field, be they the famous brand luxury jewellery designers or famous watch manufacturers, would not move beyond sampling or testing precious metal AM and this decision would have an important impact on the rest of the industry's perception of the technology. Now it seems that we are still waiting for a resolution.

However, this situation has challenged the developers of precious metal AM technology and the manufacturers of precious metal alloys to improve the performance of their systems and the quality of metal powders used. In my conversations in 2017, some operators specified that first trials had been conducted using the same grade of powder alloy as used for casting, which was indicated as a possible cause for the poor consistency and results achieved. In a recent conversation, though,

Fig. 6 Platinum designs in the Nautilus range by Nuovi Gioielli (Courtesy Nuovi Gioielli S.R.L.)

Fig. 7 18 Kt gold ring, part of a research project developed at Birmingham School of Jewellery (Courtesy Frank Cooper, Birmingham School of Jewellery, UK / Cooksongold)

Fig. 8 18 Kt gold rings, part of a research project developed at Birmingham School of Jewellery (Courtesy Frank Cooper, Birmingham School of Jewellery, UK / Cooksongold)

Damiano Zito clarified that, at the very beginning of Progold's research, the same powder gave different results when used in two different metal AM machines. This suggests that, for precious metal AM, a combination of different factors must be considered to achieve optimal results.

So, where are we three years later? The investments made by alloy manufacturers have been noticeable, thanks in large part to the adoption of advanced metal powder atomisation technology to improve powders performance. As a result, the surface quality of precious metal AM products is now far less rough and much easier to finish. Damiano Zito confirmed this point, saying that precious metal AM "is ready", but there remains the need to find objects that are actually worth additively manufacturing.

Design for AM and the need for jewellery-specific education

Ivano Torresan is confident that "the technology is mature," and with it the market is accepting precious metal AM. However, what is still missing is the essential factor: designers capable of getting the best from it. Frank Cooper confirmed, from his perspective as a lecturer, that as a technology it is mature, "if the designers understand how to get the best from it." Evidently, the factor now keeping the technology on 'stand-by' is the need to create designs that can push this revolutionary technology to its maximum capabilities. As stated before, there is no benefit in using Additive Manufacturing to produce jewellery which is already well-suited to production by casting.

This challenge should not be underestimated, because the result of the need for new design knowledge is a peculiar transition time. Old-school designers, such as myself, are trained to think in terms of subtractive technologies and the new concept of adding materials within the rigorous parameters of Additive Manufacturing requires a complete change of mindset.

During my conversation with Ivano Torresan, he suggested that new generations of designers should be taught Additive Manufacturing from as early as primary school, because the new way of thinking involved in designing for AM will be the future. Frank Cooper explained how, within his programme at the School of Jewellery (today part of the Birmingham Institute of Jewellery, Fashion and Textile), students are taught the two separate different approaches, stressing the major differences between designing for casting and designing for Additive Manufacturing.

To promote the technology, Cooksongold sponsors a dedicated category for precious metal AM at the Goldsmiths' Craft and Design Council Awards. Cooksongold ensures that, in advance of submissions to the competition, special educational sessions are delivered to those students who intend to participate, explaining in detail the specifics of precious metal AM and providing a dedicated illustrated guide. As a major promoter of AM, with a passion for the technology, I participated myself, mostly to challenge my capacity to envision designs suitable for AM, without forgetting the importance of the fundamentals of jewellery design (Fig. 10). I managed to come in third place for two years in a row, pushing me to think smarter for my next attempt!

Progold, too, through collaborations with Istituto Europeo di Design (IED) of Turin and other international design schools, is proactively promoting precious metal AM. With the aim of "transferring knowledge and expertise", students are invited to design the best pieces, balancing style and suitability for AM. The Progol3D® award ceremony is held yearly during Vicenzaoro January, the international event for the gold and jewellery industries.

It is evident that education is essential if the industry is to introduce and train new engineers and designers to the advantages of precious metal AM; for example,

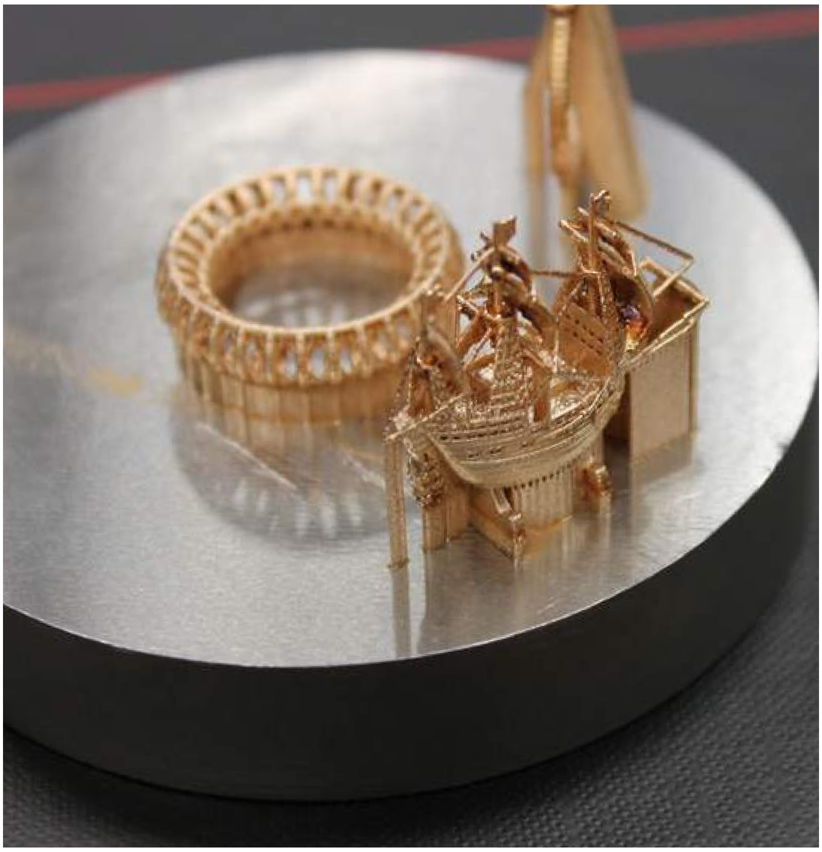


Fig. 9 Various items including a miniature 18 Kt gold galleon as built in a Precious M 080 PBF-LB system from EOS GmbH and Cooksongold (Courtesy Frank Cooper, Birmingham School of Jewellery, UK / Cooksongold)

Fig. 10 The greatest challenge is to envision designs suitable for AM without forgetting the importance of the fundamentals of jewellery design. Top, the Hidden Garden concept; bottom, Memories of my Journey, evoking desert dunes (Courtesy Michela Ferraro-Cuda)

Fig. 11 A ring and bracelet in Marie Boltenstern's 'Resonance' collection consists of eleven rows of additively manufactured 18 Kt yellow gold links joined together. Inspired by natural animal-scale structures, the bracelet moves and adapts to the wrist (Courtesy Marie Boltenstern / Bolternstern GmbH)

knowing how an object will be positioned on the build plate and consequently supported, means engineers and designers must also understand how the spots left on the surface of the part by the removed supports will impact the finishing process. An awareness of the entire process required to design, additively manufacture and complete a piece of jewellery is needed in order to guarantee the exceptional quality expected for precious items.

The ability to produce highly detailed bespoke jewellery is without doubt one of precious metal AM's most interesting features, especially in light of the jewellery sector's recent movement towards more personal and emotional experiences; why, then, not revise collections to produce smaller, more bespoke ones? When considering the great flexibility that AM offers, although the investment required to adopt this technology may be higher than for most other solutions, the product cycle as a whole must be considered. Damiano Zito commented that, often, even if the cultural approach permits a user to positively evaluate AM as a production technology, it seems that the industry is still missing the capacity to evaluate its potential.

Ivano Torresan highlighted another interesting point: high-end jewellery brands often struggle to consider AM as an option because of the lack of available statistics on its use. Their new product development processes need figures and numbers to determine whether or not to invest in a certain project; without such figures, the enthusiasm shared by product development and production teams cannot find its way to the decision makers. It is more likely that emerging designers will have a greater opportunity to take advantage of AM, because of their more flexible internal organisation and desire to showcase the uniqueness of their designs.

An example of a fine jewellery company and an emerging designer collaborating to take advantage of their respective positions in relation to precious metal AM adoption was highlighted by Frank Cooper. Cooksongold recently partnered with Marie Boltenstern, a jewellery designer based in Austria, who produces entire collections using precious metal AM (Fig. 1, Fig. 11). She has developed special interlinked designs to exploit the full capabilities of the technology, as well as encasing precious beads by interrupting the PBF-LB build process. Her brand image takes full advantage of the use of AM and the uniqueness it brings to her designs, with the tagline '3D printed fine jewellery' featuring heavily across the label's communications.

Interlinked and modular designs are, without doubt, one of the best ways to showcase the capabilities of precious metal AM for jewellery. Products using these designs include Nuovi Gioielli's the 'Zip bracelet', with its fabric-like pattern (Fig. 12), and the 'PixYourTime' watch (Fig. 13). Damiano Zito highlighted, as one of the best applications of this, the plain hollow volume rings produced by Progold (Fig. 14), which eliminate the need to solder parts together, as would have been required if produced with the lost-wax casting process.

What's next for precious metal AM in the jewellery industry?

The conversation I had with Damiano Zito revealed some interesting progress: the development of composite precious metal alloys such as AuNb and AuTi (Fig. 15). Alloy development and production is Progold's core business, so it comes with no surprise that its investments are now focused in this direction. During the 2016 Santa Fe Symposium, an annual conference for the global jewellery industry, Zito presented a paper which introduced the concept of mixing the powders of two different metals, such as gold and titanium; the results were promising and deserve further investigation, including from the point

Fig. 12 This zip bracelet in 18 Kt gold, additively manufactured by Nuovi Gioielli, makes maximum use of the design freedoms offered by the technology (Courtesy Nuovi Gioielli S.R.L.)

Fig. 13 The PixYourTime watch additively manufactured by Nuovi Gioielli using a stainless steel (Courtesy Nuovi Gioielli S.R.L.)

Fig. 14 Plain hollow volume rings produced with the idea to eliminate the need to solder parts together, as would have been required if produced with the lost-wax casting process, part of a collaboration between Progol3D® & IED Turin, Italy. Upper design: Anna Giulia Chicco, Red Gold, fineness 750%, alloy 5N+; Lower design: Elisa Zignani, Yellow Gold fineness 750%, alloy 3N (Courtesy Progold S.p.A.)

Fig. 15 An AM band produced using a gold and niobium powder blend. Weight is 12 g versus 16 g for regular palladium white gold. Premium white WGC colour, fineness 750%, manufactured by Progol3D® (Courtesy Progold S.p.A.)

of view of style. The alloys currently available for precious metal AM through three selected providers are shown in Table 1.

Conclusion

There is a clear consensus in the industry that, despite the technical readiness of precious metal AM, a lack of courage and willingness to change currently hinders its adoption in the jewellery industry. What is needed is a cultural revolution, to create an industry mindset which is capable of envisioning the new opportunities the technology offers, with more open-minded and visionary managers and decision makers, willing to think beyond the traditional processes.

In the last three years, precious metal AM has made little impact in the industry. It appears to be stuck in 'waiting mode', as the industry learns that, while it is not going to replace any other production technology, it is worth developing the knowledge and understanding to take advantage of what it can offer. All of the professionals interviewed for this article agreed on the need to create more opportunities for knowledge exchange and sharing in this area.

Perhaps it would be worthwhile to create a dedicated event just for precious metal AM. Creating a common platform would optimise the industry's efforts to exchange knowledge and understand where the technology fits in the industry, support the message that it has something to offer and help to engage the major players, other interested parties and final customers.

This is necessary as, following the arrival of precious metal AM, an impactful change or shift in the industry simply has not happened; we now need to join forces and promote dedicated studies on the potential of such innovative technology in the jewellery sector as a whole and not just individually. Metal AM technology can bring both innovation and differentiation in what is already a dynamic and creative sector - why not join the efforts?

Fig. 16 PBF-LB machines that are highly-suited to precious metal Additive Manufacturing are available on the market, including the Precious M 080 from EOS GmbH and Cooksongold, and the Mysint 100 from Sisma S.p.A.

Author

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Damiano Zito
CEO of Progold S.p.A. (Trissino, Vicenza, Italy), an alloy manufacturer and AM service bureau.

Frank Cooper
Senior Lecturer and Centre Manager-Centre for Digital Design and Manufacturing at Birmingham Institute of Jewellery, Fashion and Textile, part of Birmingham City University. Frank has widely carried out trials and experiments with the EOS M080 by Cooksongold.

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Progold:*
Platinum 950% (Pt950)
Yellow Gold 750% (2N and 3N)
Red Gold 750% (5N+)
White Gold 750% (G2Pd130)
Titanium Grade 1 (TiG1)
Cooksongold:
Platinum/Ruthenium
Yellow Gold 18 Kt (3N)
Red Gold 18 Kt (5N+)
White Gold 18 Kt (premium)
Yellow Gold 14 Kt
925 Sterling Silver
Legor:
Gold 999% (24 Kt)
White Gold 750% (PM-AU131P)
Yellow Gold 750% (2N and 3N)
Red Gold 750% (5N+)
Platinum 950% (Pt950)
Silver 925%
Bronze
Copper
Brass
Steel
**only as part of a wider service*

Table 1 Alloys available through three representative AM providers

Unrealised potential: The story and status of Electron Beam Powder Bed Fusion

In January, Boeing's new 777X aircraft made its maiden flight, powered by two GE9X engines from GE Aviation. Whilst this was a major moment for both companies, it was also a huge milestone for Electron Beam Powder Bed Fusion (PBF-EB), and the culmination of decades of process and material development work at the driving force behind the technology, Arcam AB. Whilst the many turbine blades used in the GE9X engine are the highlight of the first chapter in the story of PBF-EB, there is also a lingering sense of unrealised potential. Here, Joseph Kowen considers the story to date and highlights a new generation of firms working to increase the technology's adoption.

The metal AM world is blessed with a number of proven technologies that have been diligently developed and improved upon over the past twenty years. These technologies use a wide range of feedstock materials such as powders, wires, rods and filaments. In some processes, energy sources are directly applied to these materials to create a part, while other processes produce 'green' parts which then have to be sintered to produce functional metal parts with appropriate metallurgical properties.

When it comes to the business of AM, there is currently only one technology that has a significant, if not outright dominant, position in the market for metal Additive Manufacturing: Laser Beam Powder Bed Fusion (PBF-LB). The main advantage of this technology is that multiple parts, or even large parts, are produced at a reasonably high resolution, in a well-understood and stable process requiring no secondary sintering process, with predictable results. The process is, of course, not without its headaches and drawbacks.

Technologically respected, though often overlooked, Electron Beam Powder Bed Fusion (PBF-EB) resembles PBF-LB, but lags far behind in adoption, despite a promising value proposition in a number of application areas. GE Additive Arcam EBM is currently the dominant provider of PBF-EB technology, and accounts for the vast majority of all PBF-EB machines installed in the market. The question is why does PBF-EB lag so far behind PBF-LB in terms of adoption? In the following article, we will examine the strengths and weaknesses of PBF-EB and PBF-LB, and try to predict where PBF-EB is headed.

Fig. 1 GE Additive Arcam EBM is currently the dominant provider of PBF-EB technology, and accounts for the vast majority of all installed PBF-EB machines in the market (Courtesy GE Additive)

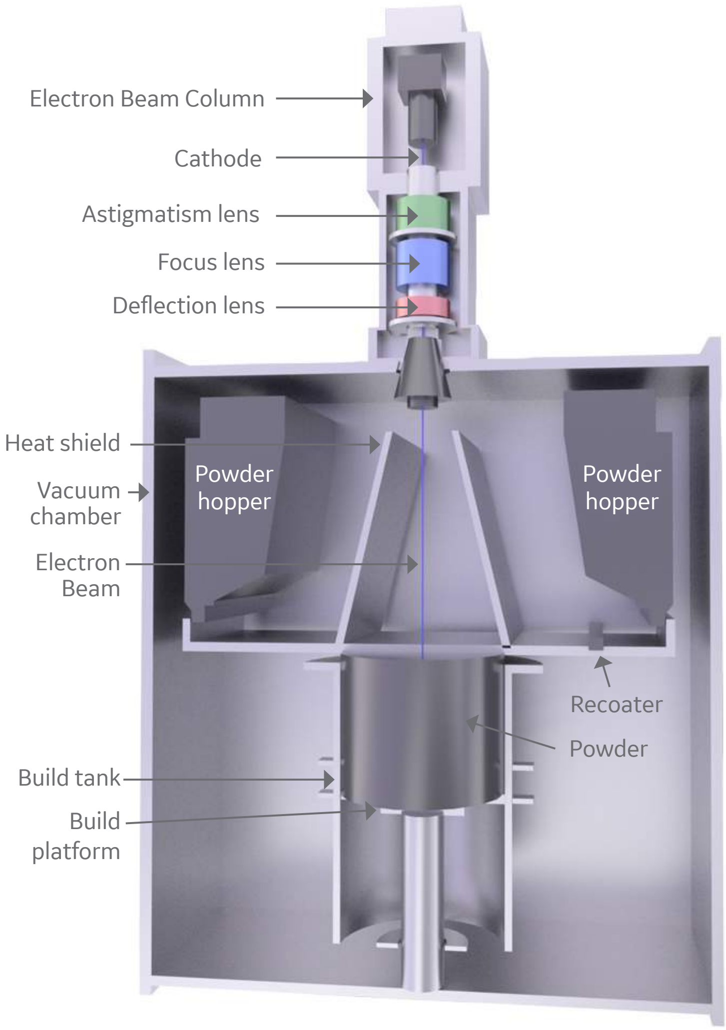

Fig. 2 Schematic sketch of a PBF-EB system (Courtesy GE Additive)

A distant second

PBF-EB has, literally and figuratively, been left in the dust by PBF-LB. Metal AM industry consulting firm Ampower estimates that the installed base of metal Powder Bed Fusion machines, which includes both PBF-LB and PBF-EB machines, stood at 9,111 machines at the end of 2019 [1]. Using figures published by the *Wohlers Report* in the years 2018–2020, we can estimate that only about 6% of these, around 510 units, are PBF-EB machines [2]. This means that, for every PBF-EB machine sold, providers of PBF-LB machines sold more than sixteen machines.

Could an explanation for this be that PBF-EB technology is newer than PBF-LB? The electron beam has been known to science for more than 120 years, whereas the laser was invented only sixty years ago. There is evidence in the literature that early work on using an electron beam to melt metal powder was performed by a group at Katholieke Universiteit in Leuven, Belgium in 1991. The leader in PBF-EB, Swedish company Arcam, began using electron beams in the second half of the 1990s. The first metal PBF machines using lasers began to be commercialised starting in 1994, so there is not much of a time advantage for PBF-LB – if at all.

How it works, and what makes it different

PBF-EB is an AM technology based on the melting of metal powder by exposing it to a beam of electrons. The process starts with the spreading of a thin layer of metal powder on a build plate. The powder is pre-heated by exposing the entire layer to a stream of electrons. This broad exposure of electrons heats the powder to an appropriately high temperature based on the material being used (Fig. 2). In the case of titanium alloys, such as Ti-6Al-4V, the powder is heated to about 800°C. Other materials require even higher temperatures.

An electron beam is deflected by an electromagnetic field which transfers energy and selectively fuses parts of the layer by raising the temperature of the pre-heated powder to above the melting point of the material being processed. After melting of the selectively-fused parts of the layer is completed, the build platform is lowered and a layer of fresh powder is spread across the build area. Heating and selective fusing of each successive layer builds up the object into the desired shape of the 3D model being produced.

The build process concludes once all layers of the build corresponding to the geometry of the part or parts have been heated and selectively fused. Heated but unfused powder forms a 'cake' around the fully-fused part and needs to be removed and recycled in a post-processing step. This is done by mechanically blasting the surrounding cake and removing excess material from internal channels inside the part as necessary.

The basic architecture of a PBF-EB machine includes an electron beam source, electro-magnetic coils to guide the beam to produce the desired shape and a build chamber with a moveable build plate and powder spreading apparatus. Typically, the maximum power output of the electron beam is between 3–6 kW. Electrons are

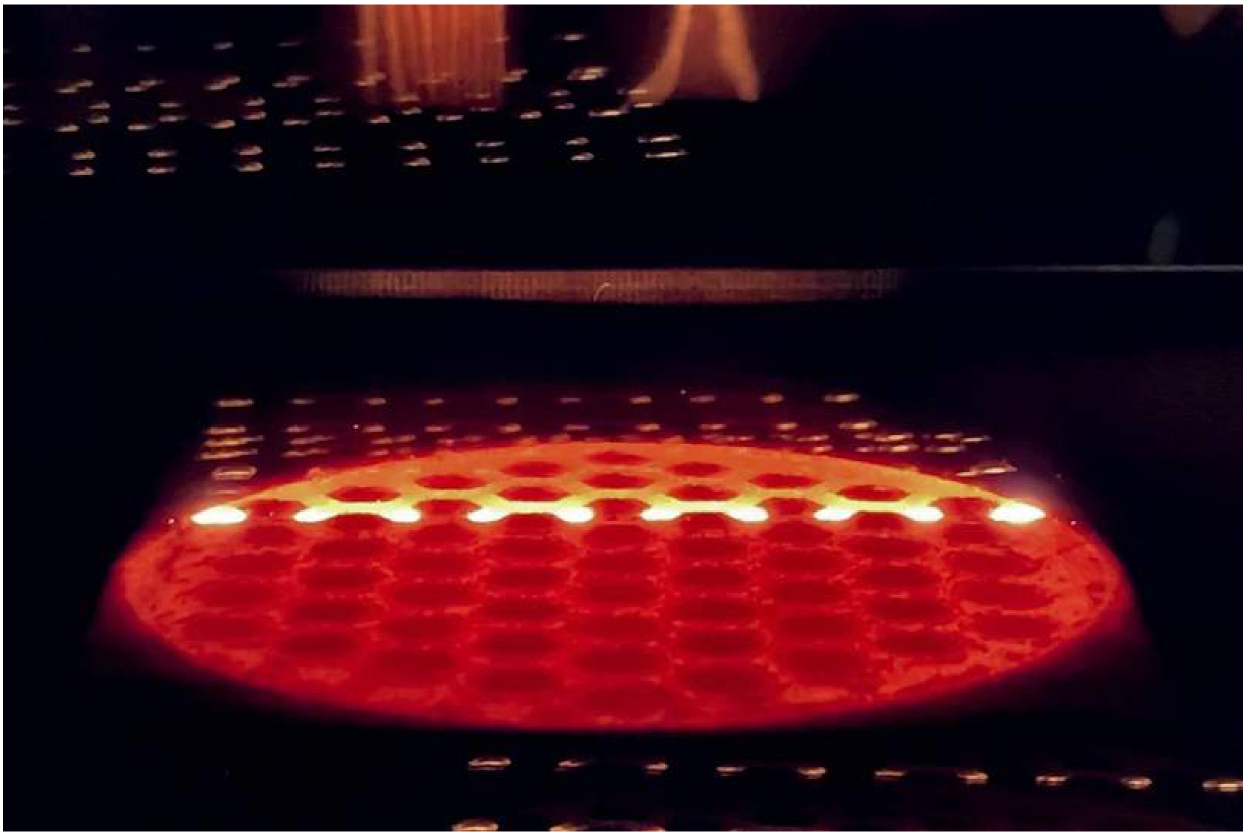

Fig. 3 PBF-EB processing enables a virtually instantaneous positioning of the electron beam over the entire build area of each layer (Courtesy Freemelt AB)

emitted from a heated filament or crystal and accelerated by a high voltage. The electromagnetic coils shape and position the electron beam similarly to how light is focused and positioned by optical lenses and mirrors. The build chamber and the EB source remain under vacuum for the duration of the build process. It takes up to about an hour to create the required vacuum. At the end of the build, the chamber is filled with inert helium gas to speed up the cooling process. After a few hours of cooling in helium, the chamber can be safely opened and exposed to air without risk of powder oxidation.

While the basic function and output from the selective melting of layers of metal powder is common to both PBF-LB and PBF-EB, there are a number of key structural differences between the two technologies. Most significantly, PBF-LB requires a mechanical mirror deflection mechanism to scan a laser beam in a vector process. In PBF-EB, the beam deflection mechanism has no mass and no inertia, enabling a virtually instantaneous positioning of the electron beam over the entire build area of each layer (Fig. 3), and for a large number of melt pools to be processed simultaneously. Melting powder using a laser necessitates the serial fusing of different parts of the layer, or the use of multiple lasers, with important consequences, as shall be discussed.

Common misconceptions

There are a number of commonly held beliefs about PBF-EB that are either misguided or simply not accurate. Some of these myths and misconceptions derive from the fact that PBF-EB lags significantly behind PBF-LB commercially. The main explanation that is offered for why this is so is that PBF-EB was a more complicated technology in its early days of development. As a result, it seems that technicians and operators found it more difficult to master, although electron beams were used for many applications long before the laser was invented.

Another reason may be that many potential users of metal AM technology simply chose the path of least resistance. This may or may not be true, but the unit sales statistics do not lie. It is fair to say that PBF-LB has achieved a higher level of technical maturity – until now. Factors that may have existed in the early days might make an interesting study for historians looking at the way new technology is adopted. What is of interest going forward is what advantages and benefits PBF-EB might offer given what we know now. It is clear is that the AM industry continues to foster key misconceptions about PBF-EB. The existence of these misconceptions has been an inhibiting factor to the further development of PBF-EB. They should be put to rest if we are to realise and maximise the potential of the technology.

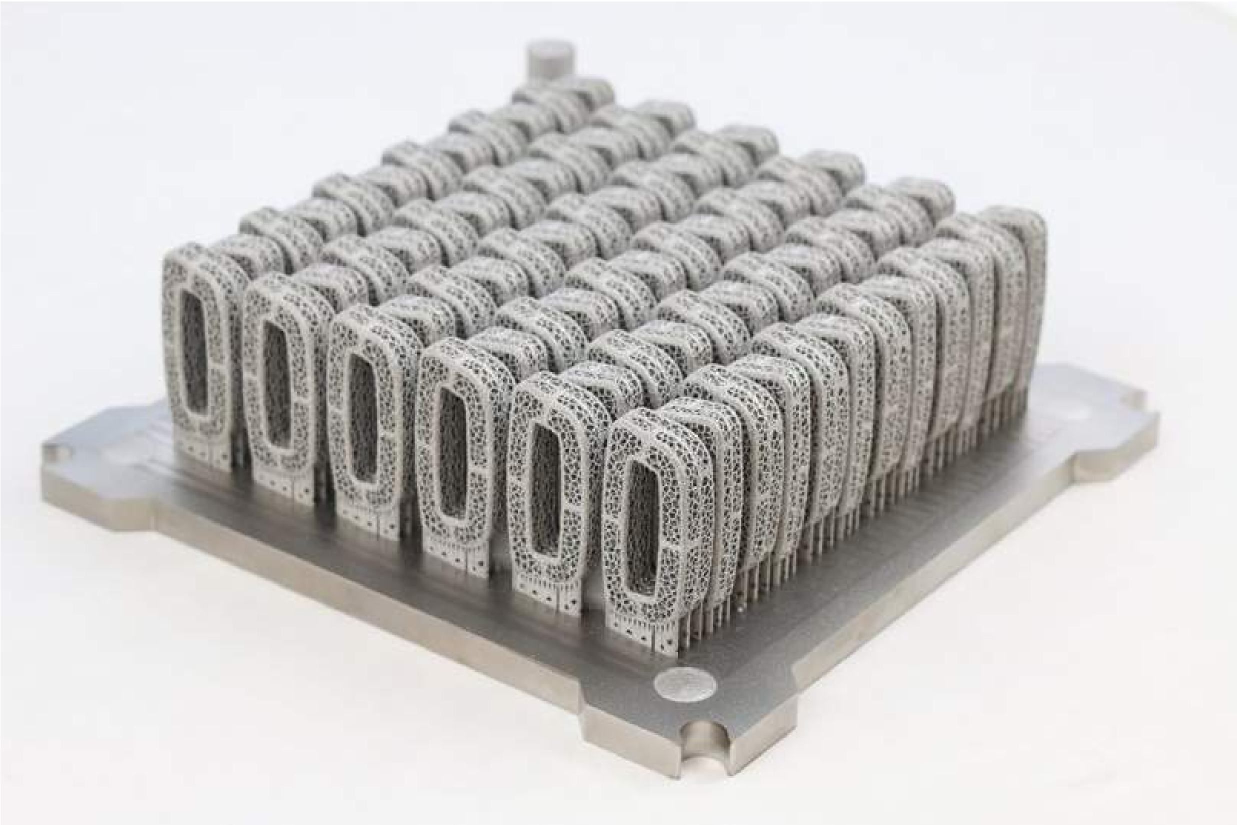

Fig. 4 Proprietary spinal cages on a build plate, designed for and manufactured using PBF-EB. Support structures are limited to the attaching of the parts to the build plate (Courtesy Amplify Additive)

1. PBF-EB is similar to PBF-LB
As we have already seen, about the only element in common is the fusion of powder by a source of energy. The entire basis of operation is different, the physics is different and the outcome and performance are different as a result. The reality: PBF-EB is an independent technology that should be considered on its own merits, without relation to PBF-LB.

2. PBF-EB only works with a limited range of materials, mainly titanium
Whilst it is true that PBF-EB is associated closely with titanium, there are historical and business reasons for this. However, there are no technical reasons that prevent the use of PBF-EB for as wide a range of alloy materials as is available for PBF-LB. What is required is the development of open platforms for testing and optimising processes for additional materials.

3. The surface finish of PBF-EB parts is inherently rougher than PBF-LB parts, and working with fine powders is problematic
Rougher surface finish has been the generally available outcome due to the configuration of machines available commercially. It was observed in early PBF-EB tests that finer powders were repelled away from the powder bed due to an electrostatic charge, causing an effect called the 'smoke' problem. This resulted in a reticence to try smaller grain sizes.

The reality: there is no proven reason that PBF-EB cannot work with finer powders and thinner layers. The smoke problem was assumed to exist based on early observations for titanium. With the precise beam control available today, and the ability to optimise beam scanning algorithms for each application, successful PBF-EB processing of finer powders and thinner layers is certainly possible. This can lead to the smoother surface finish of PBF-EB parts.

4. PBF-EB only works with expensive specialist spherical powders
As with PBF-LB, the main reason why current machines need spherical powder is due to state of the powder spreading technology in use today. The reality: improvements in mechanisms for spreading irregular powder will also enable the use of less expensive powders for PBF-EB in the future.

5. Unusually long cooling times make the process uneconomical
Cooling is only one step in the overall process chain. The reality: overall production throughput is what matters and the higher build rate for PBF-EB compared with PBF-LB in most cases more than makes up for the cooling time required.

6. PBF-EB can't make the large parts that we see made by PBF-LB
In practice, PBF-EB is generally used today for smaller part applications. However, there is no proven factor

that limits the size of parts. No machines have been developed yet for much larger parts, but, in fact, the productivity of PBF-EB should scale in a better way than PBF-LB, since maintaining a hot process scales favourably with size.

The PBF-EB difference

Making head-to-head comparisons between the two PBF processes can be misleading. For one thing, performance might be geometry- or application-dependent. However, we can list a significant number of intriguing features and differences, in many cases outright advantages, that paint a clear picture of the strengths of the PBF-EB process.

Nested parts with limited support structures
PBF-EB can be used to build large numbers of small parts, or small numbers of large parts, in a single build. Small parts can be nested in a build without the need to build the number of support structures commonly seen in PBF-LB, as the powder cake serves as the support structure (Figs. 4–5).

Homogeneous powder melting
An electron beam penetrates deeper into the powder grains than a laser, resulting in a more homogeneous melting of the powder and the ability to melt reflective materials without vaporising the surface of the powder particle (Fig. 6).

A wider range of layer thicknesses
PBF-EB is highly productive and works for a large range of layer thicknesses. This gives the freedom to tweak requirements of build speed and surface finish, depending on the application.

Processing in a vacuum
The melting process is conducted in a high vacuum, the cleanest and safest environment possible. Additionally, the vacuum provides thermal insulation and thus contributes to high energy efficiency.

Fig. 5 Hip replacement cup implants tightly stacked with sintered powder between each part and no support structures (Courtesy GE Additive)

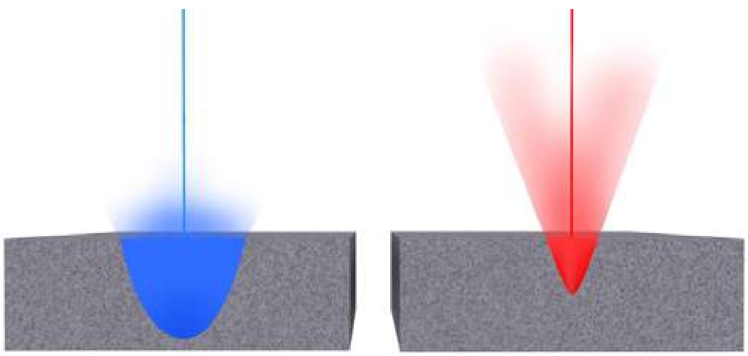

Fig. 6 Energy transfer in Ti64 powder using PBF-EB (left) and laser (right) technology (Courtesy GE Additive)

Fig. 7 A shape cutter (Ø 120 mm) in the as-built state, manufactured using PBF-EB by VBN Components AB from Vibenite® 290, an Fe/Co/W base material that combines high wear resistance and heat resistance. The component has a hardness of approximately 72 HRC (Courtesy VBN Components AB)

	PBF-EB	PBF-LB
Pro	• Fewer and shorter support structures • No stress-relief heat treatment • Excellent, permanent pore removal by HIP	• Removal of unfused powder
Con	• Removal of powder cake • Challenges with internal channels	• Labour-intensive support structure removal • Burr removal/smoothing • Heat treatment for stress relief • Careful pore elimination by HIP

Table 1 The pros and cons of post-processing PBF-EB and PBF-LB components

Cost benefits when scaling up

Electrons are inherently easier and cheaper to multiply to high beam power than laser light. This makes PBF-EB more scalable than PBF-LB for future ultra-fast Additive Manufacturing, potentially competing with traditional manufacturing technologies for high volume applications.

Less thermal stress

PBF-EB is a hot process that maintains a high temperature throughout the build, resulting in parts free from residual stresses. This eliminates or reduces the need for heat treatment, a significant saving in process time and cost, and contributes to a greater design freedom. Thanks to the superior thermal control of PBF-EB, brittle and crack-prone alloys can be successfully additively manufactured (Fig. 7), expanding the application of Additive Manufacturing to materials that cannot be built with any other process, including PBF-LB.

Powder removal and post-processing

Powder management and removal is a critical part of all Powder Bed Fusion processes and is often a source of pain during and after the build process. A related issue is support removal. This is the case with both PBF-LB and PBF-EB, and the topic merits further elaboration.

The characteristics of the PBF-EB build process allow parts to be built with only a limited amount of support structures, as already noted. The supporting cake needs to be removed and recycled by a powder blasting process, which occurs in a powder removal station after the build is completed and cooled. The process uses the build process powder itself as blasting media. The caked powder, after removal, can be fully reused. The process has been engineered to remove the cake without any detrimental effects on the physical integrity of the part. Removal of the cake is a relatively efficient function and only encounters difficulty in cases where the caked material is located inside internal channels.

Powder removal in PBF-LB is ostensibly easier. Since the powder is not bonded in any way to the body of the part, its removal requires either a manual process of removing the powder through air pressure in a powder removal station, or, optionally, with an automated powder removal system used to remove all unfused powder from difficult-to-reach places. What one is left with is a clean, powder-free part but with the support structures in place.

Another post-processing step where PBF-EB excels is Hot Isostatic Pressing (HIP). HIP is often mandatory to eliminate residual porosity in AM components used in fatigue-critical applications. Any process-induced porosity in PBF-EB material contains no gases and is irreversibly and permanently closed by HIP. This is in contrast to AM technologies carried out in a gas atmosphere, where the porosity inevitably traps gas. Gas-filled pores are more difficult to shrink by HIP and, even more troublesome, they may expand back to their original size if the AM part is exposed to high temperature. In general terms, the post-processing trade-off between the two PBF processes is summarised in Table 1.

Cost per part

At the end of the day, users of AM technology want to be able to produce a part at lower cost. So which technology offers the best deal? It is cautionary at this juncture to say that it depends on the geometry of the part in question. The size of the part and the number of parts that can be produced in a single build will greatly affect the economics. The bigger the build volume of the machine in question, the greater the number of parts that can be built at one time.

There is, however, good evidence to suggest that titanium parts produced by PBF-EB are less expensive than the same parts produced by PBF-LB. This may not be true for other alloys at this stage, since PBF-EB is presently heavily geared towards titanium alloys. In making the comparison, we measure total cost, which means that we include pre- and post-processing costs.

Information supplied by machine manufacturers is helpful in understanding the part cost. GE Additive Arcam EBM commissioned an independent study by Ampower, publishing the results in a GE Additive white paper on PBF-EB [3] and concluded that its EBM process (the trademarked name for its PBF-EB process) was "up to 50% less expensive per part."

The example provided in the white paper is a bracket which shows a clear advantage for PBF-EB. If we ignore the actual money values that are reported in this white paper, which could vary significantly based on part size, we can clearly see the areas where PBF-EB has the advantage:

- Build preparation: Much easier for PBF-EB, due to simplified support structure considerations and the possibility of 3D nesting

Case study: CRIQ uses Arcam technology for patient-specific jaw reconstruction

Québec's CRIQ uses PBF-EB for patient-specific jaw reconstruction (Courtesy CRIQ)

CRIQ is a state-owned organisation dedicated to industrial research and innovation in Québec, Canada. It has collaborated with the CHU de Québec hospital to develop groundbreaking solutions to improve medical care.

A team led by François Gingras, CRIQ's Director of Industrial Equipment, is now applying AM technologies to transform how patient-specific lower jawbone implants are designed and manufactured. This focus will allow CRIQ to offer a three-week turnaround of patient-specific implants, compared to the current six weeks required when using traditional manufacturing. The CRIQ team covers the design and CAD drawing of implants, the AM and post-processing of the implant and finally cleaning and sterilisation.

This allows CRIQ to define and influence pre-processing, design, testing and fabrication machines and ensure consistency and repeatability. The process of medical certification of additively manufactured mandibles through Health Canada commenced in October 2017 and completion of the certification requirements is expected this year – when CRIQ can enter full production.

CRIQ sees the business case for patient-specific implants at a machine level and looking at how to improve patient lives and lower overall costs. "The business case isn't in a part-to-part comparison; it needs to be justified through system-wide impact. If a patient-specific implant can accelerate patient recovery, reduce risk and lower overall healthcare costs for the Québec Government, then we have a business case," says François Gingras.

As part of its AM strategy, CRIQ has been using a GE Additive Arcam EBM Q10plus machine since June 2018. "The medical device industry is one of the pioneer industries for AM, in general, and PBF-EB in particular. AM enables companies to manufacture patient-specific implants and customised devices in small batch production, but still in a cost-effective, industrial process. This way, the technology perfectly serves the trend for more individualised treatments in healthcare," said Stephan Zeidler, Business Development Manager Medical, GE Additive.

"Improved patient care in orthopaedics, implantology and dentistry demands high-precision, perfectly fitting medical products. In medical and dental technology, there is a demand for parts produced individually or in small batches which must satisfy extremely high-quality standards regarding materials and workmanship," he added.

www.criq.qc.ca

Company	Country	Systems	Build Volume (mm)	Materials	Electron Beam Power
GE Additive Arcam	Sweden	A2X	200 x 200 x 380	Titanium, nickel alloy, titanium aluminide	3 kW
		Q10plus	200 x 200 x 180	Titanium, cobalt-chrome, copper	3 kW
		Q20plus	350 ø x 380	Titanium	3 kW
		Spectra L	350 ø x 430	Titanium	4.5 kW
		Spectra H	250 ø x 430	Titanium, titanium aluminide, nickel alloy, tool steel	6 kW
Freemelt	Sweden	ONE	100 ø x 100	Unlimited	0-6 kW variable
Tianjin Qingyan Zhishu Technology Co., Ltd. (Qbeam)	China	Lab200	200 x 200 x 240	Ti alloy, superalloy, copper alloy, refractory metals	3 kW
		Med200	200 x 200 x 240	Titanium	3 kW
		Aero350	350 x 350 x 400	Ti alloy, nickel base superalloy, copper alloy, refractory metals, titanium aluminide	3 kW
Xi'an Sailong Metal Materials Co., Ltd.	China	S200 Production	200 x 200 x 200	Titanium alloy, titanium aluminum, stainless steel, refractory metal	3 kW
		Y150 Biomedical	150 × 150 × 180	Titanium alloy, cobalt chromium, tantalum, titanium tantalum alloy	3 kW
Tada Electric (Mitsubishi Electric group)	Japan	EZ300	250 x 250 x 300	Unknown	6 kW

Table 2 Commercial machines on the market

- Cost of powder: Less expensive for PBF-EB (for titanium)
- Heat treatment: Much less costly for PBF-EB, if needed at all
- Build support removal: Generally a less complicated process than for PBF-LB

It is fair to say that, with the exception of support removal, the advantages above are geometry-agnostic.

Ampower also publishes an online cost calculator tool that estimates the cost of metal parts made by all the leading metal AM processes. The tool is based on extensive knowledge and analysis of metal AM machines by the firm. Experimenting with the tool and applying different scenarios to titanium parts of various sizes and quantities, the cost tool consistently returns values in favour of PBF-EB.

There are a number of conclusions to be drawn. The first is that PBF-EB is generally and inherently a less costly process than PBF-LB for a wide variety of titanium parts. Even if the saving is often far less than the claimed 50%, in manufacturing applications even a 10% cost saving is significant. Finally, as more development is performed on materials and when PBF-EB machine build volumes increase in future machines with higher beam power, the cost advantage of PBF-EB will only grow.

PBF-EB machines currently available

There are a growing number of commercial and non-commercial machines on the market today. To be considered commercial, the supplier must have at least one machine installed and operating in the market. Five manufacturers produce twelve different models of commercial machines (Table 2). In addition, four companies have announced the development of PBF-EB machines (Table 3).

GE Additive Arcam EBM

GE Additive Arcam EBM is by far the dominant supplier of PBF-EB machines today. It was the pioneering

Fig. 8 An Avio Aero turbine blade made on a GE Additive Arcam PBF-EB machine and used in the GE9X engine (Courtesy GE Additive)

force in the commercialisation of the technology and, for many years, was the only supplier worldwide. Founded in Sweden in 1997, its first commercial machine was launched in 2002. The company started trading on the NASDAQ OMX Stockholm exchange in 2012.

In 2018, the company was acquired by GE, which had taken a controlling stake in Arcam in 2016. Today, the company is managed as part of GE Additive. In August 2019, the company opened a new 15,000 m^2 Centre of Excellence in Gothenburg, Sweden which will eventually house up to 500 employees.

Arcam made a conscious decision early in its development to pursue high-value applications in the medical and aerospace sectors. Its material selection was limited primarily to titanium alloys and cobalt chrome. To these, they added titanium aluminide (TiAl), which is primarily used to produce turbine blades for jet engines (Fig. 8). TiAl has the required strength at elevated temperatures, yet it has only half the weight of traditional nickel-base superalloys, which is a significant benefit for an industry where every kilogramme of saved weight results in large cost savings over the life of the engine.

"The potential of TiAl materials for jet engine applications was one of the drivers behind the acquisition of Arcam by GE. TiAl is a prime example of the unique PBF-EB capabilities – this material cracks easily if processed with PBF-LB..."

In 2019, GE Aviation announced that it had purchased twenty-seven Arcam machines for turbine blade production. Avio Aero, a GE Aviation group company based in Cameri, Italy, now operates more than forty machines to make the parts (Fig. 9). The turbine blades are deployed in the new GE9X jet engine that powers the Boeing 777X aircraft, which first flew in January 2020.

The potential of TiAl materials for jet engine applications was one of the drivers behind the acquisition of Arcam by GE. TiAl is a prime example of the unique PBF-EB capabilities – this material cracks easily if processed with PBF-LB at low temperature.

Fig. 9 GE Additive Arcam machines at Avio Aero (Courtesy GE Additive)

GE Additive holds a dominant position in the PBF-EB market. However, a spokesman for the company acknowledges that the Arcam management team is welcoming of the entry of newcomers. They believe that the increased competition will help to attract attention to a technology that has yet to reach its true potential. The development of new materials and applications outside of the Arcam fold will, of course, be an advantage for their business too and a key to the future growth of PBF-EB.

Freemelt AB

Also located in Gothenburg, Freemelt shares some of PBF-EB's Swedish roots. As reported in a separate article in this issue of *Metal AM*, the driving force behind the company is the belief that what has been achieved until now is only a fraction of the potential of PBF-EB technology. Freemelt believes that the number of applications currently available for Additive Manufacturing is strongly suppressed by the limited number of qualified materials. A scarcity of PBF-EB machines with open parameters, they suggest, hinders development of faster processes and new materials.

"Freemelt believes that the number of applications currently available for Additive Manufacturing is strongly suppressed by the limited number of qualified materials."

The company's first machine, Freemelt One (Fig. 10), is designed as a tool to assist the industry with expansion of material processes for realising the full potential of PBF-EB. It is a smaller-sized open-source machine optimised for experimentation with new materials and process parameters in a cost-efficient way. Without the ability to experiment, the material choices will remain limited.

The company claims that its innovative electron beam source, with a laser-heated cathode, has much better beam quality at high power and better robustness than traditional designs. This allows very high productivity when fitted to production machines, thus making more applications economically viable in the future. Although small compared with Arcam, Freemelt is the new player that has made the biggest commercial impact over the last year, with a handful of machines shipped to customers in Europe.

Tianjin Qingyan Zhishu Technology Co., Ltd. (Qbeam)
Qbeam is a Chinese company based in Tianjin, which offers three machines in two build volumes. The development team is led by a group from Tsinghua University. The company is not active outside of China, as far as is known.

Xi'an Sailong Metal Materials Co., Ltd.
Another Chinese company, Xi'an Sailong Metal Materials, has been operating in Xi'an since 2013 and offers two machines for aerospace and medical applications. As with QBeam, the company does not appear to be active outside of China.

Tada Electric Company
Tada Electric is a Japanese company belonging to the Mitsubishi Electric group. It has started to sell a production machine called EZ300 and, as of May 2020, their first machine had been sold to Hyogo Prefectural University in Japan. Another Tada machine developed for the Japan TRAFAM research programme, reportedly has a build volume of 500 x 500 x 600 mm, which is thought to be the largest PBF-EB yet developed. This larger machine has yet to be commercialised. The EZ300 machine is half the dimension in each axis: 250 x 250 x 300 mm.

Fig. 10 Freemelt One is designed as a tool to assist the industry with expansion of material processes for realising the full potential of PBF-EB (Courtesy Freemelt AB)

Machines in development

Wayland Additive
Wayland was in the news in September 2019 when it announced that it had raised a Series A funding round. The company, based in West Yorkshire, UK, is a spinoff from Reliance Precision Limited. It has been operating in stealth mode since 2016. Its founders and the technical team behind the company come out of the semiconductor industry, which also uses electron beam technology for semiconductor applications.

Wayland has not yet brought any machines to market, but plans to show its first machine in November this year, with its first sales slated for 2021. In April, the company provided

Company Name	Country	Systems	Build Volume (mm)	Electron Beam Power	Notes
Wipro3D & Indian Institution of Science	India	Not specified	Not specified	Not specified	Joint development
JEOL	Japan	1st system	Not specified	6 kW	
		2nd System	Not specified	10 kW	
Wayland Additive	UK	Not specified	300 x 300 x 450	Not specified	
Ruselectronics	Russia	Not specified	Not specified	Not specified	

Table 3 PBF-EB machines under development

Fig. 11 Acetabular cups manufactured by PBF-EB (Courtesy Lima Corporate)

more details on its technology, which it calls NeuBeam. The 'Neu' stands for neutralise, as Wayland claims that its machine completely neutralises the negative charging of metal powder particles, which causes what is known as the 'smoke' effect.

"According to Wayland, whilst its process is a hot process, the powder remains unsintered around the parts. The biggest advantage of this, it suggests, is that the machine can build parts without the powder cake that otherwise needs to be removed by a powder blasting process."

According to Wayland, whilst its process is a hot process, the powder remains unsintered around the parts. The biggest advantage of this, it suggests, is that the machine can build parts without the powder cake that otherwise needs to be removed by a powder blasting process. If, in fact, the cake removal issue is ameliorated or avoided, it could present a productivity advantage over other machines.

That said, powder cake removal is a mature process that has become effective and continues to improve. It is also not clear how the Wayland process compensates for the benefits that the powder cake provides: a combined support structure and heat sink that is not integral to the parts and, at the same time, allowing operators to stack parts free-floating to maximise use of the available build volume. While it may be possible to put in support structures by choice to stabilise the build, this would eliminate an advantage that PBF-EB has over PBF-LB on the issue of support removal.

It remains to be seen how Wayland's process works in real life. Its future offering, as laid out in the company's April press release, looks intriguing and is certainly worth watching to see how it works in practice when the machines reach market in 2021. As with all new technologies, it must face the test of real parts manufacture.

JEOL

JEOL is a Japanese equipment manufacturer and a well-known, long-standing supplier of electron microscopes and lithography machines. It is a member of Japan's TRAFAM future AM project, a government-sponsored programme to develop new capabilities in a range of AM technologies. The project has developed two test-bed machines. The second test-bed, set up in 2018, is equipped with a 10 kW electron beam, the most powerful yet seen.

Wipro3D
Wipro3D announced the joint development of an PBF-EB machine together with the Indian Institute of Science in December 2019. No further information about the machine and its configuration is known at this stage.

Ruselectronics
Ruselectronics is a Russian holding company that is developing an PBF-EB machine. The development work will be performed by Toriy Scientific Production Association. No further information has been made public about the project at this stage.

What does this all mean and where is PBF-EB heading?

Compared to other AM processes, PBF-EB has gotten off to a slow start. However, the marathon that is the broader industrialisation of AM is far from over. For a start, there will never be a single winning technology, inasmuch as there is not a single application for AM technology. That said, in the relative positioning of the Powder Bed Fusion technologies, we see a surge in the interest and development of electron beam technology as an alternative to the laser-based machines that have led the race until now. We can expect many positive developments in PBF-EB.

What is certain is that the industry owes Arcam EBM and its investors a debt of gratitude for its grit and perseverance in bringing PBF-EB to market and leading its advancement so far. New participants, standing as they do on the shoulders of those that went before them, are now joining in and helping to take PBF-EB into the next phase of its development. The underpinnings for this renewed and growing interest in electron beam for AM are interesting physics, good metallurgy and – most importantly – attractive economics compared to laser-based machines.

New advancements in PBF-EB over the past five years have eclipsed all of the accumulated developments in the previous twenty years. That is the way of technological evolution in many cases; it is not always a straight line of growth. A segment that was led for so many years by a single dominant player is transforming into an inquisitive, robust and resourceful marketplace of innovation and new ideas.

Whichever way we choose to view and describe the latest developments in PBF-EB, it is undeniably an interesting time for electron beam technology in AM. We shall continue to watch the next stage in the marathon with eager anticipation. The industry has a long way yet to run.

Author

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Freemelt AB: Open source technology to explore the potential of Electron Beam Powder Bed Fusion

A new wave of AM machine manufacturers focused on Electron Beam Powder Bed Fusion (PBF-EB) is looking to capitalise on what is perceived as a process with significant untapped market potential. One of the most prominent of these newcomers is Freemelt AB, a developer of open source machines designed to help broaden the PBF-EB material portfolio and application areas. As *Metal AM* magazine's Emily-Jo Hopson-VandenBos reports, co-founders Ulric Ljungblad and Ulf Ackelid have no doubt as to the opportunities ahead.

Sweden is famed for many fine things; summerhouses, long summer evenings, plenty of crayfish, and, of course, electron beam-based Additive Manufacturing. The city of Göteborg has for decades been at the heart of all things related to Electron Beam Powder Bed Fusion (PBF-EB). The founders of Freemelt AB, Ulric Ljungblad and Ulf Ackelid, are a key part of this story, together accumulating more than twenty years of service at PBF-EB pioneer Arcam AB, now part of GE Additive. During this period, they are credited as the inventors of more than 30% of all the patents assigned to the company.

As is often the way with such innovative technologies, clusters of companies are formed as employees leave the first company and start their own firms, perhaps leveraging niche opportunities, focusing on materials development or even exploiting the technology as end-users. With PBF-EB such a cluster failed to materialise and as a result, the wider growth of PBF-EB applications stalled.

This changed in 2017 with the foundation of Freemelt AB. The company now numbers seventeen employees and launched its first PBF-EB machine, the Freemelt ONE, in early 2019. In September 2019, in a funding round led by Swedish venture capital fund Industrifonden, the company raised €1.4 million for its development, to grow its team and expand its offering to the metal AM machine market. This same venture capital fund was, of course, an early investor in Arcam AB.

Commenting on the mission behind Freemelt's establishment, Ulf Ackelid, Senior Scientist, explained that its co-founders

Fig. 1 View into the Freemelt ONE Electron Beam Powder Bed Fusion system's build chamber (Courtesy Freemelt AB)

Fig. 2 Freemelt ONE's frame structure does not require an outer shell, giving open access to all ports on the vacuum chamber. If needed, this frame can be modified easily to connect third-party R&D equipment (Courtesy Freemelt AB)

shared the opinion that PBF-EB had not yet realised its full potential. "It was lagging behind laser PBF systems in market acceptance, yet our belief was that there was so much more that the technology could offer. Our objective in founding the company was to facilitate the development of new applications and new materials for PBF-EB through an open source platform. Our plan is to take electron beam technology for AM to the next level."

But why did PBF-EB lag so far behind PBF-LB? According to Ackelid, there are multiple historical and commercial reasons. Early PBF-EB efforts were limited to mainly one material class, titanium alloys, and geared toward just two high-end market segments: aerospace and medical. This early focus is understandable, as these markets had the greatest practical chance of success. It also enabled product development goals that fitted within the resources available at the time for a technology initially deemed complex and sensitive, in part because of its vacuum requirement. "Because of the perceived complexity of the technology, Arcam remained the sole PBF-EB equipment manufacturer on the market for a long time," he explained.

Over the years, PBF-EB has matured into a robust and reliable technology, but the available material portfolio is still extremely limited when compared to Laser Beam Powder Bed Fusion (PBF-LB). "With new players entering the PBF-EB field, including Freemelt and others, we expect to see a boost in new materials as well as productivity. The unexplored potential of PBF-EB is huge."

Freemelt ONE: An enabler for the advancement of PBF-EB

As a PBF-EB specialist, Freemelt has since its foundation pursued its mission to first introduce a small, open source material development system to the market, and to grow the organisation in order to be able to deliver even more powerful PBF-EB technologies for future industrial systems. "Our experience taught us that the key to success with AM in general, and PBF-EB in particular, is the development of viable applications with a good business case," stated Ulric Ljungblad, Freemelt's CEO.

"We also know that developing new applications is a time-consuming and detail-driven pursuit. To achieve that, one first needs a platform that is open and on which you can try new materials and innovative beam scanning strategies. There are thousands of metal alloys out there and, without a broad community having the possibility of experimenting with them, AM processes using them might never be developed. Material development in PBF-EB is the single biggest hurdle limiting the broader adoption of the process," he added.

This goal resulted in the Freemelt ONE. The company's intention for the future is to launch a scaled up production system fully prepared for AM factory integration, based on materials and processes developed on the machine. The Freemelt ONE is therefore tailored for materials research and development, but with a view to industrial production, and has a build envelope of 100 mm high x 100 mm in diameter. The machine's vacuum chamber is equipped with thick steel walls having a high stiffness to prevent thermal distortion, and uses all-metal seals and differential pumping solutions to ensure an excellent vacuum quality. The linear motion of its recoater is actuated by a mechanism positioned outside the vacuum chamber; this offers increased durability, since it is not exposed to extreme process conditions and can be accessed and serviced easily (Fig. 3). The design and properties of the recoater blades and the overall design of the recoater can be further modified and optimised by the user, and the movement of the recoater and the powder feeding pistons can also be programmed without restrictions.

As it was destined for research environments, the Freemelt ONE was designed from its start to be versatile and user friendly. The machine's frame structure does not have an outer shell, giving open access to all ports on the vacuum chamber. If needed, this frame can be modified easily to support third-party R&D equipment connected to the system. Further, there are two operating sides to separate powder handling from machine operation: the door side, where the operator loads powder into the vacuum chamber and removes built parts, and the viewport side, from which the operator observes and controls the PBF-EB process.

"Freemelt ONE has been tailored for material R&D right from the start, in software as well as in hardware," explains Ackelid. The machine's physical and software architecture enable virtually every parameter to be changed and experimented with, among them new powder compositions, particle size distributions, layer thicknesses, recoating sequences, beam power and speed, beam scanning patterns, spot melting, powder bed temperature, controlled melt pool cooling, and more.

The electron beam source is a diode-type source with a laser-heated cathode. The reported advantage of this source type is its consistent beam spot quality throughout the entire beam power range from 0–6 kW. Freemelt ONE 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 as well as extremely high build temperatures. At the high end of the beam power range, 6 kW, the machine offers fast processing and very high powder bed temperatures over 1200°C. This enables the hot processing of crack-sensitive materials and refractory metals.

Fig. 3 The linear motion of Freemelt ONE's recoater is actuated by a mechanism positioned outside the vacuum chamber; this offers increased durability, since it is not exposed to extreme process conditions (Courtesy Freemelt AB)

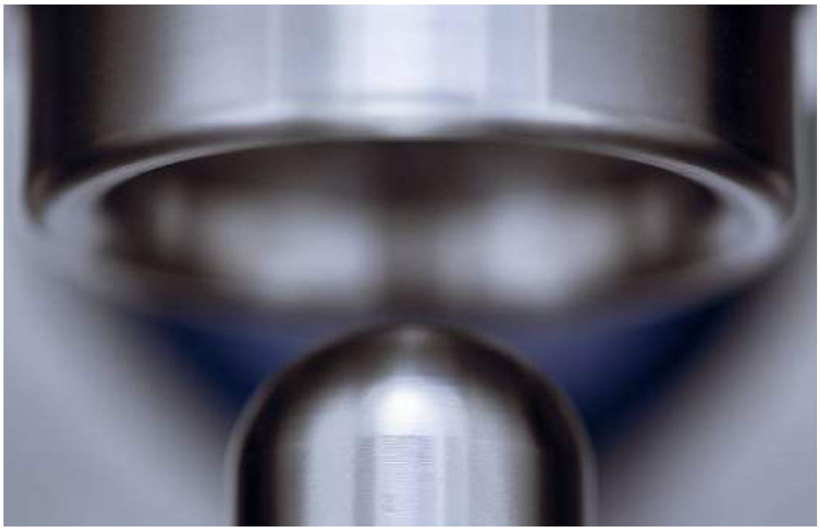

Fig. 4 Detail view of the electron gun on a Freemelt ONE machine (Courtesy Freemelt AB)

Thanks to the machine's small build tank and lean powder feeding, tests can be run with very small powder quantities, avoiding the need to work with large and expensive containers of powder. The machine's small, 70-litre vacuum chamber and high-capacity pumps enable the chamber to pump down and cool relatively rapidly.

Freemelt ONE's software is created 'bottom-up' in layers to ensure stability. A service interacts with specific hardware, abstracting it into an API: a controller implements sequences and functions that use one or several services; a build processor runs the actual build by executing a build file provided by the user, sending commands to controllers and services; a user interface provides information and receives commands for the build processors, controllers and services; and an arbiter prioritises between the different actions while a data share interface records and passes relevant data.

The electron beam in Freemelt ONE is controlled by complex magnetic fields created by many

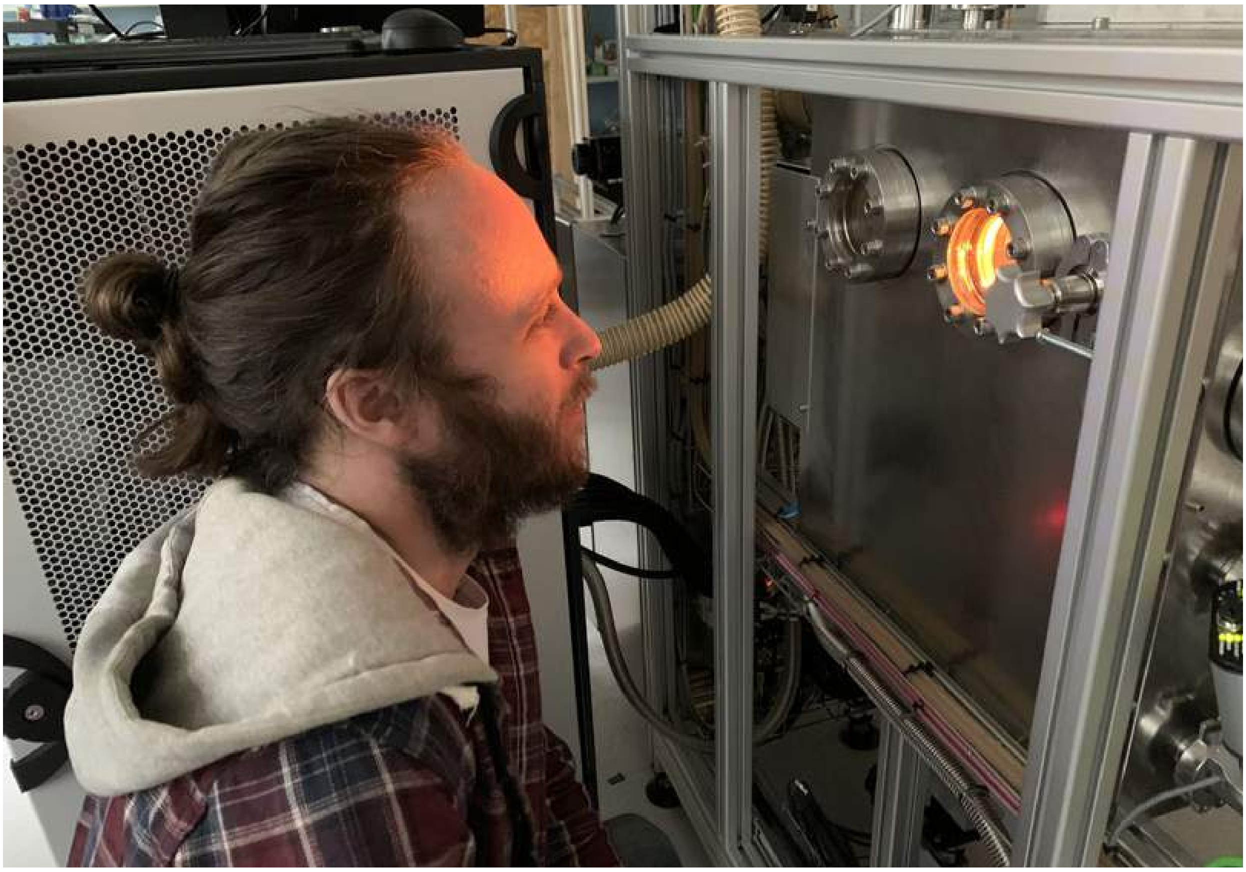

Fig. 5 Observing hot processing in the Freemelt ONE (Courtesy Freemelt AB)

magnetic coils acting together. This is made possible by the company's in-house developed Field Construct software, which leverages computing power rather than complex hardware. The result is faster positioning of the electron beam to the right place at the right time. An advanced trigger and data acquisition system is integrated with the beam control data path. This data acquisition system records high-rate sample data from sensors in Freemelt ONE where the trigger system is used to synchronise sampled data with the melt process.

The first Freemelt ONE was installed in March 2019 at Friedrich-Alexander-Universität, Erlangen-Nürnberg, Germany, and systems have since been delivered to several locations in Europe, the most recent in May 2020 to the Chair for Hybrid Additive Manufacturing at Ruhr-Universität Bochum, also in Germany.

The advantages and weaknesses of PBF-EB

Asked what he considered the main strengths of PBF-EB, Ljungblad explained, "The main advantage is the high beam power achievable with electron beams and vacuum processing. These unique features enable high-temperature processing that avoids the need for heat treatment of parts and support structures, in many cases." Moreover, he explained that these features enable the processing of a wide range of high-value materials which it would be impossible to process by any other AM technology, including the competing PBF-LB.

These advantages, alongside the fast build rate made possible by high beam power and virtually instantaneous beam positioning, are key factors in the microstructure control, productivity and versatility of the technology. "We should not forget the metallurgy," Ljungblad adds. "The purity of 3D printing in vacuum results in the highest quality material. Nobody can deny that a good vacuum is orders of magnitude cleaner than the most purified inert gas available."

In terms of PBF-EB's weaknesses, Ljungblad believes that many of the perceived weaknesses are in fact, misconceptions. "Avoiding them is just a question of resources and development," he noted. For example, Freemelt believes that the surface finish of PBF-EB parts could be greatly improved if processes were developed to that end. As an example, Fig. 6 shows two geometries in 316L stainless steel, one built with 15–53 µm powder and 30 µm layers (left) and one built with 53–150 µm powder and 100 µm layers. Both builds ran smoothly without smoke events or other issues. As can be expected, the fine powder and thinner layers give a notably better surface finish. "That is the point of its open system: to facilitate this type of process development" he stated.

In addition, Ljungblad believes the powder cake removal process can be engineered to a higher level of performance and is not an obstacle for PBF-EB either technically or commercially. "On the contrary," he explained, "the powder cake resulting from PBF-EB processing is a prerequisite for several of the advantages of PBF-EB we have mentioned. Powder removal from internal structures, especially narrow cooling channels, is challenging for any Powder Bed Fusion technology, especially using hot processing, but here we also see new solutions evolving."

Fig. 6 Two geometries in 316L stainless steel, one built with 15–53 µm powder and 30 µm layers (left) and one built with 53–150 µm powder and 100 µm layers. Each build plate is 100 mm in diameter and the powder was supplied by Carpenter Additive. Both builds ran smoothly without smoke events or other issues. As can be expected, the fine powder and thinner layers give a notably better surface finish (Courtesy Freemelt AB)

Looking ahead to the potential of PBF-EB

On the future of PBF-EB Additive Manufacturing, Ljungblad believes the segment is headed into a new phase of growth that will propel it toward greater acceptance and broader application. "GE Additive/Arcam has done an excellent job of laying the foundations of the electron beam AM segment, now more companies are being attracted into the field," he stated. "We believe that all of the system manufacturers, including GE Additive, will benefit from better knowledge and increased competition with more players, since the potential market is still mainly unaddressed."

In order to widen their knowledge of PBF-EB technology and its markets, Ackelid encourages those companies and institutions wishing to explore the potential of PBF-EB to start with the Electron Beam Additive Manufacturing (EBAM) conference, an international, biennial conference. EBAM2020, originally set for March but postponed due to the coronavirus (COVID-19), is now planned for October 5–7 this year in Erlangen, Germany. "EBAM covers the latest developments and applications of PBF-EB," he explained. "It is a primary vehicle for educating the scientific and business communities on the potential of electron beam AM."

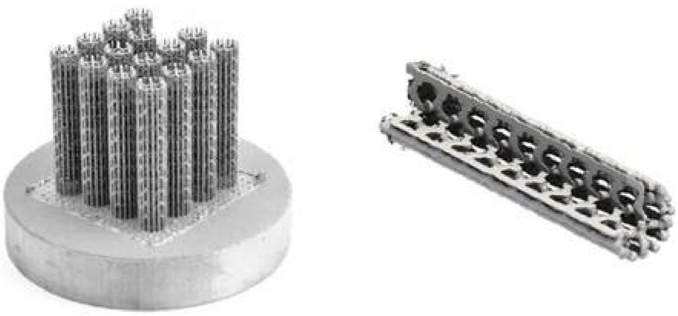

Fig. 7 Test bars built made from a Cu-70Al powder blend for catalyst structures by the University of Erlangen-Nuremberg, Germany, the first Freemelt ONE customer (Courtesy University of Erlangen-Nuremberg)

The overall benefits of increased education, understanding and acceptance of PBF-EB will be seen by all companies with a stake in this technology, said Ljungblad. "The rising tide will lift all boats. We are proud to be a leader and innovator in this fast-growing market, which we believe will help broaden the use of AM processes for sustainable manufacturing, for the benefit of system providers and our customers." As for those who are unsure why open source matters so much in application and technology development, Ackelid stated, "Put yourself in the driver's seat; select your own powder, process it the way you want and investigate, discover and innovate. Go where you want to go!"

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EBAM2020
For more information on the Electron Beam Additive Manufacturing (EBAM) conference (EBAM2020), visit www.ebam.fau.de

In pursuit of perfection: A case study on how Bugatti and APWORKS leverage the full potential of AM

It is far too easy to overuse superlatives when speaking about hypercars or Additive Manufacturing. When the discussion combines both – Bugatti's new driver-focused Chiron Pur Sport and a high-performance AM component that truly pushes today's processes to their limits – the result is worthy of a closer look. In the following in-depth case study, Bugatti and APWORKS explain the requirements, development and production of the Chiron Pur Sport's exhaust finisher and share insight into some of its hidden details, from lattice structures to nature-inspired honeycomb reinforcements.

France's Bugatti Automobiles S.A.S., famous for its ultra-high performance hypercars, was one of the early adopters of metal Additive Manufacturing in the automotive sector. The company has developed numerous components using Additive Manufacturing, many in partnership with APWORKS GmbH, Taufkirchen, Germany. One component type that Bugatti has gained significant experience of developing by Additive Manufacturing is the high-performance exhaust finisher. These have been fitted to a number of cars in the Chiron range since 2018, including the Chiron Sport, the La Voiture Noire, the Grand Tourisme and the Centodieci.

Most recently, a metal additively manufactured exhaust finisher was developed and manufactured by APWORKS for the newly developed Bugatti Chiron Pur Sport. With this application, Bugatti has become the first company in the automotive industry to use Additive Manufacturing to produce exposed titanium exhaust finishers for series production that are officially approved for road use. At approximately 22 cm long, 48 cm wide and 13 cm high, the finisher weighs just 1.85 kg including grille and bracket – some 1.2 kg less than the finisher on a standard Chiron.

"Bugatti is all about French-style luxury and exceptional vehicles, but it's a brand that stands for innovative technology, too," stated Stephan Winkelmann, President of Bugatti. "In addition to the iconic 8 litre 16-cylinder engine with 1,500 HP, technical innovation is just as much part of our brand essence – such as our components made of titanium or a special alloy that are produced by 3D printing."

Fig. 1 The Bugatti Chiron Pur Sport was developed with a focus on driving dynamics, with metal Additive Manufacturing contributing to weight savings and improved aerodynamics (Courtesy Bugatti Automobiles S.A.S.)

Fig. 2 The lightweight and temperature-resistant additively manufactured exhaust tailpipe finishers produced by APWORKS (Courtesy Bugatti Automobiles S.A.S.)

Saving weight through AM where it matters

The impressive 39% weight reduction achieved on the finisher of the Chiron Pur Sport is thanks to an innovative but highly challenging Additive Manufacturing-enabled design. Nils Weimann, Head of Body Development at Bugatti, explained, "The advantage of the 3D printing process lies in the geometric shapes that are possible. It is possible to create very finely wrought, complex forms which would tear if made using other techniques such as forging or forming." This is an ideal production method for Bugatti: lightweighting can be at the heart of a design, there are no tool costs, production is comparatively fast and individual adjustments to the design are easily possible. Complex organic geometries can also be developed, often inspired by the natural world, as is the case in this application.

"This is an ideal production method for Bugatti: lightweighting can be at the heart of a design, there are no tool costs, production is comparatively fast and individual adjustments to the design are easily possible."

In particular, the use of Additive Manufacturing enabled the development of an exhaust finisher with very thin walls; this helped to save weight where it really mattered. The exhaust tailpipe is just one part of the complex rear design of the Chiron Pur Sport, which has a new aerodynamic configuration that generates more downforce, while reduced overall vehicle weight contributes to the car's increased agility.

"By cutting weight by 50 kg, while simultaneously boosting the downforce and configuring an uncompromising, sporty chassis and suspension setup, the Chiron Pur Sport boasts incredible grip, sensational acceleration and extraordinarily accurate handling. It's the most uncompromising yet agile Bugatti of recent times," explained Winkelmann. The reduced mass of the exhaust finisher contributes to the car's new aerodynamic configuration, which is designed to contribute to both agility and dynamic cornering. Through the use of titanium alloy Ti-6Al-4V, with its high heat resistance and strength, the AM exhaust tailpipe is also highly temperature resistant.

Designing with (almost) no limits

The AM exhaust finisher fits into Bugatti's strategy of lightweighting to maximise the speed, driving experience and agility of the vehicle. Because the design of the finisher pushes metal Additive Manufacturing to its limits, various optimisations were applied during its development. These go beyond features intended to simply reduce the weight of the part while maintaining or improving on performance, and take into account the requirements of the whole manufacturing process.

The exhaust finisher's development process was supported by APWORKS' engineers and the result was a part with extensive high vertical walls and wall thicknesses as low as 0.4 mm in places. The part's design takes into account many factors, from a safe and stable manufacturing process to the most efficient build time and ease of support structure removal after the build. Whilst designing supports for ease of removal, their function and performance for in-process heat transfer also has to be calculated in order to ensure the highest dimensional accuracy.

With this in mind, some of the biggest challenges faced by the design team when reducing wall thicknesses to such a low value were heat transfer, dimensional deviations, and in-process instability. The solution that APWORKS' engineers turned to in order to overcome these challenges was generative design.

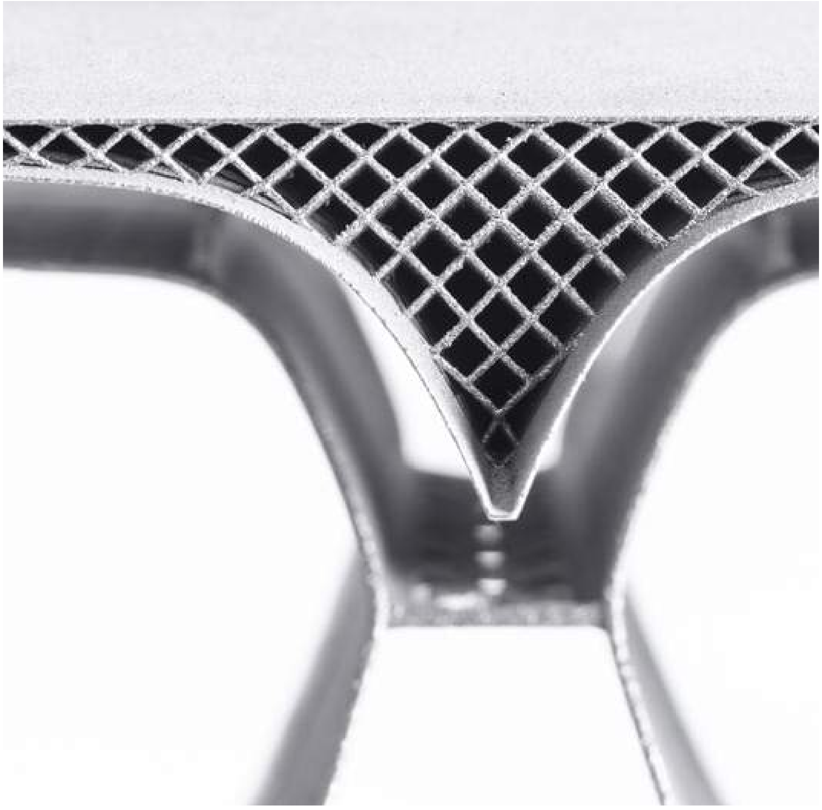

Fig. 3 The filigree lattice structures used in the Bugatti Chiron Pur Sport exhaust finisher (Courtesy Bugatti Automobiles S.A.S.)

Lattice structures

Lattice structures are very well known in the world of AM. To achieve this design feature, an initial volume is converted into a generative design model by replicating a small representative unit – the unit cell – over the whole designated geometry. This design feature offers many advantages; foremost, it reinforces two thin walls by connecting them, guaranteeing dimensional accuracy, and enabling minimal use of material.

"Wherever possible, we designed the exhaust finisher for the Chiron Pur Sport with a single layer so as to further reduce weight," explained Weimann. "The minimal material thickness in multi-layer areas is made possible by its lattice structure – where the cavity is filled with numerous filigree struts. In this way, the walls provide stable support for each other during the construction process – enabling minimal use of material." Through this process, volumetric mass was decreased by 70% (Fig. 3).

Honeycomb patterns

Another design feature which is made possible by AM and widely used in the lightweighting of components is the application of a honeycomb pattern onto a designated surface. Inspired by nature, this geometry acts as a stabilising feature for the thin walls. In this application, the pattern enables the highest possible dimensional accuracy for the thin walls by distributing tension all over the affected surfaces and increasing stiffness.

"We use a bionic honeycomb structure in the single-layer area to increase the surface rigidity of the walls. Even large components gain a high degree of surface stiffness," stated Weimann (Fig. 4). Thanks to the use of an outer wall which is double-layered for thermal insulation, the filigree cover is still able to withstand temperatures of over 650°C. In this way, the cover protects surrounding components from excessive heat under full engine load. At the same time, fresh air around the cover cools the component.

AM machine selection

High-end Additive Manufacturing, the related post-processing solutions and software are evolving at a fast pace. When considering the most suitable AM systems for a

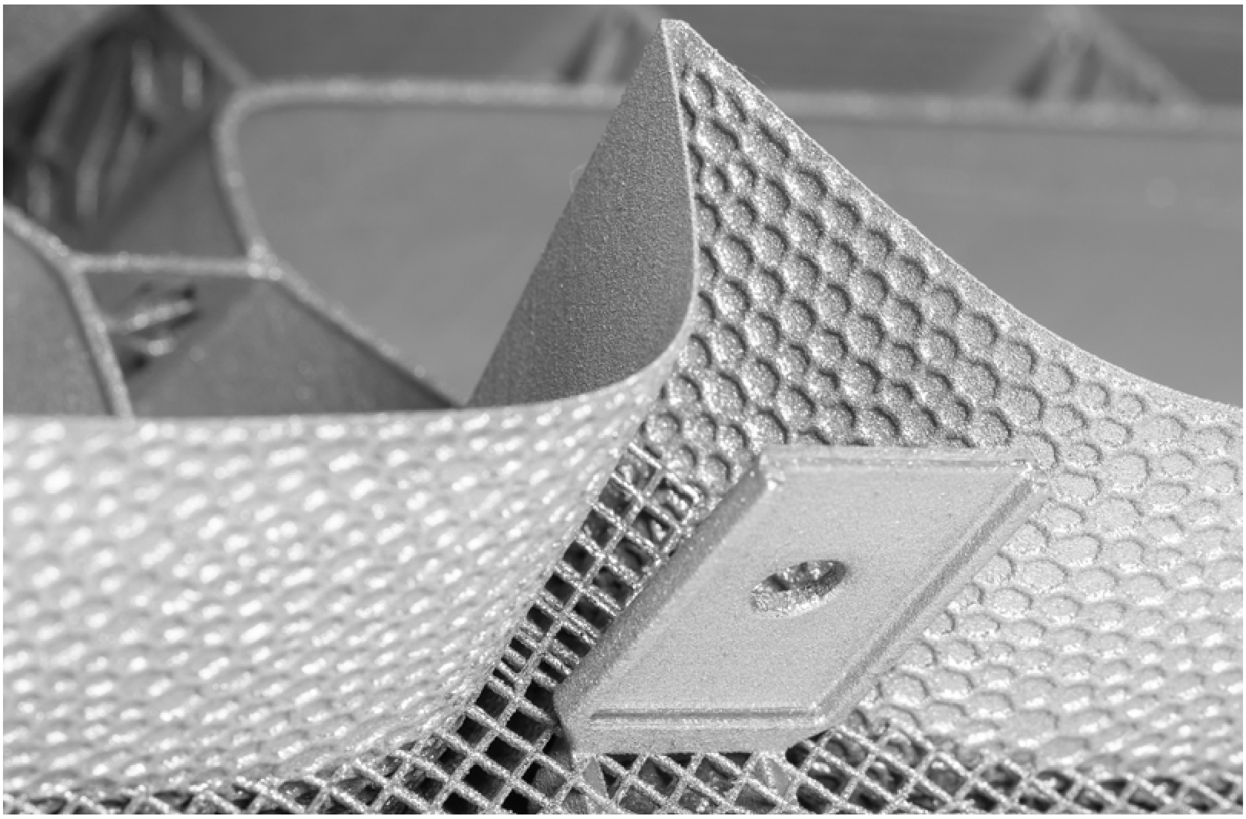

Fig. 4 The nature-inspired honeycomb pattern applied in Bugatti Chiron Pur Sport exhaust finisher acts as a stabilising feature for the thin walls (Courtesy Bugatti Automobiles S.A.S.)

project with complex requirements such as the exhaust finisher, system build size and speed are crucial. In this case, production takes place on an EOS M 400-4, a four laser Powder Bed Fusion (PBF-LB) system that offers a high level of productivity.

The twin challenges of qualification and homologation

This application is a rather unique example of a fully optimised high-performance part enabled by Additive Manufacturing that fulfills both the highest quality standards for road use, as well as homologation – the approval process a vehicle is required to go through for certification to race in a given league or series.

For this to be achieved, before entering serial production a major quality management process had to be undertaken in the form of qualification. In undergoing qualification, a supplier proves that every defined requirement is not only met, but also validated through testing, and certified by independent testing institutions where necessary. Qualifications such as these usually cover areas such as whether a part meets dimensional tolerances, and requirements like heat resistance, corrosion resistance and insensitivity against abrasion. In this case, the surface and heat resistance properties of the part needed to be tested and confirmed by independent certified testing laboratories working within Volkswagen Group standards.

As part of the serial production qualifications within an automotive OEM environment, a special process named 'sampling', similar to FAI or PPAP, was executed. In this procedure, new or changed parts need to be inspected with regards to all requirements communicated either by the technical drawing or valid OEM-specific standards. These inspections were conducted with a sample part prior to beginning actual serial production to represent the later certified status of a final part.

Once qualified, it was time to take the part to serial production. Joachim Zettler, Managing Director of APWORKS, stated, "We are proud to be part of this impressive new hypercar development by Bugatti. It is the first visible 3D printed part out of titanium receiving road homologation. We could only realise this innovative tailpipe by pushing Additive Manufacturing technology to the limit. Smallest wall thickness of below 0.5 mm enable the extremely lightweight design."

The serial Additive Manufacturing workflow

The exhaust finisher's design truly tested the limits of what is possible using AM, and in particular what parts it is possible to serially produce. To manufacture a high-quality part requires several software- and

Fig. 5 Rear view of the Bugatti Chiron Pur Sport showing the additively manufactured titanium exhaust finisher (Courtesy Bugatti Automobiles S.A.S.)

hardware-based tools, as well as for the production steps to be planned and executed so that they fit together perfectly in an effective workflow.

After the part's design was released by Bugatti, APWORKS' engineers commenced the work to prepare it for production by Additive Manufacturing through the use of various digital tools. These supported not only AM production related considerations, but also cost and failure mode analysis – all of which are covered under the concept of Design for AM (DfAM).

Once the geometry was fixed and the design could be released to APWORKS, AM data preparation began. This process includes positioning and aligning the part on the build platform, generating support structures, and optimising the design process by developing suitable build process parameters, etc. Machine parameters such as laser power and scanning speed must be optimised for the exacting requirements of highly-loaded parts, and need to be expertly adapted to achieve thin wall and lattice features such as those utilised in the exhaust finisher. This process ends at the point of the machine interface, where the part data is finally transferred from design software to Additive Manufacturing machine.

"Machine parameters such as laser power and scanning speed must be optimised for the exacting requirements of highly-loaded parts, and need to be expertly adapted to achieve thin wall and lattice features such as those utilised in the exhaust finisher."

Post-processing

After each successful build, various post-processing steps are applied to achieve the required mechanical properties and component performance. Heat treatment in an inert atmosphere at over 700°C is used to relieve the high internal stresses generated within titanium parts during PBF-LB Additive Manufacturing. Following cooldown, parts can be handled safely in different manual and automated metal processing

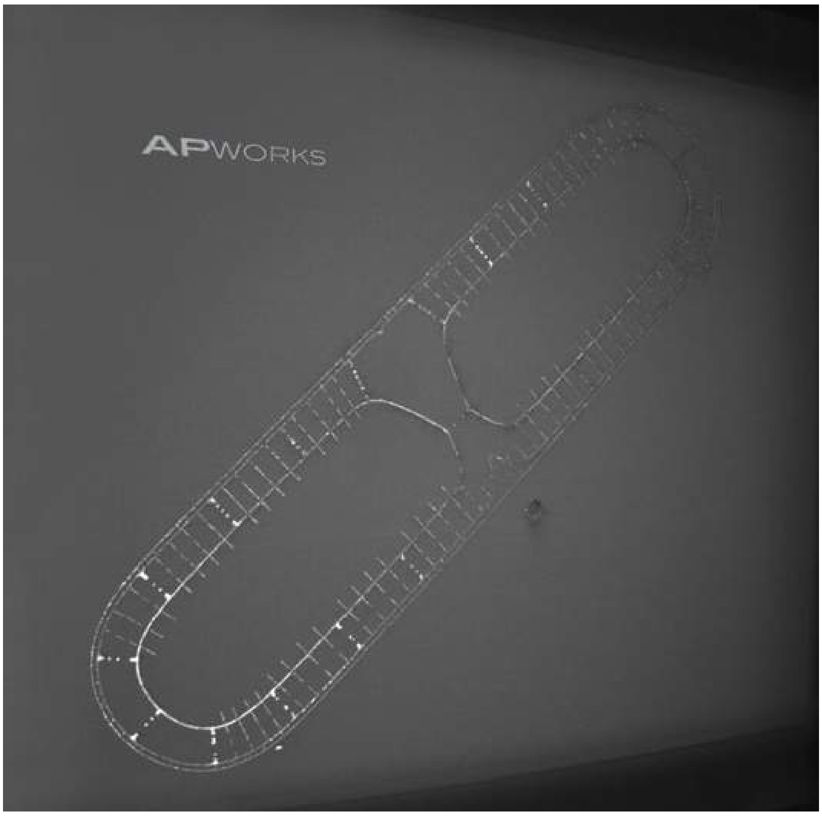

Fig. 6 The exhaust finisher seen in cross section during the build process on the EOS M 400-4, Laser Beam Powder Bed Fusion (PBF-LB) system (Courtesy APWORKS)

Fig. 7 An EOS M 400-4, Laser Beam Powder Bed Fusion (PBF-LB) system at APWORKS (Courtesy APWORKS)

steps in order to remove support structures, smooth surfaces and increase dimensional accuracy.

The mechanically finished parts are subsequently coated with a highly temperature resistant matt black layer consisting of small ceramic particles, capable of withstanding temperatures of up to 1100°C, while both insulating the part and creating a smooth surface.

The whole process is controlled using various quality assurance measures. These are primarily split into quality management system control steps according to DIN EN 9100 and dimensional testing, which includes processes such as 3D scanning and manual testing.

The latest in a series of AM exhaust components for a record breaking car

The Chiron Pur Sport exhaust finisher is not the only part of this type produced for Bugatti by APWORKS. In 2019 the company manufactured a metal AM exhaust finisher for the Bugatti Chiron Super Sport 300+ (Fig. 8). This Bugatti Chiron derivative was the first hypercar to break the 300 mph barrier (482.80 km/h), a record that was set at the beginning of August 2019 in Germany.

The innovative AM exhaust finishers applied in this car were also produced in titanium. In this case, the exhaust finishers are part of a modified longer tail section and are designed to push exhaust emissions further from the rear end of the car to reduce turbulence and improve steering behaviour at high speeds. The design freedom offered by AM enabled optimised exhaust aerodynamics, resulting in increased downforce and enhanced high-speed handling of the car.

In addition to the aerodynamic benefits, the low mass of the parts contributed to the vehicle's exceptional acceleration. Titanium was the material best suited to this application due to its combination of high strength, heat resistance and low weight. This is a prime example of an optimised high-performance part enabled by AM.

Fig. 8 This Bugatti Chiron Super Sport 300+ broke the 300 mph barrier with AM exhaust finishers produced by APWORKS (Courtesy Bugatti Automobiles S.A.S.)

Conclusion

With a legacy of ground breaking innovation, Bugatti considers itself to be continuing a long-standing tradition of innovation and unique vehicle development with the use of additively manufactured components. Company founder Ettore Bugatti himself developed unique vehicles using ground breaking technologies, from lightweight aluminium wheels to a hollow front axle. As Ettore Bugatti once stated, "An automobile component must be technically perfect. But it must be elegant and beautiful, too."

Today, this spirit remains. The use of Additive Manufacturing has allowed the designers of these exhaust components to incorporate harmonious contours and features that are more elegant and striking than is possible with conventional technologies – all while delivering extreme performance. All of this is in keeping with the Bugatti legacy; a history of combining technical functionality, aesthetics and elegance.

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Facing obstacles to profitability in metal AM: An Operational Excellence perspective

Just as Design for AM demands an entirely new mindset to be truly effective, understanding efficient AM machine utilisation in order to drive profitability also requires a major shift from conventional practices. In this article, Magnitude Innovations Inc's Matt Tusz, Founder and CEO, and Caterina Pampolari, Business Development Manager, explore operational and financial losses in metal Additive Manufacturing. They offer advice on how to overcome these growth barriers through production efficiency and profitable pricing strategies, with a focus on Operational Excellence and Continuous Improvement.

Metal Additive Manufacturing finds itself between a rock and a hard place: on the one hand, the pricing of AM services comes down to machine productivity, based on a company's go-to-market strategy; on the other, we need to consider the competitive landscape of the industry and how the pricing of services is influenced by competitors. However, unlike traditional manufacturing, determining the correct pricing strategy for metal AM is complex and inconsistent between projects. With time, manufacturers find themselves with losses of over 50% of their manufacturing capacity, and that is not good for the industry.

In this article, we will explain why this dynamic in particular hinders the growth of the metal AM industry, why it's in our collective interest to address it, and how to double the revenues from these systems without additional capital investments.

Fig. 1 An analysis of metal AM wastes and inefficiency can improve performance to an extent that was previously impossible

How did we get to this point?

For an understanding of how this has come about, it is useful to look at the history of pricing in manufacturing. During the evolution of manufacturing, machines could not be digitally programmed, therefore we needed to analyse the contribution of machine utilisation through a Machine Hourly Rate (MHR) serving as a proxy for productivity.

This was effective: since traditional system productivity is high, variations between jobs are insignificant and the margins are considerable. With that simplification, the most important aspect of machine utilisation is considered by determining system uptime.

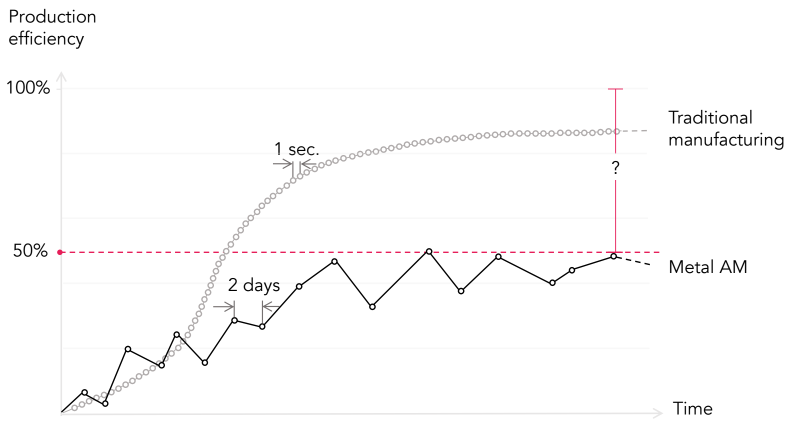

Fig. 2 Production efficiency shown by conventional Overall Equipment Effectiveness (OEE) and Magnitude's Additive Manufacturing Index (AMI)

In the case of AM, this approach was adopted early on, since it was commonly understood as a 'decent' rule-of-thumb approach. However, unlike traditional methods, AM had many factors that made it difficult to implement.

"...with the CAM software from machine manufacturers being, in essence, a black box of proprietary algorithms, it is impossible to determine what could be done to improve the process."

To begin with, additive process steps take days to execute instead of mere hours, and vary significantly between different machines, materials and even production runs. Next, with the CAM software from machine manufacturers being, in essence, a black box of proprietary algorithms, it is impossible to determine what could be done to improve the process. Adding to this, a single project can take weeks to deliver and is mixed with other production parts. All this leads to an inevitable conclusion: accounting principles cannot be used to reveal the enormous losses in efficiency occurring on a daily basis. Complicating things further, there is a fundamental gap in the manufacturing industry's knowledge of AM machines beyond prototyping; hence, factors such as scrap rate and production efficiency are typically ignored after the initial business case is made. Since the technology is still evolving by leaps and bounds, the rate of change in metal AM machines is making this problem more acute for manufacturers to track and price.

Where are we now?

As the demand for production components has become a legitimate possibility, these questions began to enter discussions within AM projects, but it was tough to step out of the approach ingrained in our common consciousness; namely, that we don't charge for parts based on system efficiency directly, but rather use an hourly rate as a proxy. Unfortunately for manufacturers, these efficiency losses are significant; in the best case, they consume an organisation's complete profit margins, and in the worst case, they amount to over 50% of machine capacity.

In order to maximise the quality and profitability of AM machines, Magnitude developed the software solution Uptimo to quantify AM production performance down to the voxel and use this information with the help of predictive performance analytics to automate the decision making process in the production chain. With machine learning and empirical results, Uptimo anticipates failures before they occur in order to deliver higher profit margins, regardless of what is being manufactured. Based on our expertise, here we share the first level efficiency gains that any organisation can obtain to increase profit margins while improving productivity and production quality.

Why aren't we measuring efficiency properly?

For the most part, traditional manufacturing efficiency has relied on Operational Excellence metrics in order to quantify the efficiency of any production process. Through the use of Overall Equipment Effectiveness (OEE), we can quantify the productivity of a system and use that to adjust the pricing that we offer for services rendered. OEE lends itself elegantly to any manufacturing process because we can break down the problem into three simple measurements: uptime, speed and quality of product, all measured out of 100%, through what we refer to as Availability, Performance and Quality. Multiplying these values then gives us the production efficiency.

This method, however, is not effective when running a metal AM system, specifically because of how the metrics are determined and the opposing focus of manufacturers. For metal AM projects, each build that is run on a system tends to be different, meaning differing build times, build parameters and output success. Additionally, since each metric is determined from different dimensions (e.g. time, build rate, volume), each material has different speeds, and the success of the output is process- and application-dependent, it is practically impossible to determine OEE.

As an alternative, years of development have resulted in an equivalent metric, the Additive Manufacturing Index (AMI), which is a combined value calculated from Planning, Parameters and Parts in order to address the shortcomings of OEE, take into consideration the complexity of metal AM and help manufacturers reduce costs and improve productivity. The AMI has become instrumental in work to free up capacity, improve profitability and lower the Cost-Per-Part (CPP) so as to bring metal AM into an area of profitable growth for manufacturers and end-users alike.

Why system efficiency matters

When using AMI, we have discovered that typical metal AM system efficiency is operating at a range of between 35–45% (Fig. 2). This means that productivity across the industry can be doubled by simply utilising the available systems more effectively. At these rates, as determined by a DuPont analysis, manufacturers are at the limits of profitability with an ROI of 1–2% per year when system efficiency is between 35–40% (Fig. 3a). Furthermore, with every increase in average AMI of 10%, the ROI improves by 6% (Fig. 3b). With a granulated analysis and help from our efficiency metrics, we can determine which applications, materials and machines are profitable, adjust the pricing strategy, and utilise data to drive corrective actions.

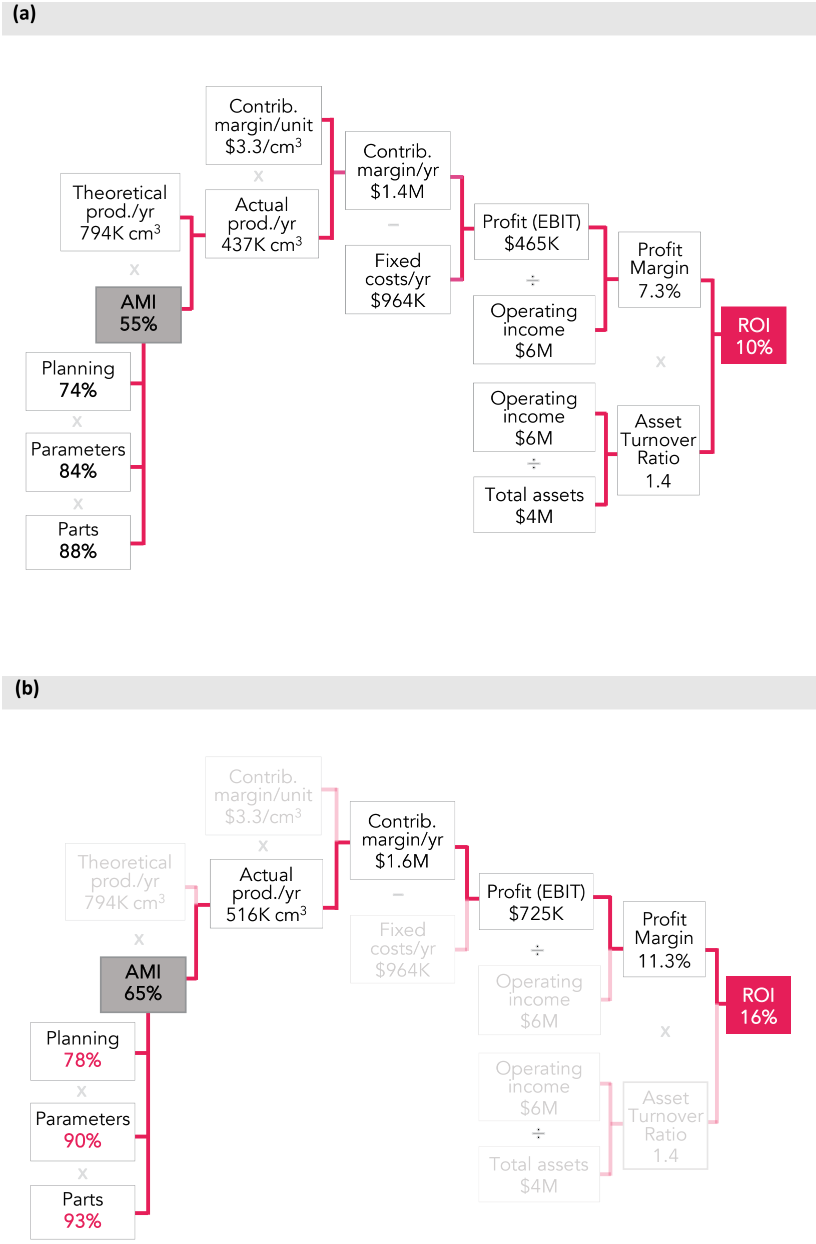

Fig. 3 DuPont analysis of a facility with seven metal AM systems utilising Inconel 718

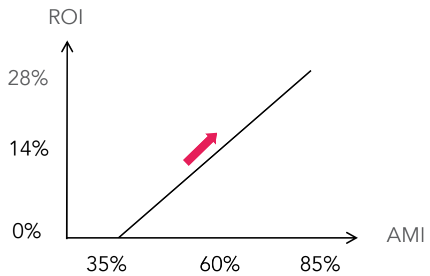

Fig. 4 AMI and ROI growth correlation for seven metal AM systems utilising Inconel 718

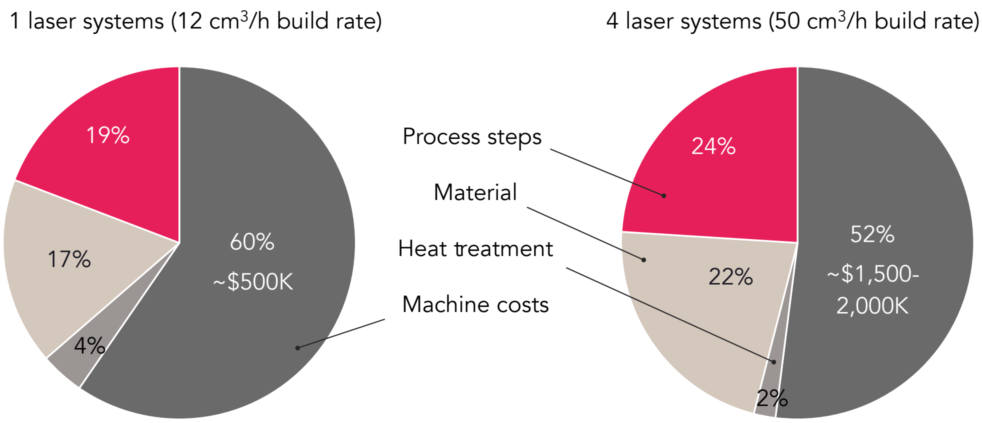

Fig. 5 Process step breakdown in CPP for single (left) and quad (right) laser PBF-LB metal AM machines

From the end-user perspective, the most important factor is the CPP, which is disproportionately dependent on system amortisation. We observe that approximately half the CPP is due to this factor alone, excluding quality control (QC) measures (Fig. 5). This means that the resultant CPP is mostly affected by a lack of machine efficiency, which can be either offset by cheaper machines or higher productivity. In comparison to powder costs, the price sensitivity of individual parts is 2.5x more affected by machine utilisation. Considering that machines are utilised at an AMI of 40%, the CPP can be reduced by 25% from efficiency gains in comparison with savings of 2–4% based on cheaper powder, not including the fact that new powder sources have to undergo costly validation tests and are available to everyone, therefore failing to deliver any competitive advantage.

Known unknowns: Invisible production wastes

As previously mentioned, the efficiency of AM machines is not easy to determine. Not only is each project different, making the calculations time-consuming, but there is invisible waste that is difficult to determine in a production environment. At Magnitude, we break down the wastes from a production into four interconnected categories:

- System downtime: Planning metric
- Parameter inefficiency: Parameters metric
- Rejected parts: Parts metric
- Breakdowns: A combination of system downtime and rejected parts

With this segmentation, we can effectively see how these losses are interconnected through a typical example:

A machine is running a project that is thirty hours long. The machine starts at 12:00 PM on Monday and continues until 6:00 PM on Tuesday. The shift in the factory comes to an end on Tuesday and the machine is not running from 6:00 PM Tuesday until 8:00 AM on Wednesday. At this point, the approach is typically either "we can't do anything about it, let's wait until the next day," or someone has to stay late at nights to start the next production. This results in a downtime reflected by a Planning metric of 68% (Fig. 6a). Assuming that the parameters and parts efficiency is perfect, the AMI is 68 x 100 x 100 = 68%. However, a quick analysis reveals that the parameters used were only 80% efficient, meaning that the build required thirty hours, but could actually have been completed in twenty-four hours (Fig. 6b). From this, we realise the true AMI is actually 68 x 80 x 100 = 54%. If, on the other hand, we would have optimised the parameters, we could have shortened the build time by two hours, which would have been enough to start another project on Tuesday afternoon and not wait until Wednesday morning (Fig. 6c). This would have improved the Planning and Parameters metric to 100% and 85%, resulting in an AMI of 85%.

In the end, we have three efficiency values: the perception is that the system for this project is running at 68% efficiency, and there was nothing we could have done to optimise the production. In fact, the system is running at 54% efficiency and we could have saved six hours of production time. Finally, if we optimised our scheduling as well as the parameters, the nominal build would have resulted in an efficiency of 85%, and no member of the group would need to work overtime. These kinds of losses are what we call 'invisible wastes', and occur on a daily basis in metal AM. In this case, this is an invisible waste

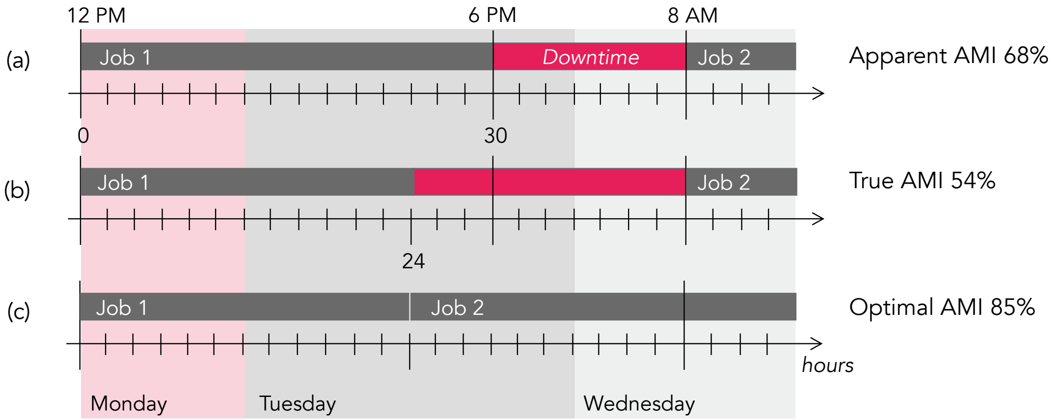

Fig. 6 Example of interconnections between production losses

that only appears when we analyse the Planning in conjunction with the Parameters metric of the job.

More importantly for the organisation, these wastes suffer from poor metrics that appear to show that everything is optimised, nothing can be done and the system efficiency is reflected within the pricing strategy. Unfortunately, since we have not properly quantified these losses, it is impossible to address them in the company strategy or operations.

Invisible losses in process speed

On a commercial level, we incur invisible losses every time a 'qualified' process is utilised. For technical reasons beyond the scope of this article, when a project is built with slower-than-possible parameters, users tend to notice a jump in build time that results in additional manufacturing hours. This is inherently what the end-user has to pay for in terms of their components. What we do not see in such an instance are the inherent efficiency losses in terms of opportunity cost. What this also shows is that manufacturer and end-user goals are at first glance conflicting: longer durations mean higher revenue, but a lack of metrics does not reveal lower profit margins.

For an example, we need to go no further than to expand on a theoretical serial production. Let us say that a 30 µm layer titanium process parameter has been qualified and selected for our production. If built in 60 µm, the parameters could build the geometry in eighteen hours when optimised and twenty-two hours with 'default' manufacturer parameters with no effect on final part quality. With the 30 µm qualified parameters, this job is built in forty hours. On the face of it, it would appear that it is a win-win situation for both the supplier and end-user; the manufacturer is now able to charge for more machine utilisation and the end-user does not need to spend additional resources on qualifying the 60 µm process. However, the resultant parameter efficiency is merely 45%, revealing that revenue is decoupled from the profitability of the project in a significant way.

Assuming the Planning and Parts metrics are perfect, we observe that the highest AMI achievable is 45% and the opportunity cost is over 50% of the machine capacity. Extrapolating this for an entire year's worth of production, we can safely deduce that the best-case scenario AMI will be 45%, resulting in enormous underutilisation. As you can imagine, this problem is further compounded when we utilise these systems in a variable production.

> *"...we incur invisible losses every time a 'qualified' process is being utilised... This is inherently what the end-user has to pay for in terms of their components. What we do not see in such an instance are the inherent efficiency losses in terms of opportunity cost."*

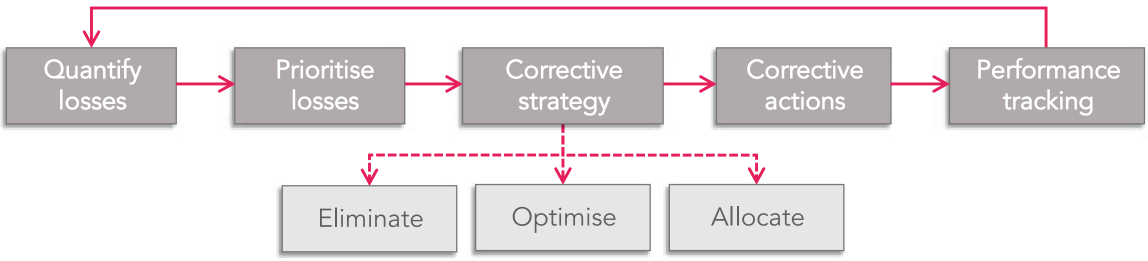

Fig. 7 Systematic approach to loss reduction encompassing all aspects of production

Typically in these situations, we observe that manufacturers tend to keep busy in order to fully utilise machine uptime without defining what their organisation represents. In the early stages of learning by doing, this is understandable. However, as organisational experience and competence mature, these projects should be scaled down and a manufacturing specialisation developed. Suppliers at this stage have a difficult, but absolutely necessary need to change their mindset, either by charging for the lost opportunity cost to make up for 100% system efficiency in the short term, by improving the CPP through cheaper systems and part redesign, or by simply refusing such business in order to focus on a more profitable niche.

Invisible output losses

The final invisible waste category that we continuously notice with customers is the challenge in identifying the opportunity cost related to machine output. Every time a part or batch is rejected due to non-conformities, these losses are not quantified, since scrap rates are difficult to track in a variable production. Because AM offers the ability to customise every product, we see that rejected product costs are difficult to compare with the true costs of other efficiency losses like machine downtime or parameter inefficiency. Without holistic metrics, these wastes are ignored and not accounted for in terms of overall production efficiency.

The approach with rejection waste is similar to downtime and parameter inefficiencies, in that we compare the losses from rejected parts and try to strike a balance with other metrics. Slowing down the process is typically effective in reducing these rejections and leads to better overall AMI. After all, if a system is running at maximum capacity, but the output is of no value to the end-user, it is the same thing as not manufacturing anything in the first place. What needs to be considered here are the two major reasons for these losses: first rejections are a result of the steep learning curve in utilising this technology, while the remainder of rejections are related to process limitations connected with specific geometries, materials and machines.

How do we systematise our work?

Coming back to the bigger picture, companies are missing a systematic approach to solving these problems within their organisational structure. To address this, they need to convey to individual team members the quality that their production represents and have a systematic approach to solving these issues. These guiding principles need to be written in a simple structure that encompasses every production variability so that the whole organisation can participate. As organisations define this structure, they tend to struggle with conveying to individuals the process because of gaps in terms of metrics as well as specific problems that arise. If individuals feel that their concerns are not included in the corrective strategy discussion, the acceptance of such practices is mostly ignored, at which point the only solution is non-flexible rules within the manufacturing process. This results in additional invisible losses.

What we propose to a general problem-solving schematic is to divide all of the issues in production into three categories and then systematically solve them. Through this approach and with metrics that keep track of all process shortcomings, we can convey to individuals the importance of their tasks in the larger picture of the value chain.

To begin with, organisations need to be open about their approach and goals. With goals, we refer to the simple focus of output, profitability and strategy and their alignment with individual incentives. If these are communicated correctly, team members will be forthcoming with issues in production, because it will eliminate the 'us vs them' mentality in an organisation. If done incorrectly, this appears on the shop floor as a competition between individual production steps, which leads to a dynamic of blaming others for shortcomings without ensuring overall team success.

Next, the corrective actions need to be prioritised in order of significance to the whole organisation. This involves holding regular review meetings with the team and prioritising losses through metrics that are easy to understand. Once these losses are quantified, we segment them into categories according to whether they can be eliminated, minimised, or, in the event that they are unavoidable, allocated as the true cost of an individual project (Fig. 7).

Within each of these categories, the team needs to be involved to determine the best way to proceed, first eliminating the largest losses, then minimising the losses that cannot be completely removed and ensuring that true costs are reflected in the price of services rendered. Going forward, we need to keep track of the overall performance as we move through this exercise by tracking improvements and exchanging on best practices observed.

In illuminating these invisible wastes, AM performance can be improved to an extent that was not previously possible. With metrics enabling total production oversight, we can automate the AM decision process and lower the CPP in order to improve quality and reduce costs throughout the AM value chain. Due to the high sensitivity of AM process efficiency, only predictive analytics can help users of the technology to fully utilise their systems and result in long-term profitability. As shown earlier by the DuPont model in Fig. 3, every 10% improvement in average efficiency results in a 6% increase in ROI for a production system, implying that total investment costs can be recuperated five years earlier, or a business case for a larger space of applications can be developed.

"In illuminating these invisible wastes, AM performance can be improved to an extent that was not previously possible. With metrics enabling total production oversight, we can automate the AM decision process and lower the CPP in order to improve quality and reduce costs..."

Even though this first level optimisation can be performed manually, only automated solutions such as Uptimo can deliver a holistic approach to loss reduction. With Uptimo, we can quantify all of the losses in production and execute and track the impact of corrective actions in order to ensure the highest possible efficiency gains over time. Additionally, Uptimo does not lead to lost time on the manual effort required to determine true efficiency losses as well as the coordination of corrective actions. In comparison with Manufacturing Execution Systems (MES), these methods consider the efficiencies of the whole production chain and lead to precise prioritisation of corrective actions.

In the end, organisations can tackle these challenges through good metrics, systematic corrective actions, correct pricing and by fulfilling a niche in the industry. Based on our experience, only with a holistic approach to tracking and solving these problems will organisations achieve true OpEx and deliver on the promise of Industry 4.0.

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Mass-production using PBF-LB: How laser beam measurements can help pave the way

Laser Beam Powder Bed Fusion (PBF-LB) is a technology rich in process parameters and exacting material specifications, all developed with the aim of delivery quality and repeatability as the industry moves towards volume production. However, without control of a laser's focal spot, neither the material specification nor the handling of the material in the build chamber can guarantee the hoped-for results. As Ophir Spiricon Europe's Christian Dini explains, when it comes to lasers, there is no control without the gathering of reliable data.

Is Additive Manufacturing ready for mass-production? The answer really boils down to reproducibility. When it comes to Laser Beam Powder Bed Fusion (PBF-LB), the constancy of the laser parameters is of great importance. Both AM machine manufacturers and machine users need to be aware of the quality of the focused beam that they are using. So, is it possible to test this quickly and cost-effectively during operation? To answer this question, one must take a closer look into the function and construction of laser-based AM systems.

Most PBF-LB metal AM machines have a number of beam delivery components in common. Starting at the fibre laser source with the beam delivery fibre and beam expansion optics, either a 2-axis or a 3-axis system follows. The 2-axis system (Fig. 1, left) consists of a 2-axis galvanometric scan head and a focusing F-Theta lens. For the 3-axis systems (Fig. 1, right), the F-Theta lens is replaced by another beam expander built from three lens elements with two fixed and one moving lens, changing the focal distance of the entire assembly as needed when the beam is steered over the working plane, using again an X-Y-galvanometric scanning head.

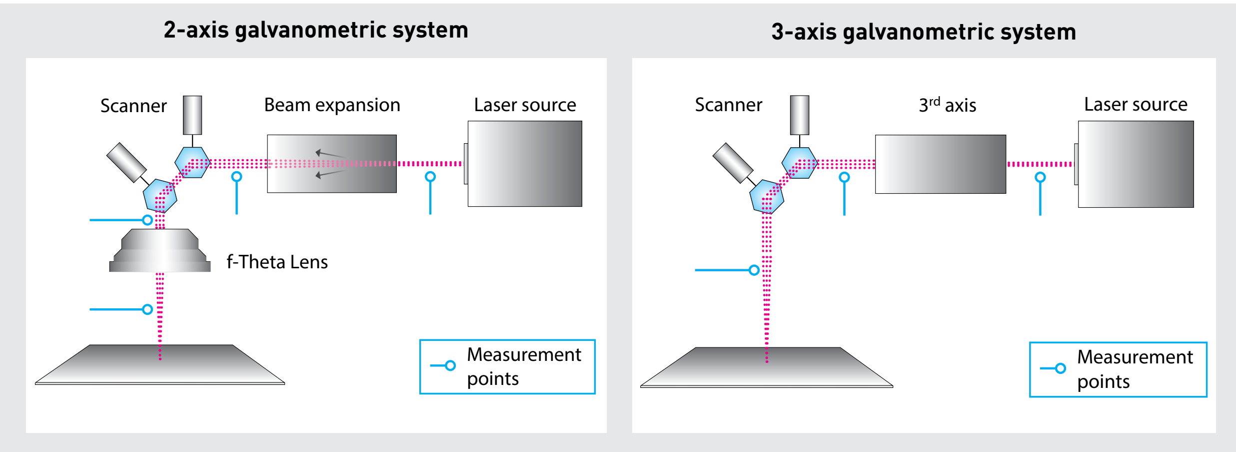

Fig. 1 Left, the structure of a 2-axis galvanometric system; right, a 3-axis galvanometric system. Measurements between the components provides information about their performance

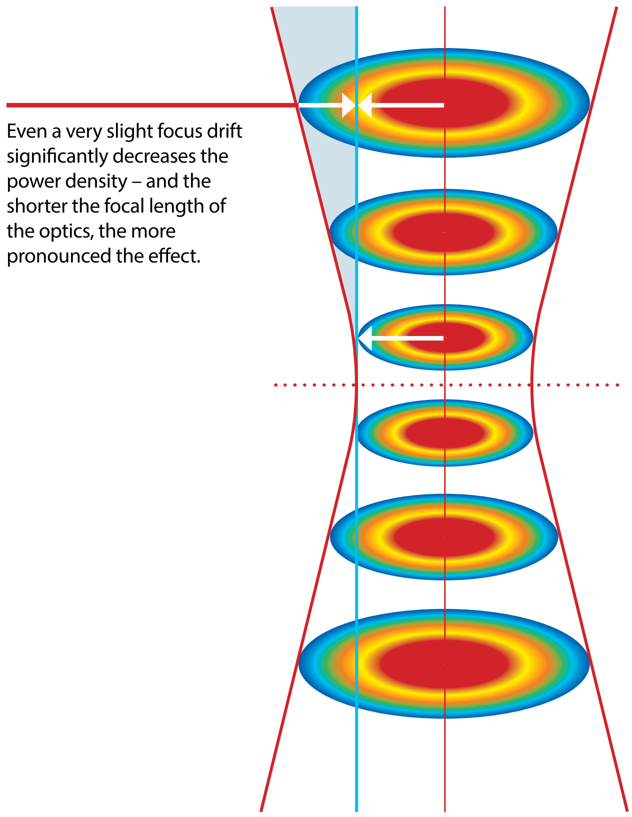

Fig. 2 Relationship between power density and focus drift

Finally, a protective window separates the optics or the scanner from the work chamber. To improve flexibility, there might be a pair of beam benders (or turning mirrors) in the beam path to help alignment of the expanded beam into the scan heads. Different strategies are applied within the working chamber, such as heating it up or purging it with process gas, but they will not be the focus of this article.

Leaving material-related and work strategy questions out of the equation, the crucial question in terms of achieving reproducibility is how the optical components, with their coatings, power densities and alignment, influence the production process, and how the interplay between them can be managed to achieve constant beam parameters. As if the challenge to set up one laser beam path and manage the optics involved isn't enough, larger parts are built using even more complex multi-laser systems. The basic structure of the entire beam delivery is replicated up to four times in one PBF-LB system, working in a stitching mode. The individual laser beams not only need to be aligned precisely in order to achieve durable, high quality parts. They also need to be matched to almost identical performance – a more than challenging task.

Why is power density the key?

One of the key parameters within PBF-LB processes is the power density of the laser beam. As the power density is defined as power per unit area, its calculation is straightforward. The beam's power is divided by the area of a beam using the radius. Most lasers present a beam profile that is most intense in the centre and decreases in power density as you move away from the centre. This symmetrical bell-shaped pattern is called a Gaussian distribution. Alternatively, a so-called top hat or flat top beam profile might be used with the aim of maintaining literally the same power density across the beam cross section. For any beam shape in common, the critical point is that even a slight shift in focus position (see Fig. 2) causes a significant change in power density as the area of the beam varies.

Take, for example, a 4000 W laser focused to a 100 μm diameter spot size; the average power density of the focused beam will be 51 MW/cm². A 10 W beam can create an average power density of 32 kW/cm² if focused to a 200 μm spot, or 127 kW/cm² average power density if focused to a 100 μm spot (see Fig. 3)

The parameters of concern

In most cases, the beam exiting the laser will not have the size, shape or intensity profile needed for the application. The laser beam will be expanded and may be shaped, and can be steered by galvanometer mirror systems and travel through several transmissive optics before reaching the process. However, optics and mirrors gradually absorb more laser light as they degrade, causing the delivered laser power to decrease over time.

Some wavelengths of light are very hard on system components. Thermal effects caused by absorption will change the size or location of the focused spot. This is known as 'thermal lensing' leading to 'focal shift'. If the laser focuses before the work plane, the power density is reduced as the beam is expanding before impinging on the work surface and, even further, high power densities might lead to creation of a plasma in the focal spot region that can impact the beam quality. If the laser focuses beyond the work plane, the power density is also reduced. Knowing the exact location of the focused spot is essential to quality output.

To ensure a consistent process over time, regular measurement of the laser beam is necessary to control performance. The engineers developing new PBF-LB machines, as well as the production technician, need to know:

- Spatial intensity distribution
- Location of the focused spot
- Power and energy at the focused spot
- Quality of the beam
- Divergence
- The stability of each of these parameters over time.

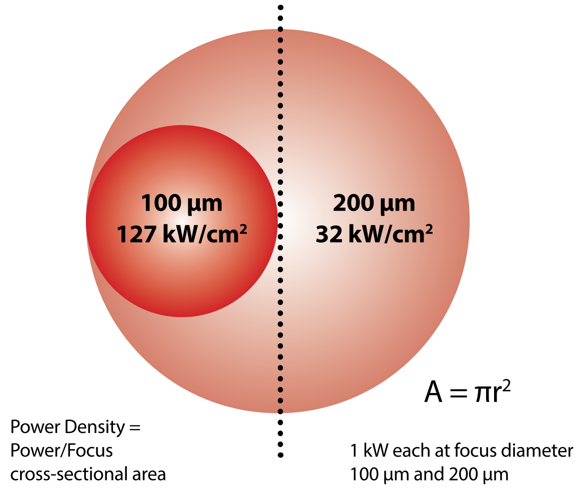

Fig. 3 The size of the laser beam changes the power density by a factor of 4

How to define a measurement strategy

Within the process of defining a measurement strategy, the machine manufacturer and the user will have to answer the same questions:

- Where and how often do we have to measure?
- What are the drivers to choose a certain measurement technology?

As the measurement process of the machine manufacturer starts way before the laser beam enters the build chamber, the answers will certainly be different to those of a machine user. Within the development of an PBF-LB system, different measurement points along the beam path are chosen to determine possible losses at the individual elements and to correctly align the beam delivery components to the laser beam axis (see the measurement points in Fig. 1). During the lifecycle of an PBF-LB system, the machine manufacturer needs to take many measurements: in the product development, in production, in quality-related end-of-line testing and when the system is serviced once it is installed on the customer's premises. In order to be able to compare the gathered data points taken in those different stages, their continuity should be guaranteed ideally by using the same metrology technology all the way.

End-users, on the other hand, usually have no access to the beam delivery path. They have to rely on the information about the focused beam as measured in the build chamber to judge the quality of the PBF-LB process. This also results in a different approach when choosing the suitable measurement strategy. While the machine manufacturer is most interested in obtaining absolute measurements to define the parameters needed for the PBF-LB process, for the user, it is normally sufficient to have trends. By measuring the laser beam each time between unloading and loading the machine, even slight deteriorations will be revealed quickly and the process can be changed accordingly by adjusting the process parameters or performing preventive maintenance in order avoid putting a whole build job at risk, losing time and expensive material in the process.

For the measurements that are taken within the build chamber in particular, the ease of use of the measurement device plays a key role. Fast positioning, easy alignment and a low risk of damaging the device will enhance your team's acceptance of the practice of taking frequent measurements. A short measurement time is also important, as this is the prerequisite to be able to integrate regular measurements into the production process. Using CCD Camera-based technology will provide a time resolution at video rate to reveal changes of the focused laser beam when going from cold to warm, the typical state of operation even through the build process. Thermal equilibrium is very rarely achieved as an operational condition of a laser system employing scanning systems for beam steering.

Measurement solutions

The most commonly used approaches over the last twenty years have been the scanning slit beam profiler for low and medium powers, and the scanning tip with a pinhole for higher powers, which samples a small portion of the beam and presents it to a single element detector. For both, the rotational scanning of the slit and translational scanning of the pinhole through the beam creates a 2D image of the beam profile. While the scanning slit devices are rather compact and low cost, the method of scanning tip does require large-scale equipment with moving mechanical parts and a water chiller, along with expert knowledge on the part of the operator and time to complete a measurement. Since scanning tip

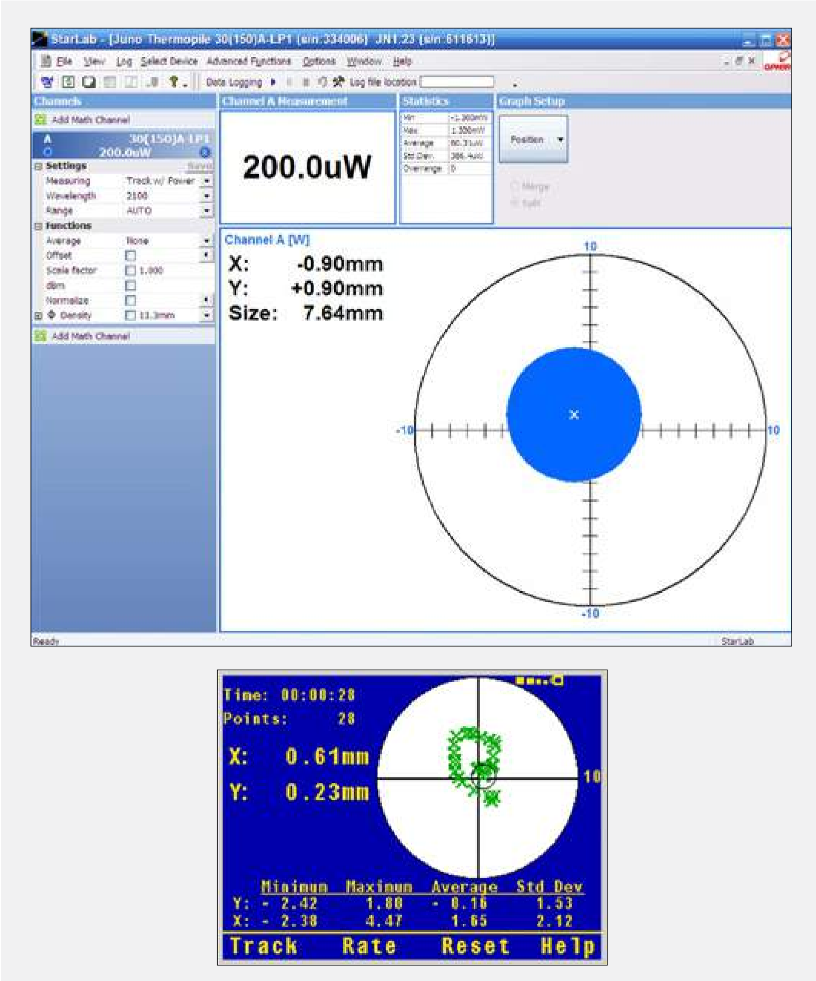

Fig. 4 Measurements taken with PPS sensors can provide first indications of the status of a laser-based system

equipment is relatively expensive to purchase and to maintain and slow to take measurements, the use of this technology is not very practical in production environments.

Secondly, there are quadrant sensors or power position sensors (PPS), which measure not only the power but also the position and size of the laser beam, going a step further than conventional power gauges. They are used to adjust the beam delivery, as well inside the build chamber. When the sensor is positioned centrally and moved vertically, the beam position should not show any movement. Any change in the measured beam position indicates an offset in the deflection head or a misalignment in the beam path. To a certain extent, this sensor technology can also be used to determine the accuracy of the beam adjustment in the peripheral areas of the building plane – in terms of both power and beam position.

Ophir LBS-300 HP-NIR beam profiler

Recently, a third option for measuring the high-power beams used in PBF-LB has emerged. Thanks to a newly developed beam attenuation technology, it is now possible to use a lower-cost CCD beam profiler (a well-known, low-power technology) to measure the laser beam in the working chamber. This approach can be seen in the new Ophir LBS-300 HP-NIR (Fig. 5), a beam attenuation system designed for focused spot beam analysers that combines dual sampling optics and neutral density filters for beam attenuation before the focused spot reaches the camera. This innovative beam splitter is designed for high-power lasers and employs newly engineered sampling optics that allow measurement of NIR (1,000–1,100 nm) focused or collimated laser beams profiles up to 5 kW or 15 MW/cm^2. With this technology, a low-cost system is now available that provides the usual 2D and 3D beam profiles, as well as the capability for fast measurements of both an image integrated over a certain period of time and of the full-beam profile with dynamic changes at video rate.

Ophir BeamWatch AM

The fourth alternative to measure the laser beam within the working chamber is by using a non-contact measurement technology based on Rayleigh scattering of the laser beam. This technology was developed by Ophir and further enhanced for use in Additive Manufacturing systems such as the Ophir BeamWatch AM measurement device (Fig. 6). The lightweight, compact system measures beam position and angle of incidence, focal spot size, position and quality parameters such as M^2 and beam caustic in real-time. These measurements allow users to easily determine when the beam is aligned and in focus, providing more consistent material behaviour. Measurements can be displayed in tabular, 2D or 3D views, providing a quick and realistic display of laser characteristics. The advantages of non-contact laser beam measurement are particularly important at higher power densities of more than 2 MW/cm^2, as currently required in PBF-LB. Because the instrument can record power of up to 1 kW for as long as two minutes without needing active cooling, it can be used in R&D as well as in production and service. The comparability of the measurement results, which plays such a crucial role for manufacturers, is guaranteed at all times.

When designing Ophir BeamWatch AM, an important factor for Ophir was its ease of use. The non-contact measurement technology, on the one hand, guarantees that there is no wear and tear as the beam does not affect the device. On the other hand, the device has a centring 10 mm dowel pin hole that enables fast alignment in the working chamber. Reproducible measurements can thus be achieved easily. As the measurement itself only takes fractions of a second, the focus shift can be measured, delivering a realistic picture of the process. Conventional measurement devices are much slower and thus are simply unable to detect focus shift at all.

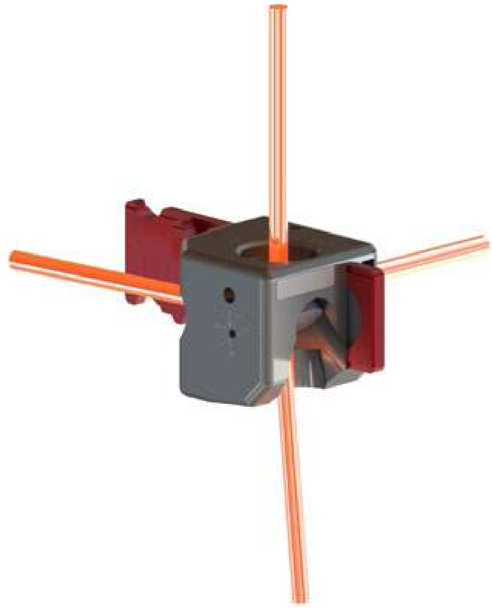

Fig. 5 Ophir's LBS-300HP is a compact, camera-based focus spot beam analyser

Conclusion

More parameters than just the optical performance of the laser beam influence the reproducibility of AM parts. However, neither the material specification nor the handling of the material in the build chamber can guarantee the required narrow bandwidth of the PBF-LB process without control of the laser focal spot. There is no control without the gathering of reliable data.

The different measurement technologies offer suitable options for all use cases. Scanning slit and PPS sensors represent the entry-level of data gathering in PBF-LB systems in terms of the delivered information and investment. The newly available option to use CCD cameras for PBF-LB applications, even at higher power levels, goes a significant step further as it offers fast and easy-to-use beam profiling. Major barriers for laser beam monitoring, including time to set up and time for measurement, can thus be overcome.

Fig. 6 The Ophir BeamWatch AM measures beam position and angle of incidence, focal spot size, position and quality parameters such as M² and beam caustic in real-time in AM machines

The combination of new attenuation optics and CCD camera delivers a relatively low price tag, as well as a compact and lightweight design that supports the increased use of performance monitoring. Monitoring trend lines of power density enables narrower process windows and operation of the PBF-LB machine closer to its optimum specifications.

When it comes to regularly measuring the performance of the laser in the working chamber, a compact non-contact device such as the Ophir BeamWatch AM offers many advantages. Due to its short set-up and measurement times, it allows the manufacturer to produce and calibrate more PBF-LB systems in a shorter time frame. Furthermore, the manufacturer's service team can efficiently measure PBF-LB systems in the field using the same beam profiling system as the production process does, which – once again – ensures product quality and reproducibility of the laser beam performance. From a user perspective, beam quality can be measured quickly and frequently in the production process.

No matter what option the machine manufacturer and user select, a major step towards reproducibility is to be aware that the laser beam needs to be monitored, as it has a significant impact on the reproducible quality of the produced parts.

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Link3D's 'Additive Manufacturing Maturity Model': Developing an agile and resilient supply chain

As the metal Additive Manufacturing industry matures at a rapid rate, organisations are now faced with the challenge of scaling their AM operations. Based on a study of 253 companies in a number of sectors, US-based AM software specialist Link3D has developed an 'Additive Manufacturing Maturity Model'. This simple model can be used as a tool to understand an organisation's AM maturity whilst also helping them navigate the steps to developing an agile and resilient AM supply chain. Shane Fox, CEO and co-founder of Link3D, explains.

The Additive Manufacturing industry has started to fulfil its promise and many of the world's largest economies are taking notice. The 21.2% growth of the overall industry in 2019 (estimated to be worth $11.867 billion) is foundational proof of its momentum [1]. However, investing in new technologies is always risky, and Additive Manufacturing is no exception to the rule.

Over the last two years, Link3D has conducted a study of 253 companies across the aerospace, automotive, consumer, defence, medical and other industrial sectors to better understand the risks of scaling up industrial AM production environments. Headquartered in Boulder, Colorado, USA, Link3D's Additive MES workflow software is designed to help organisations scale their digital manufacturing strategy and applies modern technologies, such as the Internet of Things (IoT), workflow automation and machine learning, to enable manufacturers to unlock the benefits of Industry 4.0.

Using the results of a two-year study, we have developed a framework known as the 'Additive Manufacturing Maturity Model'. Within this model, as organisations mature their processes, production efficiencies are expected as they transition through defined stages; these being named *reactive*, *informed*, *managed*, *automated* and *predictive*. They can choose various paths to mature their processes, including incremental growth, leapfrogging or starting from zero. It is important for businesses to navigate the risks that all change poses and manage them to ensure success by minimising overhead costs, eliminating poor data management and gaining leadership and employee buy-in.

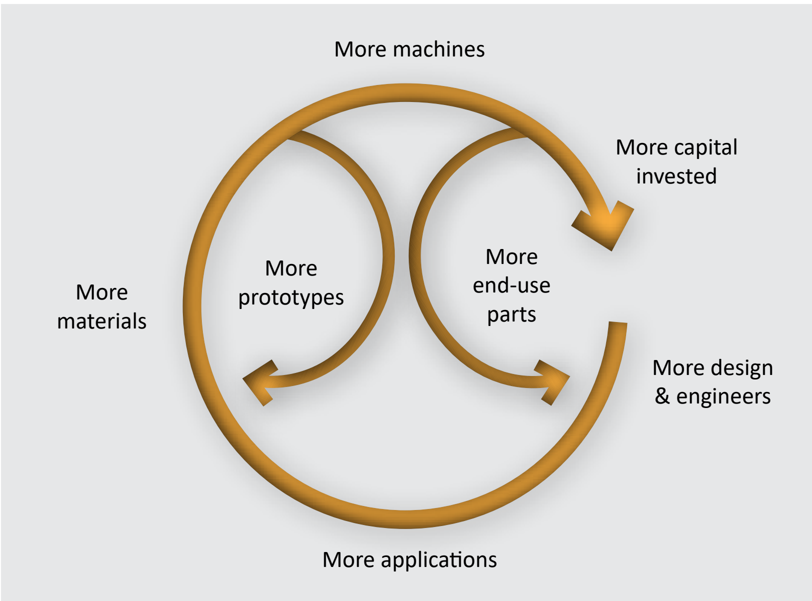

Fig. 1 An illustration of the 'virtuous cycle' of AM, a recurring cycle of events in which the result of each one is to increase the beneficial effect of the next

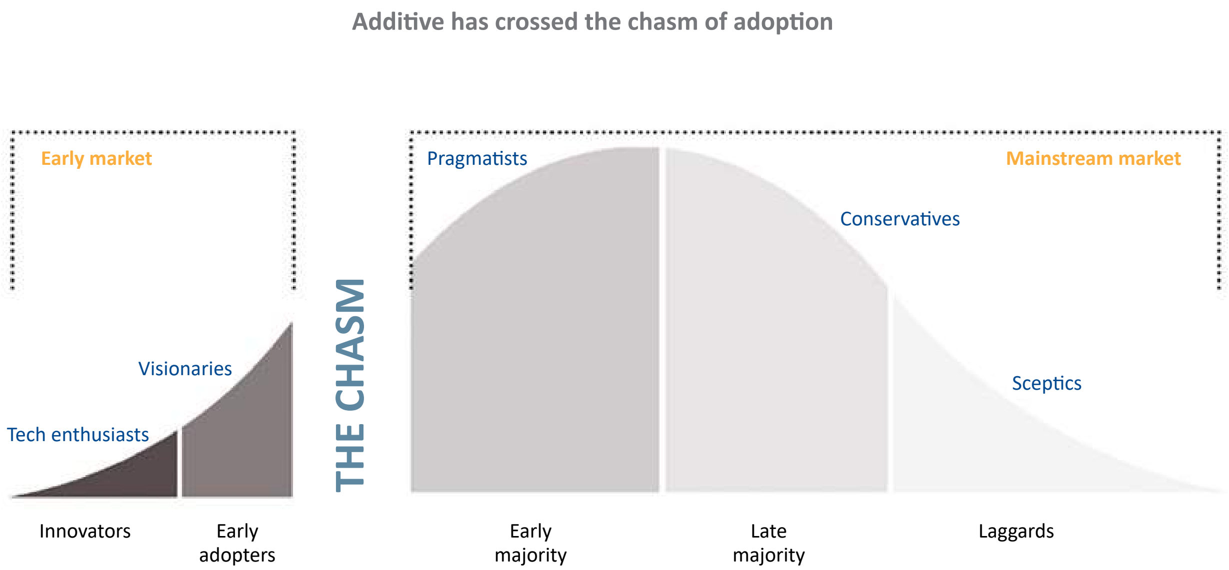

Fig. 2 AM has progressed from its early market of innovators and early adopters, through the chasm into the mainstream market

In this article, we will consider how Fortune 500 organisations, contract manufacturers and service bureaux can overcome risks to enable a sustainable business model and ensure business continuity.

AM is enabling new technologies in a cyclical 'virtuous cycle'

The Additive Manufacturing industry has now entered the 'virtuous cycle', a recurring cycle of events, the result of each one being to increase the beneficial effect of the next – literally, the opposite of a 'vicious cycle' (Fig. 1). In the virtuous cycle, the more engineers that design products, the more applications there are. The more applications there are, the broader the AM material selection becomes. Thanks to this cycle, we are starting to see new generations of machines with broader material capabilities, larger build volumes and serial production build times and quality. These advancements are now pushing the downstream technologies into a virtuous cycle to complete the manufacturing process.

This virtuous cycle has meant that Additive Manufacturing technologies have rapidly matured and will only continue to be improved upon in the future, as the loop reinforces itself. In summary, innovation within materials, AM machines and a host of post-processing and downstream technologies showcases the capabilities and processes that are constantly evolving.

As many of us already know, AM is no longer just for tech enthusiasts and visionaries. Use cases for AM have, in recent years, extended well beyond R&D and prototyping as organisations have begun to utilise the technology for series production with previous success under their belts. The virtuous cycle has pushed the industry beyond the narrow but necessary adoption window in which innovators and early adopters are the target market, through the 'chasm' and into the mainstream market (Fig. 2). Innovators set the foundation for AM and now its adoption is becoming mainstream across a variety of industries.

"This virtuous cycle has meant that Additive Manufacturing technologies have rapidly matured and will only continue to be improved upon in the future, as the loop reinforces itself."

Currently, the majority of organisations are either in the discovery, building or scaling stage of their AM journey. As the demand for AM services such as the production of prototyping, tooling, jigs and fixtures and serial parts, grows, these organisations are naturally under pressure to standardise their workflows to deliver repeatable, timely and consistent results. We see AM continuing on a positive trajectory, as organisations are strategising and creating their five to ten-year digital manufacturing plans and building

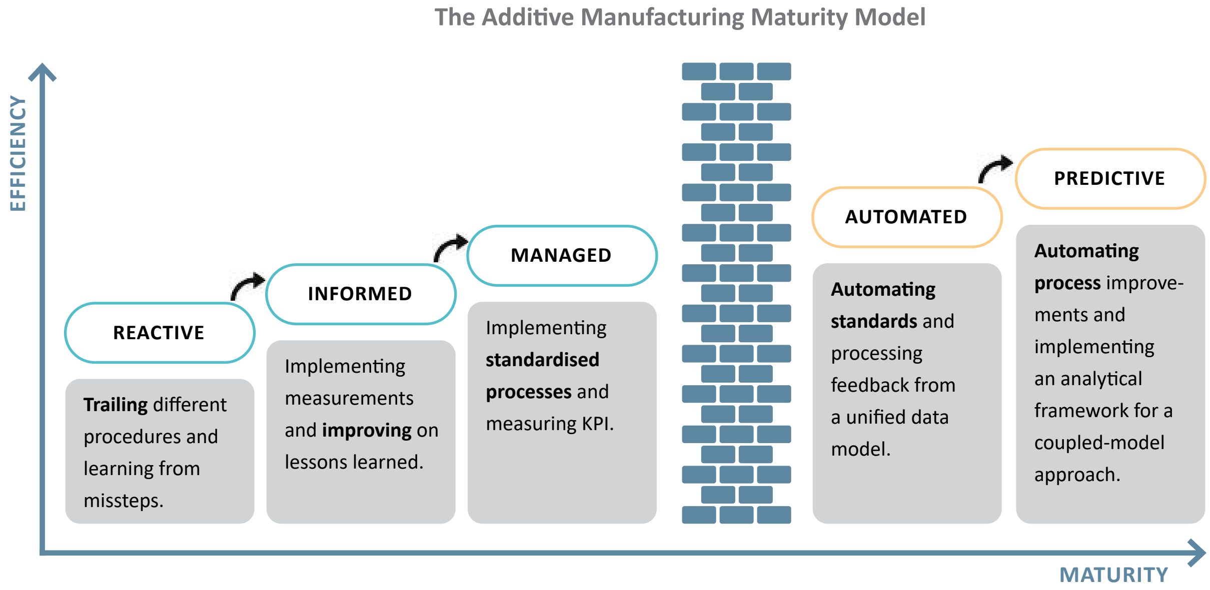

Fig. 3 As organisations mature their processes, greater production efficiencies are expected as they transition from the reactive to the informed, managed, automated and predictive stages

practical approaches to utilise AM alongside their traditional manufacturing technologies for series production.

The growth of AM leads to added complexity and challenges

Although the progress of AM enables the development of agile supply chains, opportunities for cost reduction, better supply chain resiliency and product advancement, and enables 'vision to delivery' on technology that it has not been feasible to manufacture before, these advancements come with challenges and added complexity. Because the Additive Manufacturing industry is in a constantly evolving state, organisations face the challenge of keeping up with an ever-changing technology at the same time as trying to scale up their AM operations to meet demands.

Innovation within AM has historically been focused on machines and the technology within them; machines to produce complex geometries, machines to build faster, machines capable of building in different materials. However, as organisations begin to use AM for on-demand manufacturing, concurrent manufacturing, and series production, the focus has to shift from the hardware to the environment in which these machines operate.

Isn't the end-goal for AM to achieve repeatable, quality parts that meet standards and regulations and to be a 'new' tool within the supply chain? If so, there is a critical need for innovation beyond hardware.

How organisations can mitigate risks within their AM supply chains

While the virtuous cycle and the adoption curve are both tools to assess the progress of the AM industry, the 'Additive Manufacturing Maturity Model' developed by Link3D can be applied to its customer base and future prospects to assess each organisation's AM maturity across its people, process and technology.

A critical component in how organisations grow their Additive Manufacturing operations is discipline – from both a process and financial perspective. Link3D guides organisations through their AM maturity and consolidates data into a single unified data layer, translating information into actionable insights to prove return on investment for AM.

We believe that understanding an organisation's stage of maturity through the use of the Maturity Model is a necessary discipline in order to enable them to set up a strategy to reach their digital manufacturing vision. This can be used as a benchmark for organisations to visualise the growth of their AM operations and understand how they can mitigate scaling pains associated with risks.

As stated in the introduction to this article, as organisations mature their AM processes, greater production efficiencies are expected as they transition from the *reactive* to the *informed*, *managed*, *automated* and *predictive* stages (Fig. 3). Whether they mature their processes through a path of incremental growth, leapfrogging or starting from zero, businesses must manage the risks which all change generates and work to ensure success by minimising overhead costs, eliminating poor data management and gaining leadership and employee buy-in.

Enabling the necessary transition from managed to an automated state

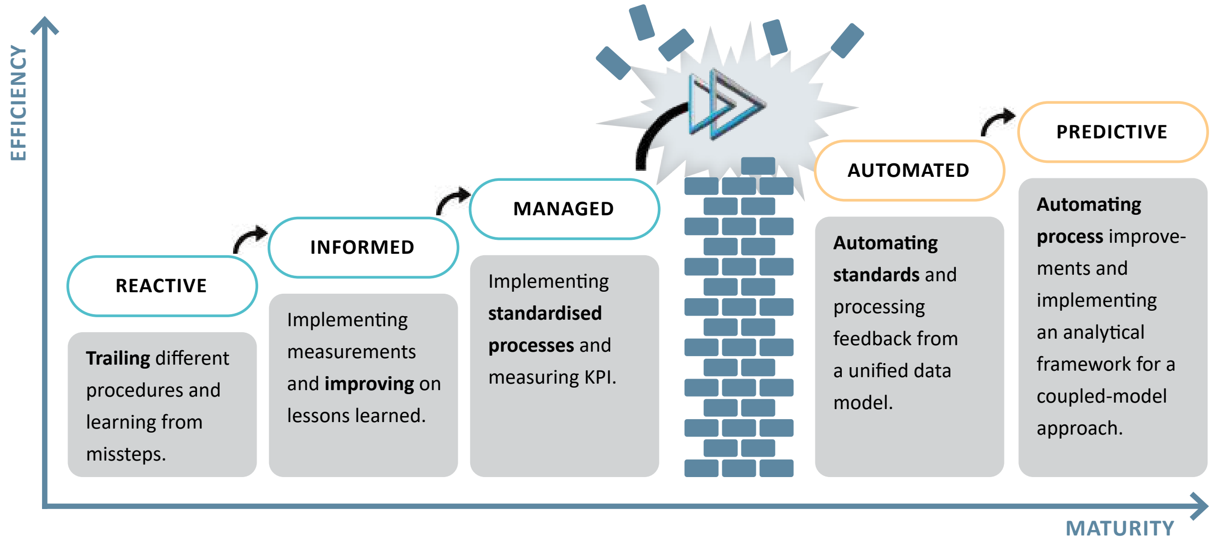

Fig. 4 Organisations in the managed stage have made a sizable investment in infrastructure, people and technology, but are stuck at a 'brick wall' which limits a unified data layer and blocks the ability to move into an automated stage

Reactive stage

Organisations in the *reactive* stage are just beginning to dabble in AM. Typically, they are evaluating the host of technology options available and comparing them to opportunities they have identified for best fit. Organisations within the *reactive* stage tend to be focused on R&D, and possibly low-volume production, and are starting to envision new possibilities based on their successes.

When organisations are in the *reactive* stage, they are just beginning their journey and there tend to be fewer strategic decisions inclusive of capacity, facilities, verticals and technology integration. Ultimately, the risk of living in the *reactive* stage is the inability to create strategic vision around the potential future, as organisations are acting in response to rather than creating or controlling situations. This becomes a limiting factor for organisations as they find strategic opportunities to leverage the technology through their R&D efforts.

Informed stage

Through lessons learned in the *reactive* stage, organisations in the *informed* stage have begun identifying strategic uses for AM within their business model. They may have started identifying ways to include AM in their operational and financial plans, but are usually struggling with the growing complexity driven by the manual work and volume of data AM involves.

As the AM industry is complex, fast-paced and constantly evolving, organisations at the *informed* stage risk remaining stagnant, as they may miss new market opportunities and become obsolete.

Managed stage

When organisations operate in the *managed* stage, they tend to have high human capital with manual workflows. As demand has increased, new or previously adopted siloed solutions present additional risks as systems are disconnected, leaving room for human error, loss of data and challenges to meet stringent customer quality requirements. By remaining in the *managed* stage, organisations' future growth and profitability is limited.

We have observed that organisations in the *managed* stage tend to be past the point of no return, with a sizeable investment having been made in the infrastructure, people and technology required for AM adoption. However, they are stuck at a 'brick wall' with analogue and point solutions. This wall inherently limits a unified data layer and ultimately blocks the ability to move into an *automated* stage (Fig. 4).

Automated stage

Moving into the *automated* stage is the foundational first step organisations must take in order to start their true digital manufacturing journey. This transition is only possible with the adoption of a unified data model powering a true end-to-end solution. Organisational alignment across key stakeholders regarding a digital manufacturing strategy enables best-in-class integration into a central operating system.

Any internal misalignment of change management presents risks, as an organisation may attempt to build a solution in-house without viable long-term expertise, or adopt an unfit solution, leading to failure.

Predictive stage

Forward-thinking organisations in the *predictive* stage are taking AM a step further by incorporating data analytics into their processes. At this *predictive* stage of AM adoption, teams are performing the same functions as they did during the *automated* stage (mitigating friction points and delivering design optimisation insights), but are doing so in ways that both enable and drive their profitable expansion of Additive Manufacturing. Moreover, data-centric teams have the power to deliver insights when and where they are likely to be most impactful.

Establishing the foundation of your AM strategy is inherently important, as this is the foundation that the digital thread is built upon. If the correct data model was not established in previous stages, the predictive outcomes that are guiding your organisation's key decisions can be misleading.

Sustainable paths to scale

Incremental growth

Organisations lacking financial and human resources often opt for incremental growth to mature their processes. When it is no longer sustainable to continue operating effectively, standardising processes and introducing small-scale technologies can incrementally improve operations from one stage of AM maturity to the next.

However, such organisations are often challenged by a lack of human resources. As operations are lean, dedicating employees to discover, evaluate and implement new technologies becomes difficult. Hiring consultants or relying on a vendor's customer service programme can be a solution to alleviate risk for implementing continuous improvement programmes and driving business objectives.

Zero to one

Additive Manufacturing has been around for over thirty years and organisations that have been watching the industry closely have seen success and failure. More often than not, they hire AM experts to launch larger programmes within their organisation to support their business divisions.

Instead of introducing lean practices for validating new technologies with manual workflows, organisations following the 'zero to one' path will often develop a holistic business plan that takes into account facility requirements, headcount, AM technologies (machines, materials, auxiliary equipment) and software (CAD, build prep software, workflow automation software). By prioritising the implementation of an end-to-end digital manufacturing solution, they can lay an infrastructure foundation which is able to scale as AM plant operations and supply chains mature.

Leapfrog

Not all organisations have the opportunity to jump from zero to one; however, they can 'leapfrog' towards the *automated* or *predictive* stage. During the *reactive* and *informed* stage, they are not inundated with order requests and so, at this time, can allocate time and resources to introduce the scalable workflow automation software that can enable them to scale their AM production.

Conclusion

Trends for AM growth across organisations include an increased number of developed applications for AM and increased AM literacy, driving production and reduced design cycle times with tech-enabled CAD design software for digitising parts at scale. With the increase in AM demand, organisations will experience growth challenges at every stage of their AM journey, but the AM Maturity Model is designed to help them to reflect and plan how they want to mature their processes and what level of efficiency they would like to achieve.

Link3D is dedicated to helping businesses scale their Additive Manufacturing operations for industrialisation and mitigate the associated risks. Our experience and studies have shown that organisations must consider their digital manufacturing strategy earlier in the AM journey to ensure sustainable business growth as they expand their AM capabilities.

The digital revolution is still in its early stages, but is clearly starting to take shape. This year, the strain put on global supply chains by the coronavirus (COVID-19) has offered yet another example of why organisations must prioritise agility and resilience when it comes to their supply chains. Digital connectivity among designers, engineers, managers, technicians and physical industrial assets will unlock enormous value and has the potential to change the manufacturing landscape forever.

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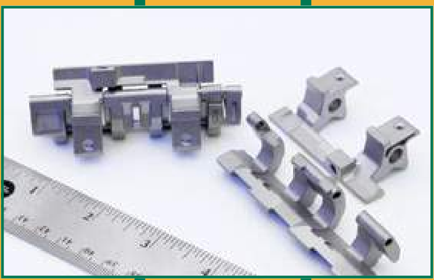


Design for Additive Manufacturing (DfAM): Binder Jetting Technology demystified

Able to achieve quicker build speeds and lower cost per part than its rival technologies, metal Binder Jetting (BJT) has generated increasing interest and rapid industry investment over the past two years. But while many engineers are now becoming familiar with the principles of design for Powder Bed Fusion AM, design for BJT is less widely understood. In this article, Olaf Diegel and Terry Wohlers attempt to demystify some of the key factors that must be considered when designing parts for BJT.

Over the past two years, a lot of interest has developed in the use of metal Binder Jetting (BJT). Desktop Metal, HP Inc. and others have generated much of the attention this class of AM technology is getting. While some may be under the impression that metal BJT is a relatively new AM process, it has been commercially available for nearly two decades from The ExOne Company. Höganäs's Digital Metal was second to make its BJT technology available, first as a service and more recently by selling machines.

BJT offers some potential advantages over alternatives such as metal Powder Bed Fusion (PBF), with cost being one of them. Taking everything into account, the cost per part can be lower for small parts produced by BJT. Build speed, too, is fast compared to some competing AM technologies, which also factors into its lower cost. BJT may offer cost and speed advantages, but one needs to consider other factors, such as the part shrinkage that occurs during sintering. Depending on the process, metal and method used, shrinking can range from 3% to more than 20%. Because errors from shrinkage magnify with size, and controlling it is difficult, users of BJT tend to favour the technology for the production of small parts. Porosity and structural integrity are also considerations in BJT.

How metal BJT works

A layer of metal powder is deposited onto a build platform and a liquid binder is then applied using an inkjet nozzle to form the shape of a slice of the part design. Where the binder is applied, the powder

Fig. 1 Gears produced in 17-4PH stainless steel using ExOne's metal Binder Jetting technology (Courtesy The ExOne Company)

particles in the layer bond together. The build-platform is then lowered, a new layer of powder spread on top, and the process repeates until the part geometry is completed within the powder bed. After completion, the build platform is raised and the loose powder removed. Green parts must then be sintered into solid metal parts.

The BJT process involves the following steps and considerations:

1. Binder Jetting
A machine deposits thin layers of metal powder onto a build platform and applies a binder (i.e., liquid glue) layer by layer. The minimum feature size for metal BJT is typically in the range of 2 mm. The process can be used to produce details as small as 1 mm, but these features are difficult to handle without damaging them. This applies to both features and text on a part.

2. The 'green' state
After the building phase is complete, the parts are in a fragile 'green' state. It is important to consider the design of a part to ensure it can be handled during this temporary but critical phase. Green parts can be picked up, but they have little strength and can easily be broken.

3. Powder removal
Loose powder around the parts is carefully removed by brushing and/or vacuuming as part of a depowdering process to fully expose the green parts.

4. Debinding and the 'brown' state
In the case of most BJT systems, a debinding process is needed to remove the main part of the binder system. The parts are placed in a furnace to burn away the binder, resulting in 'brown' parts. These are extremely fragile and will crumble if touched.

5. Sintering
The parts are heated in a furnace until the particles of the metal sinter and form a solid. Significant shrinking occurs with during this phase, but the result is a homogeneous part. Sintered BJT parts typically have some internal porosity, and are often around 97% dense. This means their as-sintered mechanical properties are inferior to the same material in wrought form. As a point of comparison, metal PBF parts can be 99.5% dense. It is common, however, for high volumes of sintered parts produced by Metal Injection Moulding (MIM), technically similar to metal Binder Jetting, to undergo Hot Isostatic Pressing (HIP) to produce full dense parts. There is little reason why this step cannot also be applied to BJT parts, should the application require it.

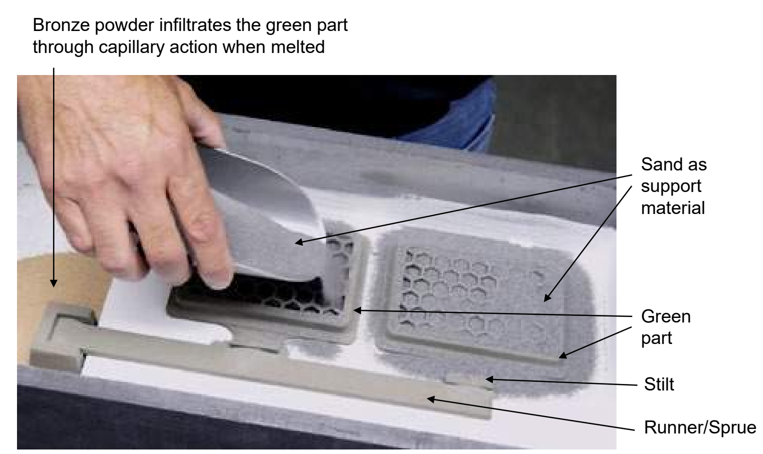
A well-established technology variant: Binder Jetting and infiltration to produce matrix materials such as ~ 60% stainless steel and ~ 40% bronze

Once a green part has been produced, an alternative to sintering is infiltration by a second material, such as bronze. The lower hardness of these materials makes it easier to machine and polish them. They can also exhibit useful corrosion resistance properties.

When processing in this way, sprues and stilts need to be added to the part design to serve as passages that allow a molten metal to infiltrate. Since they are still in a green state and fragile, they are fully surrounded with sand, which acts as a temporary support material. The model is then infused with bronze at a high temperature, resulting in parts that are a two-alloy matrix. In the case of a stainless steel/bronze part, the material ratio will be in the range of 60–70% stainless steel and 30–40% bronze. Infiltrated parts will typically be about 90% dense.

The sprues and stilts typically have a surface area of about 1–1.5 mm where they connect to the part, so the artefacts left by these stilts and sprues after infiltration require finishing, usually by machining. Any residual powder around the model is removed by blasting it with air. Care must be taken to not damage delicate features.

As the infiltration process can be labour intensive, its opportunities for high volume production may be limited, compared to Binder Jetting followed by conventional debinding and sintering.



The bronze infiltration process (Courtesy The ExOne Company)

Is shrinking the curse of metal BJT?

It is important to understand that parts shrink, often significantly, during the sintering step to consolidation to near full density. This is one of the biggest factors to consider when using BJT for production. The level of shrink will vary between various systems, depending on the volume of binder used. The MIM industry learned to embrace this aspect of the technology over several decades and successfully produces hundreds of millions of parts annually for everything from superalloy stator vanes to the stainless steel buttons for smartphones. In BJT, the software provided by machine manufacturers attempts to compensate for shrinkage in the CAD model, but many external factors contribute, including the part design and sintering furnace parameters.

Proper part size and design makes a big difference

Some companies recommend BJT only for small parts, typically less than 5 x 5 x 5 cm. Suppose a part measures 10 mm in length and dimensional error from shrinkage is 1%. The resulting error is 0.1 mm, which may be within an acceptable tolerance. If a part is 300 mm in length, the error from shrink is 3 mm, which is less likely to be within an acceptable tolerance. The silver lining to this cloud is that when a part shrinks, extremely small features also shrink, effectively increasing resolution. In this way, you are able to plan for details that are finer than is otherwise possible, with improved surface resolution.

Part design is a factor that a designer can control. The key design guideline for BJT is to avoid large masses of material or uneven wall thicknesses. These can cool at different rates, so they are more likely to cause the part to distort or shrink unevenly.

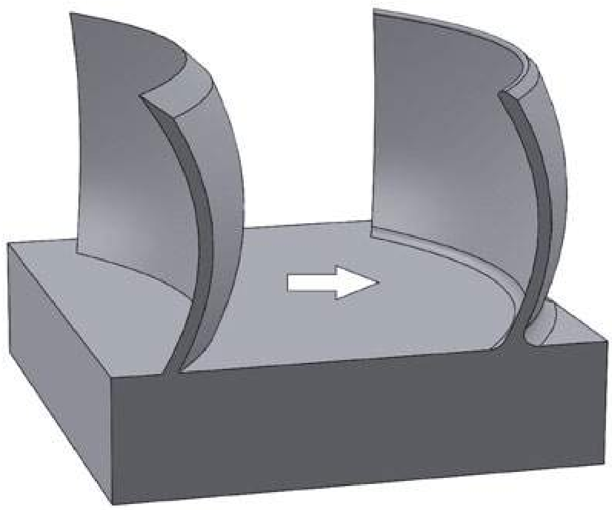


Fig. 2 Round all 'knife' edges to help prevent them from breaking, and fillet internal corners to avoid stress concentrations

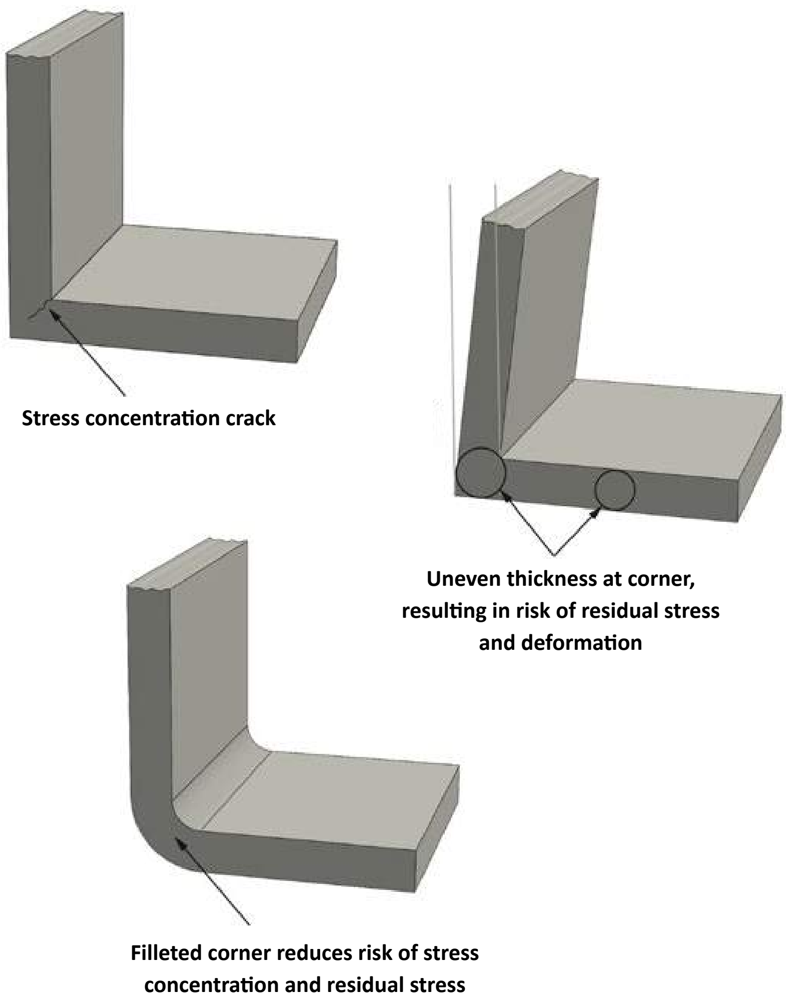


Fig. 3 Simple filleting reduces both stress concentrations and residual stress

Fig. 4 Make parts strong enough to handle in their green state

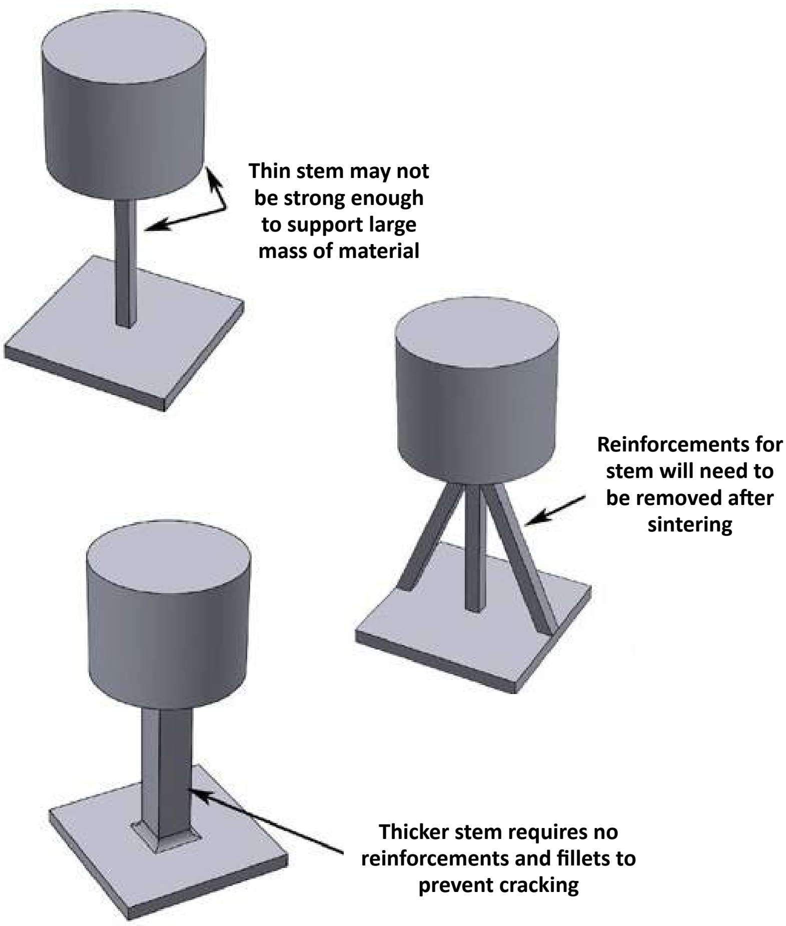


Fig. 5 The stem design in the lowest image offers the greatest chance for success

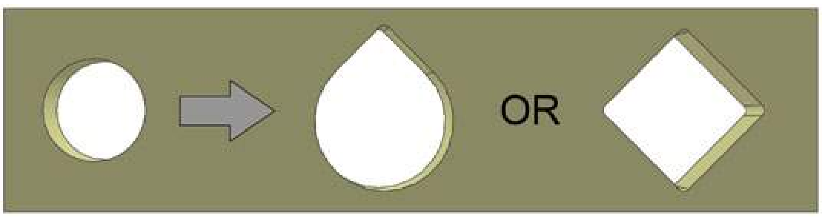


Fig. 6 For horizontal holes, use a teardrop or diamond shape whenever possible

BJT does not have the same support material requirements for overhangs or down-facing surfaces as PBF. Consequently, the down-facing surface quality of BJT parts is typically better. Gravity, however, is the enemy during sintering and whilst PBF-style supports are not required, some designs may need to be adapted with reinforcements against slumping when sintering.

Fillet and round everything

A general design guideline is to avoid sharp edges. If possible, fillet and round all internal and external corners. Sharp external corners and knife edges can chip and crack when depowdering, handling, or heating while parts are in their green state. Rounding the edges with at least a 0.5 mm fillet prevents parts from breaking (Fig. 2). If required, sharp edges can be recreated when post-processing the parts.

Internal corners are where stress concentrations occur, so filleting them reduces the problem and improves the overall structural strength of a part. Stress concentrations may cause a part to fail prematurely and residual stress may cause distortion in a part when sintering.

In the simple part shown in Fig. 3, the sharp internal corner may cause a stress crack. Also, the sharp corner has a larger mass of material than the horizontal and vertical walls, resulting in residual stress that can cause the wall to distort. A filleted corner and an even wall thickness reduces the possibility of a stress fracture.

Fragile metal BJT parts

Until parts have been fully sintered, green BJT parts are very fragile, so the entire design must take this into consideration. Poor design may result in parts being damaged during handling, e.g. to move to a debinding unit. Because of this temporary fragility, certain shapes and geometric features cannot be used. If they are, a part may be built without a problem, but you may not be able to handle it in its green state. It is often necessary to include strengthening ribs or walls in a design that support handling (Fig. 4).

Fig. 5 shows three different designs of the same part, with significant differences in the stem design for greater green strength.

Horizontal holes

With BJT, building parts with circular horizontal holes can be problematic because the weight of the material above the hole will compress its shape downward during the sintering process. This is particularly severe when large masses of material are above the hole. If a distorted pipe is straight, it can be made round by a subsequent drilling operation. If the pipe is curved, achieving a round hole can be difficult. For this reason, it is better to use teardrop or diamond-shaped holes whenever possible.

In general, round holes larger than 6 mm in diameter may distort heavily, so teardrop or diamond-shaped holes are recommended (Fig. 6). The smallest horizontal holes that can be additively manufactured with BJT are about 0.7 mm when infiltrating bronze. For fully-sintered, homogeneous parts, the smallest is 1.2 mm. Average powder particle size also plays a role in the hole size that is achievable.

Additional thoughts

BJT can be less expensive for producing relatively large volumes of small parts, compared to PBF. When using laser-based PBF in particular, parts cannot be stacked or nested easily, which is possible with BJT. This makes it possible to use a machine's entire build volume by stacking parts in the vertical direction. The build speed of BJT is also typically faster than with PBF. If plenty of sintering furnace capacity is available for the green parts, the overall production time is attractive.

It is impossible to conclude whether BJT or PBF are better or worse because both have their benefits, pitfalls, and design considerations. Both require strong knowledge of the process and material to design for an optimum outcome. BJT is relatively new for production applications where structural integrity is important, however those familiar with MIM can call upon that industry's experience and research. PBF is being used much more extensively for production, even for some structural applications. The key is to understand the idiosyncrasies of each process and where they can add value to make the process commercially viable.

"It is impossible to conclude whether BJT or PBF are better or worse because both have their benefits, pitfalls, and design considerations. Both require strong knowledge of the process and material to design for an optimum outcome."

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Industry events

2020

Space Tech Expo Connect
August 10-13 - Digital Event
www.spacetechexpo.com

3D Printing Asia Zone (Asiamold)
August 11-13, Guangzhou, China
https://asiamold-china.cn.messefrankfurt.com/guangzhou/en/programme-events/3d-printing.html

PM China 2020
August 12-14, Shanghai, China
http://en.pmexchina.com

PM Life - Additive Manufacturing Module
August 24-28, Dresden, Germany
www.pmlifetraining.com/about/additive-manufacturing

Formnext + PM South China
September 9–11, Shenzhen Shi, China
https://formnext-pm.hk.messefrankfurt.com

Manufacturing World Nagoya 2020
September 9-11, Nagoya, Japan
www.japan-mfg-nagoya.jp/en-gb.html

EPHJ Trade Show
September 15-18, Le Grand-Saconnex, Switzerland
https://ephj.ch/en

Metal Additive Manufacturing Conference 2020
September 30-October 2, Vienna, Austria
www.mamc2020.org

EBAM 2020 – International Conference on Electron Beam Additive Manufacturing
October 5-7, Erlangen, Germany
www.ebam.fau.de

Euro PM2020 Virtual Congress
October 5–7 - Digital Event
www.europm2020.com

3D Print Congress & Exhibition
October (TBC), Lyon, France
www.3dprint-exhibition.com/en/

AM Summit 2020
October 27, Kastrup, Denmark
www.amsummit.dk

Formnext
November 10-13, Frankfurt am Main, Germany
www.formnext.com

ASTM International Conference on Additive Manufacturing
November 16-20, Orlando, FL, United States
https://amcoe.org/events/astm-international-conference-on-additive-manufacturing-astm-icam

Space Tech Expo Europe
November 17-19, Bremen, Germany
www.spacetechexpo.eu

Additive Manufacturing for Medical Devices
December 1-2 - Digital Event
www.pharma-iq.com/events-additive-medical-devices-online

AMTech Expo
December 9-10, Mumbai, India
https://amtechexpo.in

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. View our complete events listing on www.metal-am.com

2021

MAPP 2nd International Conference
January 13-14, Abingdon, United Kingdom
www.mapp.ac.uk/events/mapp-2nd-international-conference

Additive Manufacturing Strategies 2021
February 9-12 - Digital Event
www.additivemanufacturingstrategies.com

MIM2021
February 22-24, West Palm Beach, FL, United States
www.mim2021.org

5th Additive Manufacturing Forum 2021
March 11-12, Berlin, Germany
www.am-forum.eu

AMUG 2021
March 14-18, Chicago, IL, United States
www.amug.com

Hannover Messe – Home of Industrial Pioneers
April 12-16, Hannover, Germany
www.hannovermesse.de

Rapid + tct
April 26-29, Chicago, IL, United States
www.rapid3devent.com

Space Tech Expo USA 2021
May 10-12, Long Beach, CA, United States
www.spacetechexpo.com

HI-AM Conference 2021
June 1-2, Halifax, Canada
www.nserc-hi-am.ca/2021

PowderMet2021 & AMPM2021
June 1-2, Orlando, FL, United States
www.powdermet2021.org & www.ampm2021.org

TCT 3SIXTY
June 29 - July 1, Birmingham, UK
www.tct3sixty.com

EPMA Powder Metallurgy Summer School
July (TBC), Ciudad Real, Spain
www.summerschool.epma.com

AMTC^4
October 12-14, Aachen, Germany
www.munichtechconference.com

Euro PM2021
October 17-20, Lisbon, Portugal
www.europm2021.com

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