Vol. 7 No. 4 WINTER 2021

THE MAGAZINE FOR THE METAL ADDITIVE MANUFACTURING INDUSTRY

METAL AM

in this issue

CZINGER: REDEFINING CAR PRODUCTION

BUYING TIME: AM FOR SPARE PARTS

THE SCALABILITY CHALLENGE

Published by Inovar Communications Ltd

www.metal-am.com

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

Printed by
Cambrian Printers, Aberystwyth, UK

ISSN 2057-3014 (print edition)
ISSN 2055-7183 (digital edition)
Vol. 7 No. 4 Winter 2021

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

METAL
ADDITIVE
MANUFACTURING

A little bit of luck and a lot of magic

So, Formnext happened. Had it been scheduled for a week later, it is quite possible that the story would be rather different. News of steeply rising COVID cases in Germany dominated news coverage in the final days prior to setup of the exhibition, along with warnings about large events from the authorities. But throughout the autumn, Formnext's organisers held their nerve, announced a 'vaccinated or recently recovered' entrance policy, and momentum built.

Despite a summer that allowed us to believe that life could start to move a little closer towards normality, I think we all knew that an event in mid-November in Frankfurt was always going to need luck on its side. But key international travel restrictions eased, as if higher powers really did want this event to go ahead, confidence grew and, at 9.00 AM on November 16, exhibitors were at their booths ready for the opening bell.

Four halls of Messe Frankfurt were transformed into a spectacular display of all that is Additive Manufacturing, but the big question was: would visitors come? We exhibitors were invested in the event in every sense, but it would have been far easier for visitors to give it a miss. By mid-morning, however, there was a distinct buzz in the halls – the Formnext magic was back!

It felt as if the AM industry needed this gathering. Excuse the cheap pun, but it really was a shot in the arm for everyone working to advance Additive Manufacturing to the next level. A little bit of luck? Maybe a lot of luck. But certainly all of the Formnext magic.

Nick Williams
Managing Director

Cover image
A Czinger 21C hypercar on Hollywood Boulevard (Courtesy Czinger Vehicles)

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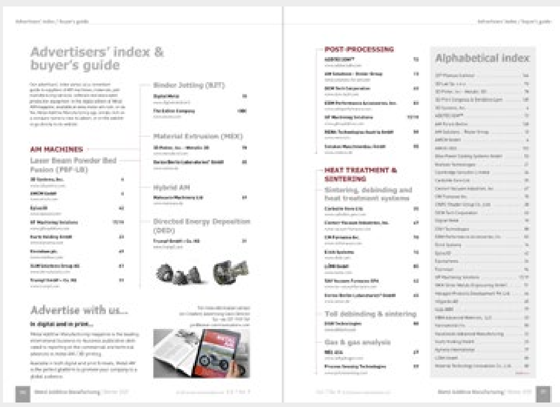

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CHECK OUT ALL THE BENEFITS AT
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Industry news

EOS acquires stake in metal powder manufacturer Metalpine

EOS GmbH, headquartered in Krailling, Germany, has acquired a stake in Metalpine GmbH, a metal powder manufacturer based in Graz, Austria, with the aim of jointly developing innovative and sustainable metal powders. Utilising Metalpine's atomisation technology, along with the material, process and system development competence of EOS, the partners are said to be well positioned to offer sustainable and economically efficient powder products for Additive Manufacturing.

Metalpine's atomisation technology, specially designed for industrial AM, makes it possible to produce new types of powder with optimum efficiency. The company's recently opened production centre in Graz produces highly spherical metal powders from a very wide range of metals and metal alloys, including copper, steel, nickel-base alloys, titanium, molybdenum and tungsten.

"The technology and the team at Metalpine excited us from the very first moment," stated Sascha Rudolph, senior vice president EOS Metal Materials. "We can now offer our customers even more powerful and sustainable solutions in the interplay between our industrial 3D printing process and the metal powder production used for this purpose."

"The Metalpine process enables a whole new dimension of flexibility and is consistently geared towards the application field of 3D printing," he continued. "The systems are particularly compact, can be quickly set up for new materials and are so low in emissions that they can also be operated in metropolitan areas without hesitation. We see a lot of common development potential and look forward to working with a highly motivated and professional team."

Andreas Rohrseitz, the owner of the HTM-Invest group, commented, "We see the future collaboration with EOS as a confirmation of many years of research in the field of metal powder production for Additive Manufacturing. The process, which was developed by Dr Martin Dopler and his team at the research site in Niklasdorf, combines the highest product quality with the lowest resource consumption."

Gerald Pöllmann, CEO of Metalpine, added, "The industrialised production process produces uniquely spherical, non-porous and virtually satellite-free metal powder. We are very happy to be able to convert our materials into outstanding components through the joint work with the competent EOS team and to make the future of Additive Manufacturing more sustainable."

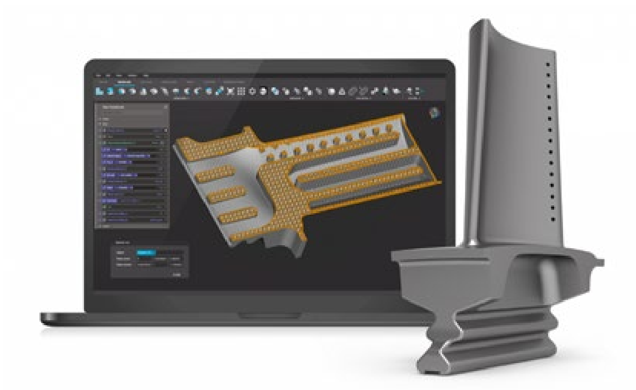
The common goal of both partners is to offer their customers further application possibilities for AM, as well as more sustainable powder products. At the same time, this partnership is said to contribute to the corporate purpose of sustainable manufacturing introduced by EOS.

www.eos.info
www.metalpine.at

EOS GmbH has acquired a stake in Metalpine GmbH in order to jointly develop metal powders (Courtesy Metalpine)

nTopology receives $65 million in Series D funding

nTopology, New York City, USA, has secured $65 million in Series D funding, bringing total secured financing to $135 million. The funding round was led by Tiger Global with participation from Oldslip Group and existing investors Root Ventures, Canaan Partners, Haystack, and Insight Partners. The company intends to use this capital to expand the range of engineering applications compatible with its software, strengthen its global footprint and expand its team.



nTopology's generative design software is used to optimise parts where performance is critical (Courtesy nTopology)

"nTopology customers use this software to design the most critical parts of their products," stated John Curtius, Partner at Tiger Global Management. "We're excited for nTopology to emerge as the new leader in engineering software as advanced manufacturing continues to push the boundary of how products are made."

nTopology was founded in 2015 to enable engineers and designers to create any geometry, no matter how complex, and meet the requirements of high-performance products. The company's software is used in research through to production to create processes and products for the aerospace, automotive, medical, and consumer industries. In less than a year, nTopology was reported to have doubled its revenue and customer base. Today, its software is said to be used by engineers in over 300 companies, including Ford, Lockheed Martin, Honeywell, Emerson, and Wilson.

www.ntopology.com

Materialise agrees to acquire Link3D for US $33.5M

Materialise, an Additive Manufacturing solutions company headquartered in Leuven, Belgium, reports that it has agreed to exercise its previously announced option to acquire Link3D Inc., an additive workflow and digital manufacturing software company headquartered in Boulder, Colorado, USA. Subject to conditions, the transaction is expected to close by the end of the year. Materialise will acquire 100% of the Link3D equity interests for US $33.5 million.

Building on the success of its existing AM software suite, Materialise has outlined a cloud-based platform strategy: the Materialise software platform will offer companies cloud-based access to a continuously growing set of digital tools, enabling users to personalise and manage their AM processes and streamline their workflows. The acquisition of Link3D is expected to strengthen and accelerate the creation of the Materialise software platform, particularly for companies that are scaling up their AM operations to volume production.

"Materialise continues to lead the way in advancing the AM industry and this acquisition strengthens our position in the high-growth manufacturing market," stated Fried Vancraen, CEO of Materialise. "As companies accelerate the adoption of Additive Manufacturing into increasingly digital production environments, they require a strong and unified AM software platform. Today's announcement creates a merger of forces that serves as the foundation for such a scalable and sustainable platform."

By integrating Link3D's Manufacturing Execution System (MES) solution with the Materialise Magics software suite into a unified, cloud-based software platform, manufacturers are expected to be able to run and continuously improve processes to mass-produce identical or customised products. This process extends beyond the actual AM operations and creates a closer alignment between Additive Manufacturing and conventional manufacturing, signalling the removal of the wall between both production environments.

Stefaan Motte, VP and General Manager of Materialise Software, commented, "In recent years, we have carefully developed our platform strategy. By joining forces with Link3D, we can accelerate the realisation of this strategy, which will allow our customers to define and run the most optimal, efficient and sustainable production process. Not only for the production of one-offs, but, in particular, for scaling production in complex and distributed ecosystems."

Vishal Singh, CTO and co-founder of Link3D, added, "It has always been our mission to help companies scale Additive Manufacturing and help them achieve their ROI goals. This is a landmark day for the AM industry. The combination of two innovation leaders committed to relentless pursuit of the promise of digital manufacturing."

www.materialise.com
www.link3d.co

Medical device manufacturer PrinterPrezz acquires Vertex Manufacturing

Medical device manufacturer PrinterPrezz, Inc., Fremont, California, USA, has acquired Vertex Manufacturing, a provider of Additive Manufacturing, CNC machining and services, based in Cincinnati, Ohio. Vertex was established in 2020 by Greg Morris, founder of Morris Technologies Inc. (MTI), and former MTI employee Steve Rengers.

PrinterPrezz develops advanced medical devices using processes that combine expertise in AM, orthopaedics, semiconductors and nanotechnologies. The company aims to solve challenges for various parts of the medical innovation value chain by providing prototyping, development, and manufacturing services for numerous medical devices.

"Bringing together the complementary strengths of two innovative companies in the advanced manufacturing space is a transformative event that will allow customers across multiple industries to benefit from best-in-class proprietary technologies, IP, and workflows," stated Shri Shetty, CEO of PrinterPrezz. "Solving the problem of the fragmented nature of the Additive Manufacturing supply chain, we created an end-to-end platform to optimise the process from device innovation through volume manufacturing. This acquisition provides PrinterPrezz with core fundamental post-processing technologies relevant to accelerate time to market for medical devices."

PrinterPrezz will continue to primarily focus on medical devices, leveraging in-house regulatory experience, clinician-driven design, AM knowledge, and in-house nanotechnology development. The Fremont design, engineering and manufacturing centre will continue to maintain all requirements for medical device manufacturing including ISO-13485:2016 and all relevant regulatory requirements.

Vertex Manufacturing will continue to support all advanced manufacturing industries including medical, aerospace, defence, oil & gas, energy and consumer goods industries. The Cincinnati engineering and manufacturing centre will maintain all of its current certifications including ISO 13485:2016 and SAE AS9100:2016. The Cincinnati facility remains and will continue to be fully ITAR compliant and registered.

Shetty added, "Over the past two years, our two companies have had a great working relationship. They immediately strengthen our technical capability and provide a location with a deep history of manufacturing expertise. We value their experience and perspective and look forward to leveraging Vertex Manufacturing's vast knowledge as we create a global platform."

Vertex Manufacturing operates a number of different AM machines (Courtesy Vertex/PrinterPrezz)

Greg Morris, CEO of Vertex Manufacturing and PrinterPrezz CTO, commented, "I have been a part of the PrinterPrezz organisation since its earliest phases, originally as a member of the Board of Advisors, and more recently as Chief Technology Officer. The opportunity to bring Vertex into the PrinterPrezz organisation is an incredible opportunity for both companies' customers."

"We believe the cross-pollination of various industries is a tremendous strength," he continued. "As such, our Cincinnati, Ohio facility will rapidly grow to support the installation of new Additive Manufacturing and post-processing tools to support all of our existing customers as well as to support the increasing demand from the medical industry."

www.vertexmanufacturing.com
www.printerprezz.com

Aubert & Duval marks a decade as supplier of metal AM powders

Aubert & Duval, a subsidiary of the High Performance Alloys Division of the Eramet Group based in Paris, France, is celebrating ten years as a supplier of metal powders to the Additive Manufacturing industry.

Its powder range covers nickel- and cobalt-base alloys and steels produced via a gas atomisation method with argon or nitrogen, with VIM (Vacuum Induction Melting). The company's Pearl® micro metals are intended for Laser Beam Powder Bed Fusion (PBF-LB), Electron Beam Powder Bed Fusion (PBF-EB) and Directed Energy Deposition (DED).

These powders are reported to feature highly spherical morphology, fully controlled low oxygen & carbon levels, no satellites or internal porosities, as well as high levels of cleanliness, stability and reproducibility. Customised compositions and speciality alloys are also available.

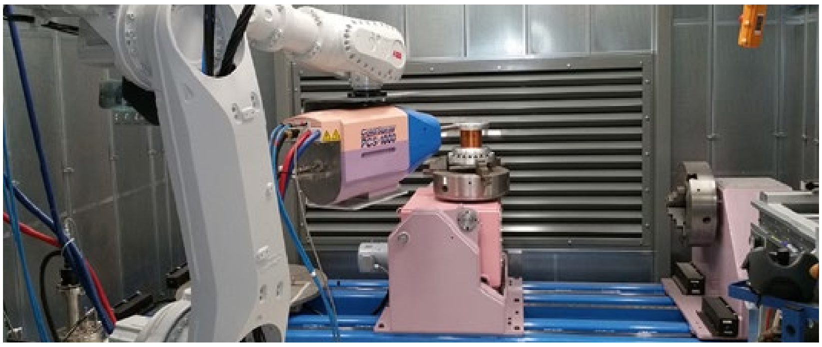
Thus far, Aubert & Duval's powders have served markets such as aerospace (for which its factory has EN9100 accreditation), energy, medical, defence and automotive.

www.aubertduval.com

Titomic establishes European base following purchase of Dutch cold spray company Dycomet

Titomic Ltd, Melbourne, Australia, has acquired leading European cold spray technology company, Dycomet Europe B.V., Akkrum, the Netherlands. Currently, Dycomet's portfolio includes turn-key cold spray solutions; research and development services via an in-house laboratory; software development; and the provision of servicing, spare parts and consumables for its systems. From its beginning thirteen years ago, Dycomet has offered low- and medium-pressure cold spray technology solutions to various industries before adding high-pressure cold spray solutions in 2016. Its clients include Rolls-Royce, Mercedes, Airbus, Siemens, VW, and several leading universities.

The transaction will provide Titomic with a base in Europe, with Klaas Rozema, Dycomet's founder and Chief Executive, taking the new role of General Manager of Titomic Europe.



Dycomet offers a range of low- and high-pressure cold spray systems (Courtesy Dycomet)

"The acquisition of Dycomet is a significant step in Titomic's strategic pathway to being a global company. We are excited to welcome Dycomet onboard and look forward to working with Klaas and his team on the many exciting opportunities that this acquisition presents," stated Herbert Koeck, Chief Executive of Titomic. "With our complementary machinery and product portfolio, the combined expertise now available to the company will further accelerate the company's growth into new markets and provide current customers with a broader product offering."

Klaas Rozema added, "I am delighted that Dycomet has been acquired by a new owner who understands our industry. Titomic is an excellent complementary fit with our current product set and expertise and can support the next phase of growth, offering a wealth of opportunities for our team. I will continue to lead the business in Europe, and I look forward to working with Herbert to bring the two companies together and ensure the synergies between the two businesses are fully harnessed."

www.titomic.com

www.dycomet.nl

Tekna 'firing on all cylinders' to meet growing demand for AM powders

Tekna Holding AS, Sherbrooke, Quebec, Canada, reported its financial results for the third quarter 2021, recording revenue of CAD $5.6 million, down from CAD $6.5 million in Q3 2020. Materials revenue in the quarter grew 10% from Q3 2020, with 77% of sales generated from recurring customers. Total order backlog stood at CAD $12 million, of which CAD $8 million came from materials. Adjusted EBITDA for the third quarter stood at CAD $-1.3 million, compared to breakeven in Q3 2020 due to a CAD $1 million federal emergency grant received in that quarter.

"While Tekna's Systems revenue posted a decrease in the quarter, the outlook for Additive Manufacturing, which accounts for approximately 60% of Tekna's total revenue, remains strong and we're firing on all cylinders to get production capacity up to meet accelerating demand," stated Luc Dionne, Tekna Holding's Chief Executive Officer. "Tekna began operating an additional plasma system in the third quarter that, along with productivity improvements, will increase capacity by 25%."

Tekna is also pursuing negotiations to lease a production facility in Sherbrooke, Canada, which would provide capacity of up to 25 tons of powder annually by 2023.

Dionne added, "The EV and 5G markets are booming, which is driving the demand for Tekna's nano-size silicon and nickel powders. Therefore, we have initiated discussions with several major silane manufacturers to secure our long-term supply."

Also in the third quarter, Tekna launched its PlasmaSonic systems product line of plasma wind tunnels and integrated diagnostic solutions, targeting civil aviation in the orbital space and hypersonic flight industry, which has an estimated size of CAD $270 billion.

"Leveraging our thirty years of expertise in plasma energy and system design, Tekna PlasmaSonic solutions is able to recreate, on Earth, the wide range of extreme temperatures and pressures experienced by spacecrafts travelling in the stratosphere, at over five times the speed of sound. It is an exciting new segment for us in a rapidly developing industry, in which we see an estimated revenue potential of up to CAD $250 million over the next ten years."

www.tekna.com

Desktop Metal triples manufacturing capacity for Production System P-50

Desktop Metal, Inc., Boston, Massachusetts, USA, has announced the opening of a new in-house manufacturing facility that will more than triple the final assembly space currently dedicated to its Production System™ metal Additive Manufacturing machines. This new facility is said to be part of a strategic plan to accelerate the production of its flagship Production System P-50 machine, with initial builds targeted for shipment in the fourth quarter of 2021.

"After a significant development cycle, we are experiencing growing, pent-up demand for our Production System P-50 solution," stated Ric Fulop, CEO of Desktop Metal. "As we continue to convert these opportunities, expanding our in-house final assembly capabilities has become a critical step to scaling deployment of our Single Pass Jetting technology."

"This new facility in Massachusetts, in conjunction with our contract manufacturers and suppliers, supports our ability to meet growing demand for high-volume applications," he continued. "We are now well-positioned to supply our global customers with the fastest metal 3D printing platform to enable cost-effective mass production via Additive Manufacturing."

The Production System P-50 is an industrial-scale manufacturing platform utilising Desktop Metal's Single Pass Jetting™ technology. The company's Binder Jetting (BJT) process is claimed to offer production quantities of up to millions of parts per year, at costs competitive with conventional mass production techniques. The P-50 features a print bar with native 1200 dpi, an inert processing environment and constant wave spreading for print bed uniformity, said to enable the quality, reliability and economics required for high-volume end use applications.

www.desktopmetal.com

The new facility will accelerate the production of its flagship Production System P-50 AM machine (Courtesy Desktop Metal)

6K Additive acquires Specialty Metallurgical Products

6K Additive, a division of 6K, headquartered in North Andover, Massachusetts, USA, has acquired Specialty Metallurgical Products (SMP), based in Red Lion, Pennsylvania. SMP specialises in titanium and zirconium tablets used as a grain refiner for the metal alloys market. The terms of the acquisition were not disclosed.

The acquisition is said to augment 6K Additive's existing line of Ty-Gem compacts used in similar applications and markets. The new product enables 6K Additive to expand its commercial relationships into both new and existing companies for titanium customers while developing new applications and customers for zirconium additives.

"We have over twenty years of experience supplying our Ty-Gem grain refining products to the aluminium industry," commented Frank Roberts, president of 6K Additive. "Adding SMP's titanium products to our portfolio will complement our existing offering while enhancing our expertise in the process. The acquisition will also add an entire new product line to our current portfolio in zirconium tablets. The quality products SMP brings to 6K Additive enables us to go broader and deeper with our customers providing a quality, sustainable alloying solution no other company in the world can offer."

Jim Clark, former president of SMP and now a strategic advisor for 6K Additive, stated, "We have a long history of supplying the top end of titanium additives to the industry and have established SMP as the leading supplier of zirconium. Becoming part of the 6K Additive team ensures our customers are provided with the same quality product, but backed by a larger organisation that has the logistics and operational infrastructure to support our rapid growth."

Gary Hall named new CFO

In October, 6K also announced the appointment of Gary Hall as Chief Financial Officer. Hall will oversee all financial aspects of the company, including financial planning & analysis, financial reporting, accounting & control, tax, and treasury. Hall will also be responsible for both the HR and IT strategies, staffing and implementation for the company. He will report directly to 6K's CEO Dr Aaron Bent.

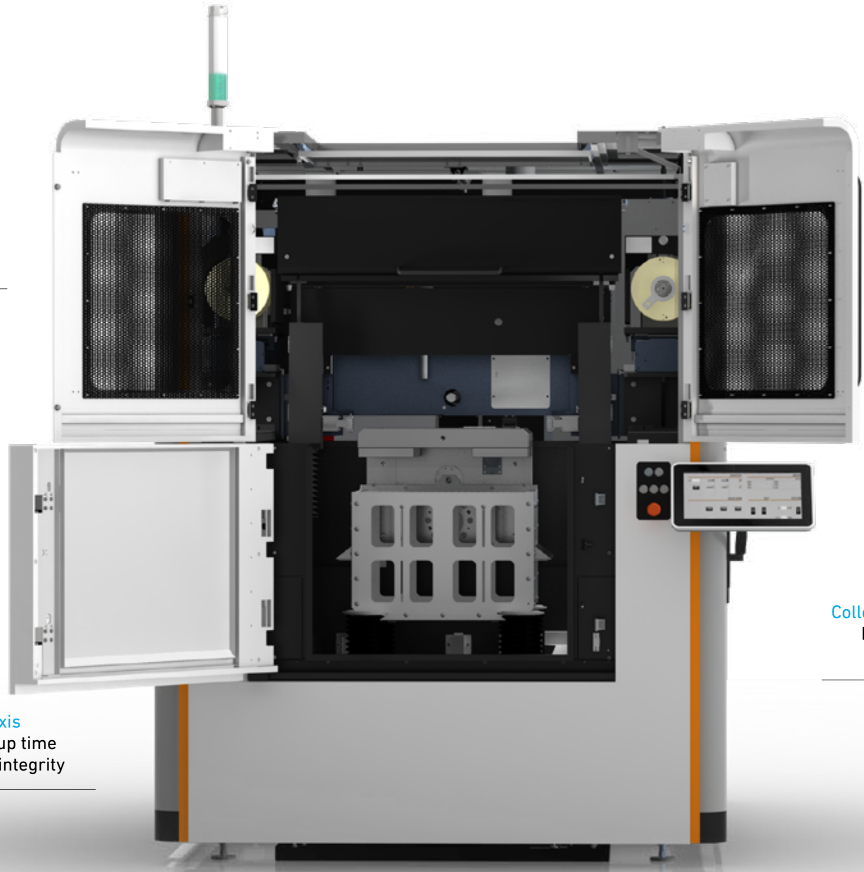
www.6kinc.com

GF Machining Solutions

+GF+

CUT AM 500

Unique EDM separation of AM parts



Cutting rate	Total leadtime*	Total Cost of Ownership	Total Cost of Ownership*
3-4x faster than standard EDM	3-4x faster than a bandsaw	3x cheaper than standard EDM	4-6x cheaper than a bandsaw

These figures are based on real case studies with various geometries printed in maraging steel, nickel alloy and titanium.
* including building process

Learn more at
www.gfmsadditive.com

Additive Industries introduces new MetalFABG2 AM machine series

Additive Industries, Eindhoven, the Netherlands, unveiled its new MetalFABG2 series metal Additive Manufacturing machine at Formnext 2021. Along with a number of AM solutions that included MF Calibrate for automated multi-beam qualification, and Additive Studios for consultancy services, the company also announced partnerships with Makino, Sigma Labs and Materialise.

The new MetalFABG2 series is reported to double productivity compared to previous models and includes over 150 updates. It features optimised gas flow, optimised heat management, updated process parameters and automated beam quality measurements. The AM machine is Sigma Labs PrintRite3D ready and is available in three versions: Core, Automation and Continuous Production.

The MF Calibrate is a multi-beam qualification tool to ensure repeatable and predictable output. The tool automates the procedures for each beam, saving precious time. A normal manual procedure for beam quality validation for multi-laser systems can take up to a day. With this tool, it reportedly takes less than an hour.

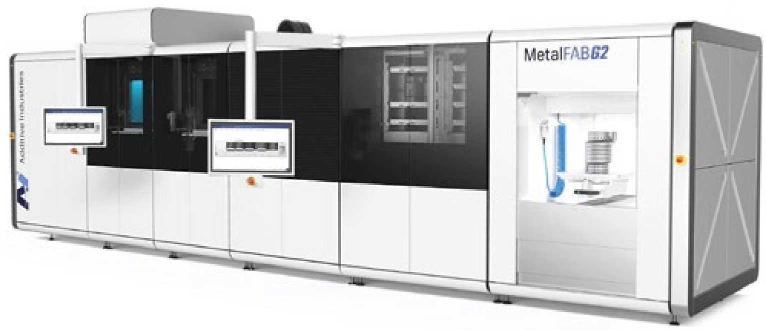
From its offices in Bristol, UK; Los Angeles, USA; Eindhoven and Singapore, Additive Studios provide services in the field of applications, design for AM, optimising build strategies, process parameters and material development, production optimisation and post-processing methods.

Additive Industries' partnership with Sigma Labs to realise PrintRite 3D integration of Melt pool monitoring (Beta). PrintRite3D® is a real-time melt pool analytics and monitoring solution that reduces waste, improves throughput and enables faster product development and part qualification. With the use of in-process meltpool monitoring, it is easier to analyse additively manufactured parts by reducing or completely avoiding post analysis using destructive testing or CT scanning. This integration is especially interesting for large and massive parts, giving indications of potential errors during production. It may become part of future qualified production processes, automating the quality control per part.

Additive Industries partnered with Materialise to develop workflow improvements, which included an update of the Build Processor, V2.6. It is now capable of slicing bigger data and offers double faster processing. Furthermore, this version is capable of processing e-Stage-support by creating e-stage on slicing and is optimised for use with the Additive Industries Dynamic Laser Assignment Tool. In addition, Additive Industries entered a partnership with Makino, a machinery equipment manufacturer and digital innovation specialist, to develop end-to-end AM solutions.

"We are excited to launch this broad array of new solutions and services, which underline our ambition to provide the next generation in productivity leadership," stated Ian Howe, CEO at Additive Industries. "One of the most exciting aspects of Additive Manufacturing is the versatility of the technique. Applications can be found in almost every industry, in parts that range from simple brackets to complex assemblies with moving parts and many integrated functions. With our services and solutions, we ensure our partners are able to utilise AM to the fullest."

www.additiveindustries.com



Additive Industries new MetalFABG2 metal Additive Manufacturing series (Courtesy Additive Industries)

Desktop Metal acquires Meta Additive

Desktop Metal, Inc., Boston, Massachusetts, USA, has purchased Meta Additive Ltd., Stoke-on-Trent, Staffordshire, UK. Meta Additive was founded in 2019 at the University of Liverpool with the goal of entering the Additive Manufacturing industry from a scientific, rather than engineering, perspective.

Earlier this year, the company was awarded the Innovate UK SMART Grant for its Binder Jetting (BJT) process, which leverages the benefits of BJT whilst further improving its suitability for mass manufacturing. Meta Additive's technology utilises a binder that simultaneously binds and infiltrates the pores between the powder bed, with organometallics and particles of functional build material – hierarchical binders – in place of sacrificial binders.

"This revolutionary binder IP has the potential to reduce part shrinkage during sintering, enabling larger parts, improved tolerances, and increased productivity," stated Ric Fulop, founder and CEO of Desktop Metal.

www.meta-additive.com
www.desktopmetal.com

Ready to Help You Scale

While the world is busy imagining the future of additive manufacturing, Burloak is living it.

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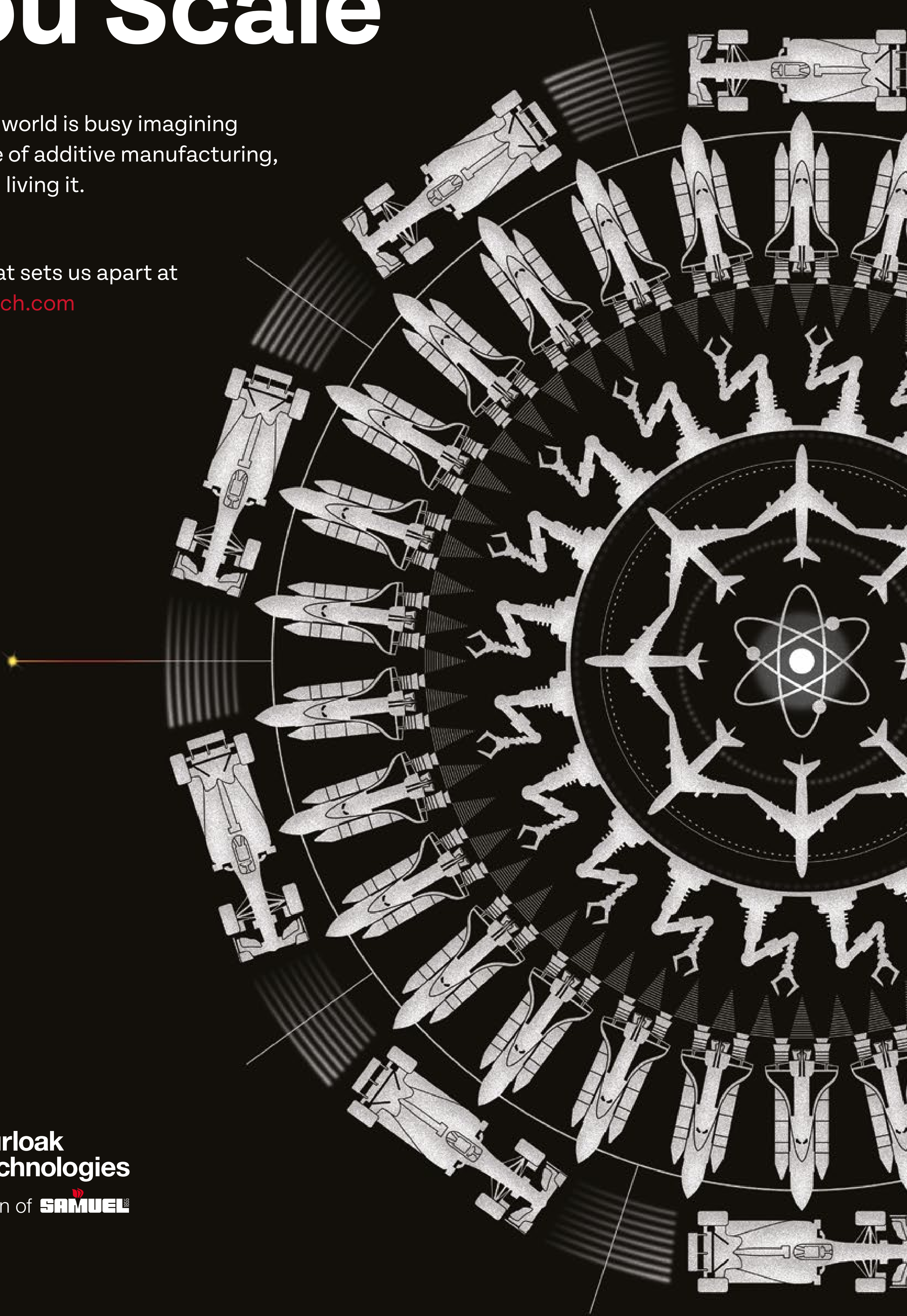


Burloak Technologies

a division of SAMUEL

Conflux Technology secures AUS $8.5 million in investment round

Conflux Technology, Geelong, Australia, has secured Series A investment round funds from two investors – Germany's AM Ventures and Australia's Acorn Capital, both known for their investments in AM businesses – totalling AUS $8.5 million.

"The investments will enable us to significantly increase our capacity and capability," stated Michael Fuller, CEO and founder, Conflux Technology. "We will be increasing the number of metal AM machines and investing in the latest series-production platforms, continuing to grow our team and furthering our vertical integration with final post-processing of parts. Our transformation from research and development to a fully-fledged production facility is now in action. It's exciting to be able to advance our offering and expedite long-held plans."

These investments are said to recognise Conflux's continued innovation in the design and application of AM heat exchanger technology. Following seed funding from AM Ventures in 2017, Conflux has serviced a geographically diverse customer base with its industry reach covering aerospace/aviation, microelectronics, automotive/motorsport and sustainable energy.

Ben Dalling, Portfolio Manager at Acorn Capital added, "Acorn is thrilled to be partnering with Conflux Technology. We have a long history of investing in and supporting technology and advanced manufacturing in Australia, and Conflux is a world leader in Additive Manufacturing of heat exchangers – a critically important technology across many industries, from aerospace to computing. We are very excited to be part of the Conflux story going forward."

Arno Held, Managing Partner at AM Ventures stated, "Heat exchangers are one of the biggest applications in 3D printing. Highly complex geometries enabling more efficient thermal management in order to reduce energy consumption and waste of materials require highly qualified experts who are capable of mastering the best manufacturing technologies and software tools. This is exactly what makes the Conflux team unique in this world."

Fuller concluded, "We are thrilled to have partnered with such experienced and successful investors. Both Acorn and AM Ventures have enviable track records in accelerating businesses to scale and enabling transformative technologies that have positive impacts on our world. We look forward to a very exciting next chapter in Conflux's journey."

www.confluxtechnology.com

Sandvik increases metal powder production capacity for AM

Sandvik AB, Stockholm, Sweden, has expanded its metal Additive Manufacturing powder production capacity by installing two additional atomisation towers at its production site in Neath, Wales, UK. This expansion follows a recent investment in a new plant for the manufacturing of titanium and nickel-base alloys for AM, in Sandviken, Sweden.

Sandvik offers a wide range of metal powders for AM, including titanium, stainless steel, duplex- and super-duplex steels, nickel-base super alloys, aluminium, copper, and more. The alloys are all atomised in-house and tailored to meet the needs of customers in demanding industries.

"Sandvik offers extensive capabilities in terms of providing high-quality and consistent metal powders, to customers engaged in a range of additive manufacturing processes such as Laser Powder Bed Fusion [PBF-LB], electron beam melting [Electron Beam Powder Bed Fusion, or PBF-EB], and Binder Jetting (BJT)," stated Annika Roos, Business Unit Manager of Sandvik's metal powder business. "By installing these new atomisation towers – one of which is already fully operational and quality assured, while the other is under construction – we bring our total tower count to twelve, and thereby significantly increase our ability to produce even larger quantities of premium metal powders."

While much attention in the AM arena focuses on revolutionary designs, innovation on a material level is equally important. With its wide range of Osprey® metal powders, Sandvik states that it has the in-house capability to produce the market's broadest portfolio of alloys and the metallurgical knowledge to customise the best suited material for each application and AM process technology.

Roos added, "Materials technology is very much integrated with Sandvik's DNA. From our own AM service business, we have first-hand experience of printing in a wide range of materials for Additive Manufacturing – from tool steels and duplex steels to titanium and super alloys for high-temperature applications – and understand the importance of using premium raw materials in order to obtain an optimal end result. Gearing up our manufacturing capacity means we are now even better positioned to meet the increased demand in terms of metal powders for AM."

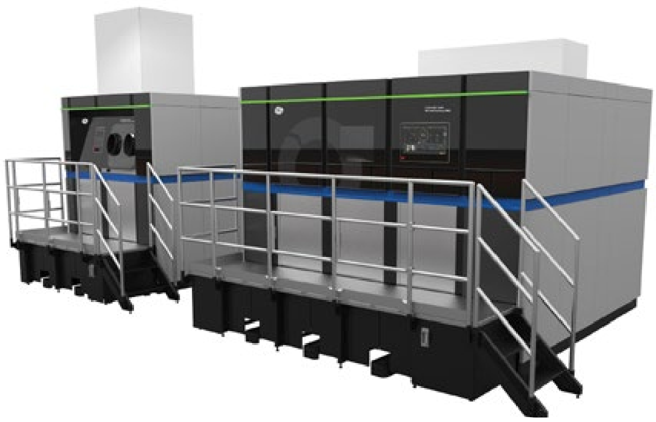
The quality management system of the powder manufacturing facility in Neath is certified in accordance with AS9100D, ISO 14001, ISO 45001, ISO 50001, and ISO 9001. In addition, Sandvik's production site for titanium and nickel-base alloys in Sandviken, Sweden, is also ISO 13485 certified for deliveries to the medical segment.

www.home.sandvik/en

GE to form three public companies focused on aviation, healthcare and energy

GE has announced its plan to form three independently run global public companies, focused on the growth sectors of aviation, healthcare, and energy. The company intends to establish a tax-free spin-off of GE Healthcare, creating a pure-play company at the centre of precision health in early 2023. It will combine GE Renewable Energy, GE Power and GE Digital into one business, creating a tax-free spin-off in 2024. Following these transactions, GE will become an aviation-focused company.

"At GE, we have always taken immense pride in our purpose of building a world that works. The world demands – and deserves – we bring our best to solve the biggest challenges in flight, healthcare, and energy," stated H Lawrence Culp, Jr, GE chairman and CEO. "By creating three industry-leading, global public companies, each can benefit from greater focus, tailored capital allocation, and strategic flexibility to drive long-term growth and value for customers, investors, and employees. We are putting our technology expertise, leadership, and global reach to work to better serve our customers."



GE Additive's Concept Laser M Line offers a modular machine architecture that enables economical series production on an industrial scale (Courtesy GE)

"Today is a defining moment for GE, and we are ready. Our teams have done exceptional work strengthening our financial position and operating performance, all while deepening our culture of continuous improvement and lean. And we're not finished – we remain focused on continuing to reduce debt, improve our operational performance, and strategically deploy capital to drive sustainable, profitable growth," Culp continued. "The momentum we have built puts us in a position of strength to take this exciting next step in GE's transformation and realise the full potential of each of our businesses."

Culp will serve as non-executive chairman of the GE healthcare company upon its spin-off. He will continue to serve as chairman and CEO of GE until the second spin-off, at which point he will lead the GE aviation-focused company going forward. Peter Arduini will assume the role of president and CEO of GE Healthcare effective January 1, 2022. Scott Strazik will be the CEO of the combined Renewable Energy, Power, and Digital business, while John Slattery will continue as CEO of Aviation.

The transactions are subject to the satisfaction of customary conditions, including final approvals by GE's Board of Directors and satisfactory completion of financing.

www.ge.com

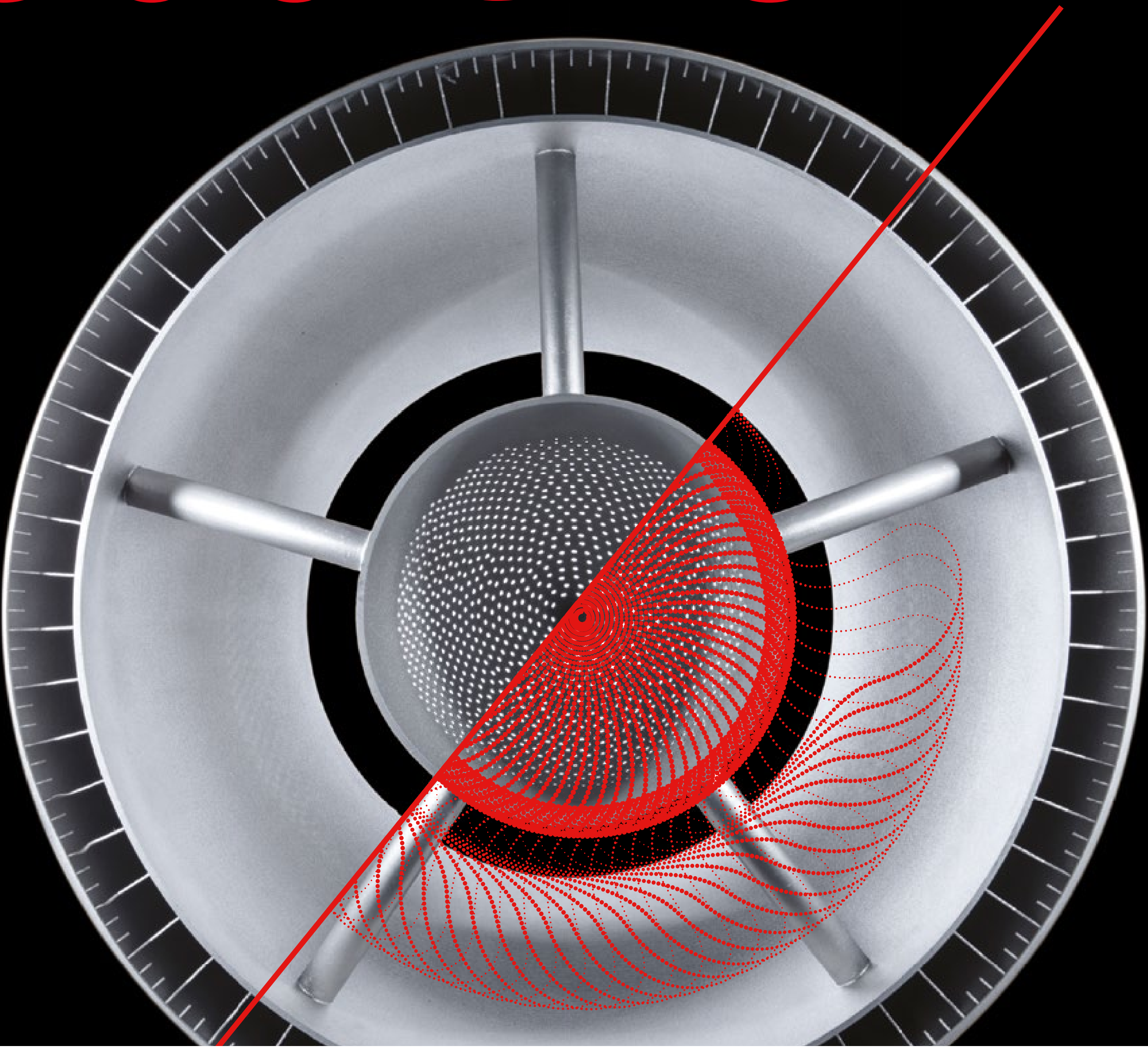
AML3D enters aerospace sector

AML3D Limited, Edinburgh, Australia, has additively manufactured a high-strength alloy part for a leading North American aerospace company. The order sees AML3D enter the supply chain for one of its key target sectors for the first time. The bespoke prototype was manufactured from a high-strength, corrosion-resistant alloy using WAM® – also known as Wire Arc Additive Manufacturing (WAAM), a wire-based form of Directed Energy Deposition (DED). AML3D reports it was selected for this project due to the high strength and robust properties associated with the WAM process. The order is also a key element of AML3D's strategy of expansion into the North American market.

"To have secured a key purchase order for prototype with a globally recognised space exploration company is further validation of our technological capability at AML3D," stated Andrew Sales, AML3D Managing Director. "AML3D was identified for the provision of a specialty part that is manufactured by our peerless WAM 3D printing technology. The special alloy that will form the makeup of this part is unique to AML3D's products and we look forward to supplying companies in the aerospace sector for years to come."

He added, "I am confident that the momentum generated from this new aerospace purchase order will deliver a strong pipeline of opportunities in global space exploration part production both here in Australia and internationally, as we continue to demonstrate our capabilities to companies within this particular sector. AML3D has the desire and expertise to play a significant role in this burgeoning industry."

www.aml3d.com



HP announces commercial availability of its Metal Jet AM machine in 2022

HP has confirmed it intends to move towards broader commercial availability of its Metal Jet Additive Manufacturing machine in 2022, as it continues to validate production applications with partners and customers.

"3D printing is unlocking new levels of personalisation, business resiliency, sustainability, and market disruption," stated Didier Deltort, president of Personalization & 3D Printing, HP Inc. "Together with our partners and customers, we will continue to pave the path to mass production with advancements to our Multi Jet Fusion platform, the commercial launch of HP Metal Jet, and investments in software, services, and partner capabilities."

HP displayed a number of new parts built on its Metal Jet platform at Formnext 2021, where it highlighted progress with partners such as GKN and Volkswagen. Volkswagen is integrating HP Metal Jet produced final parts for the A pillar of its T-Roc convertible. The structural parts were reported to have passed crash test certification and weigh almost 50% less than conventional components.

"Our early Metal Jet partners and customers such as GKN, Parmatech, Volkswagen, Cobra Golf, and others, are successfully demonstrating our metals mass production advantage," commented Ramon Pastor, Global Head of HP's 3D metals business. "As we continue to advance our technology, materials, and capabilities, we remain on track to launch in 2022. We look forward to delivering industry leading efficiency, cost savings, and design freedom to help the industry accelerate and scale digital manufacturing."

www.hp.com/go/3Dmetals

HP has confirmed it intends to move towards broader commercial availability of its Metal Jet AM machine in 2022 (Courtesy HP)

Essentium to become public company following merger with Atlantic Coastal

Essentium, Inc, Austin, Texas, USA, reports that it will become a public company following a definitive business combination agreement with Atlantic Coastal Acquisition Corporation. Upon completion of the transaction, expected to occur at the end of Q1 2022, the combined company will retain the Essentium name and is expected to be traded on The Nasdaq Stock Market, LLC, under the ticker symbol ADTV.

Founded in 2013, Essentium manufactures and delivers industrial Additive Manufacturing machines, materials, software and services. The company has an extensive IP portfolio across polymer and metal systems, processes and materials, with more than 150 patents to date. It is developing a suite of metal AM machines designed to offer unique metallurgies and advanced microstructures for applications with demanding structural integrity.

Atlantic Coastal Acquisition Corp is a special purpose acquisition company, and following the merger the combined company is expected to have an implied pro forma enterprise value of $974 million, including $346 million in cash on the balance sheet, assuming no redemptions and net of transaction expenses. All proceeds are expected to primarily fund organic growth initiatives. The transaction includes $345 million cash held in trust by Atlantic Coastal as well as a fully committed common stock PIPE of over $40 million anchored by strategic and institutional investors including BASF, Atalaya Capital Management LP and Apeiron Investment Group, the private investment firm of entrepreneur and investor Christian Angermayer.

"Today's announcement represents a major milestone in our efforts to provide long-term, sustainable solutions for a new manufacturing paradigm that can meet these global challenges head-on," stated Blake Teipel, PhD, Chief Executive Officer of Essentium.

Following the closing of the proposed transaction, Essentium will continue to be led by its existing management team including Dr Blake Teipel, Lars Uffhausen, and Jonathan Bailiff, and by an experienced board of directors including Burt Jordan, president of Atlantic Coastal Acquisition Corp. and a former executive at Ford.

www.atlanticcoastalacquisition.com
www.essentium.com

GE Additive and Wichita State partner to accelerate AM in US Department of Defense

GE Additive and Wichita State University's National Institute for Aviation Research (NIAR), Kansas, USA, have signed a non-binding Memorandum of Understanding (MoU). This aims to act as the cornerstone of a new collaborative effort aimed at supporting the US Department of Defense's (DoD) accelerated adoption of metal Additive Manufacturing technology.

Additive Manufacturing has grown within the commercial and military aerospace and defence sector over the past decade and, in that time, GE and Wichita State's NIAR have worked closely with the DoD, Federal Aviation Administration (FAA), and other stakeholders to accelerate safe adoption of AM for highly critical applications.

"Based on our experience with NIAR's material qualification capabilities and how they complement our work at GE Additive, we realised the benefits of putting our relationship with NIAR on a more formal footing," added David Handler, General Manager – Government Business at GE Additive. "We visited the team at Wichita to see their facilities firsthand, and that accelerated our discussions to determine how we can bring our complementary abilities to bear for the warfighter."

The partnership aims to accelerate metal AM adoption within the military aerospace and defence industrial base by advocating for common practices, rapid qualification and certification, and the development of a shared database for AM data and knowledge. Both organisations are said to have been recognised by the DoD as industry leaders: NIAR in developing digital twins of various ageing vehicles, and GE Additive in providing technology to additively manufacture out-of-production and obsolete spare parts from digital twin data.

"GE has been doing this for a long time, and they have cracked the Additive Manufacturing code. You can see it in their data and process control," stated John Tomblin, Wichita State's senior vice president for Industry and Defense Programs and NIAR executive director. "The real beauty about this partnership is bringing the knowledge of the two sides together to advance AM technology to benefit the DoD. The time is now."

"NIAR's material database capabilities are an important asset needed to build a comprehensive, secure, accessible, standard format for materials data that all depots can use," said Handler. "GE Additive and NIAR aim to establish an industry platform that is flexible enough to be used across all branches of the DoD. The partnership will accelerate the DoD's desire to go from old metal to digital, and then supply needed spare parts by going from digital back to new metal."

Rachael Andrulonis, NIAR Senior Research Engineer for Composites and Advanced Materials, added, "It is critical that the platform provides quality specifications and material allowables that are naturally integrated into DoD processes and readily available and accessible across the DoD and to its industry partners, when permitted."

Development of the database will also involve the implementation of students in an applied learning capacity, enabling a new workforce that understands AM qualification and implementation.

In order to be an efficient and relevant resource, GE Additive and NIAR plan to move quickly; the partnership and involvement of student employees are expected to allow the team to rapidly develop specifications to convert metal to digital and digital to metal – part by part.

"GE realises the importance of investment in these platforms," added Handler. "It correlates directly: the broader the scope of parts, the broader the scope of the partnership, the broader scope of sustainment solutions for the warfighter."

www.ge.com
www.witchita.edu

Renishaw adds two machines to RenAM 500 range


The RenAM 500Q Flex (Courtesy Renishaw)

Renishaw, Wotton-Under-Edge, Gloucestershire, UK, launched a new range of Additive Manufacturing machines, based on its RenAM 500 range, at Formnext 2021: the RenAM 500S Flex, a single-laser AM machine, and the RenAM 500Q Flex, a four-laser AM machine, which underwent beta testing at the DMC. Both machines feature a simplified powder handling system said to be well suited to manufacturers who must regularly swap build materials during production, such as research and development, pre-production or bureau environments.

The range features the same optical, chamber and gas-flow designs as the RenAM 500 series and produces the same quality parts, but provides additional flexibility when changing powders. The simplified, non-recirculating powder system enables manufacturers to more easily change between materials, without compromising on part quality or build capacity. To avoid cross contamination, engineers clean the system between powders by changing out hard-to-clean parts, rather than investing in a new machine for each material test. Parts can also be swapped in again if the operator wants to retest a material.

"Manufacturers can quickly change powders in the RenAM 500S Flex and RenAM 500Q Flex in-house, giving them the flexibility they need to meet customer demand," stated Lily Dixon, AM Project Manager at Renishaw. "Once the pre-production stage is complete, the common build environment allows any parameters to be directly transferred to a RenAM 500Q with powder recirculation, without the need to retest the gas flow, chamber and optics. Manufacturers can also build full-size parts on a small scale before mass production."

"If the manufacturer no longer requires a flexible AM system, the Flex can even be converted into a recirculating machine – a feature that is unique to this system. Converting the system provides manufacturers with the highest productivity AM option for serial production," Dixon concluded.

www.renishaw.com

Schunk to offer Additive Manufacturing series production from ExOne

Following the recent purchase of an X1 25Pro from The ExOne Company, North Huntingdon, Pennsylvania, USA, Schunk Group, headquartered in Heuchelheim, Germany, has announced that it will integrate metal Binder Jetting (BJT) Additive Manufacturing into its existing series production technologies. Depending on the component, application and quantity, Schunk customers can now choose between metal BJT, Metal Injection Moulding and press & sinter Powder Metallurgy.

Prior to the integration of BJT, Schunk Sinter Metals production quantities started at 100,000 units from its location in Thale, Germany. With the increasing move away from the traditional Internal Combustion Engines (ICEs) and the shift to new types of drive, production quantities may vary. The company's aim is to increase its flexibility in testing and production with both new and existing series equipment and facilities, and to be able to produce new geometries for any type of drive.

"If we still want to be an attractive development partner tomorrow, we have to use and further develop technologies that move our customers forward," stated Tobias Heusel, Global Account Manager, Schunk Mobility. "We can no longer do this with our existing sintered metal components for combustion engines alone. That's why we want to integrate innovative 3D printing technologies into our existing series production and open up new applications and markets with new products."

Eric Bader, Managing Director, ExOne GmbH, added "The combination of our strength in Binder Jetting and Schunk's extremely sound understanding of Powder Metallurgy and sintering experience creates exactly the intersection that is needed to be a sustainable partner and supplier to future customers together. It takes a fair amount of vision to enter 3D printing here and now. Schunk is clearly demonstrating its commitment to new developments."

In the future, Schunk intends to continue to focus on automotive and aerospace markets. In addition, it is expected that AM will bring increased flexibility, thus opening the possibility of producing complex components for a wide range of industries. There is already interest reported from a machine manufacturer, for example, but components for the consumer sector, for white goods or the medical industry are also conceivable.

www.exone.com
www.schunk-group.com

Schunk Group has purchased an X1 25Pro metal Binder Jetting machine (Courtesy ExOne)

API publishes AM standards for natural gas and oil industry

The American Petroleum Institute (API) has released the first edition of its Standard 20S, Additively Manufactured Metallic Components for Use in the Petroleum and Natural Gas Industries. These standards, reported to be the first published for AM in the oil and gas industry, aim to bring critical manufacturing functions closer to where components will be used while maximising production capability and reducing supply chain stresses and emissions.

Key features of Standard 20S include requirements for qualification in the manufacturing, production, marking and documentation of metallic components manufactured using Additive Manufacturing. It includes the introduction of three AM specification levels that define technical, quality and qualification requirements to help ensure that metal AM components produced are fit for purpose. In addition, the standard lists requirements for training, inspection, monitoring and measuring equipment, as well as materials testing, acceptance and quality control of final products.

"This new standard expands API's best-in-class safety and efficiency requirements and supports cutting edge operations, helping producers to deploy new 3D printing technologies to meet rising global demand for natural gas and oil products," stated Alexa Burr, vice president for Global Industry Services, API.

Standard 20S is intended to reflect the natural gas and oil industry's focus on new technologies and innovations to meet the rising global demand for energy while protecting the environment. Burr has stated that the ability to use innovation and deploy cutting-edge technologies is one of the pillars in API's Climate Action Framework, which details the industry's commitment to protecting the environment by reducing carbon emissions.

www.api.org

Digital Metal adds low-alloy steel and superalloy to range of BJT materials

Digital Metal, part of Sweden's Höganäs Group, has added DM 4140 low-alloy steel and DM 718 nickel-chromium-base superalloy to the range of materials that can be processed on its Binder Jetting (BJT) AM machine. Other materials in the range already include pure copper DM Cu, stainless steel 316L and 17-4PH, tool steel DM D2, superalloys DM 625 (equivalent to Inconel 625) and DM 247 (equivalent to MAR M247), and titanium Ti6Al4V.

Control Finger for automotive gear boxes, binder jetted with DM 4140 and shown here in a green state (Courtesy Digital Metal)

DM 4140, a low-alloy steel powder, was developed within Hyundai Motors in order to manufacture gearbox Control Fingers using BJT. By adding carbon steel to its BJT technology, Digital Metal is said to have expanded its offer of tool-free design freedom, shortened lead times, and potential weight savings. The material is additively manufactured with an ink that is commonly used for other steel and nickel-base alloys, although the process has been modified to reach properties that are consistent with Metal Injection Moulding (MIM) standards (ISO22068). By alternatively applying quenching and subsequent tempering treatment in an as-sintered state, tensile properties may be tuned toward application requirements.

Low-alloy steel components, manufactured by MIM, have been used in general engineering and automotive manufacturing since the early 1980s. Its strength, toughness, and resistance to deformation during quenching are said to have made DM 4140 a popular grade. DM 4140 is well suited to producing components exposed to high loads, such as gear wheels, connecting rods, fasteners, couplings, gears, belt pulleys and shafts. With adjustment to curing conditions, DM 4140 is also available as a turnkey solution for customers who already have Digital Metal systems processing other steels and superalloys.

DM 718 is a nickel-chromium-based precipitation-hardening superalloy, reportedly equivalent to UNS N07718 (Inconel alloy 718). It is said to offer high strength, as well as creep and corrosion resistance, in cryogenic and elevated temperatures (up to about 650°C). This alloy composition is thought to be the most used nickel-chromium superalloy in metal AM, in addition to being one of the most commonly used superalloys overall.

The alloy can be strengthened using industry-standard treatments, consisting of solution annealing and quenching, followed by ageing steps.

www.digitalmetal.tech

Sandvik to list Sandvik Materials Technology in 2022, appoints first members of SMT Board

The Sandvik Board of Directors has confirmed its previous decision to proceed with the preparation to distribute Sandvik Materials Technology (SMT) to Sandvik's shareholders and list the company's shares on the Nasdaq Stockholm Exchange. The board's current target is to complete the listing during the second or third quarter 2022, subject to approval by Sandvik's shareholders.

"The internal separation of SMT is proceeding as planned and the previously communicated reasons for a distribution and listing remain relevant. We believe that both Sandvik and Sandvik Materials Technology can develop more favourably on their own," stated Johan Molin, chairman of the Sandvik Board of Directors.

The Sandvik Board intends to formally propose the distribution and listing of SMT at a shareholders' meeting next year. As part of this process, the Sandvik Board of Directors has appointed Andreas Nordbrandt as chairman of the board of SMT. Additionally, Claes Boustedt and Karl Åberg have been appointed as members of the SMT Board of Directors. Additional members of the SMT Board will be appointed at a later stage to fulfil any requirements and ensure a suitable board composition.

Nordbrandt is a member of the Sandvik AB Board of Directors. He has operative experience from a global industrial environment, particularly within international mining. He previously worked at Atlas Copco Group and Epiroc Group from 1995–2018.

Boustedt is a member of the Sandvik AB Board of Directors, as well as chairman of the Audit Committee. He has been executive vice president of LE Lundbergföretagen AB since 1997, and president of LE Lundberg Kapitalförvaltning AB since 1995.

Åberg has been Head of Investments and Analysis at Industrivärden AB since 2017. His previous experience includes being a partner at Zeres Capital, where he was also a co-founder, and partner at Capman Public Market.

www.home.sandvik/en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VBN celebrates opening of new facility

VBN Components, Uppsala, Sweden, celebrated the opening of its previously announced new premises on November 10, 2021. While the inauguration was postponed due to the COVID-19 pandemic, the move took place in the spring of this year as a response to growing customer demand. The new facility is three times larger than its previous premises, and is expected to enable the increase of production capacity and a more streamlined workflow. As well as the additional space, VBN has already expanded its personnel and plans to add more machines in the coming months.

VBN offers six unique metal powders for AM under the Vibenite name. Compared to traditional materials, these are reported to enable increased performance and significantly improve the lifetime of a component.

Johan Bäckström, CEO, stated, "It feels good that we can finally inaugurate our new, spacious and production-adapted premises together with our partners, and that it coincides with the fact that we have received new serial production orders."

www.vbncomponents.se

Pometon establishes PometonPlus for metal AM powders; joins Dubai 3D Printing Strategic Alliance

Pometon S.p.A., headquartered in Maerne, Venice, Italy, has established PometonPlus, a new business division specialising in the production of metal powders for Additive Manufacturing.

Founded in 1940, Pometon is a manufacturer of metal powders for the automotive, chemical, aerospace and electronics industries, offering a wide range of ferrous and non-ferrous powders, as well as stainless steel abrasives. The company believes that Additive Manufacturing is one of the most promising sectors and, in order to satisfy this trend and meet the needs of its clients, Pometon decided to invest and start producing metal powders specifically for AM.

PometonPlus aims to begin production of new spherical powders for AM towards the end of 2021. Powders will initially belong to six major product families, including:

- Copper and copper alloys
- Steel, stainless steel and alloys
- Cobalt-chromium and alloys
- Nickel-chromium and alloys
- Titanium and titanium alloys
- Aluminium and aluminium alloys.

Pometon metal powders selected for Dubai's 3D Printing Strategic Alliance

Pometon also announced it has been selected to be part of the 3D Printing Strategic Alliance for Dubai, launched in 2020 by HH Sheikh Hamdan Bin Mohammed Bin Rashid Al Maktoum, Crown Prince of Dubai, Chairman of the Executive Council, Chairman of the Board of Trustees at Dubai Future Foundation.

The alliance is made up of a network of institutions around the world, including government entities, academia and AM companies, involved in developing innovative solutions and strategies to accelerate the adoption and use of Additive Manufacturing technology, and aims to offer a wide range of products, supplies and services in vital sectors to meet market needs and achieve self-sufficiency, supporting government, economic, healthcare and scientific sectors worldwide.

Following the establishment of PometonPlus, the company will produce metal powders for use in a new AM machine being developed by the alliance for medical and dental applications.

www.pometon.com

Hyperion Metals to acquire Blacksand Technology

Hyperion Metals, Charlotte, North Carolina, USA, has executed a one-year option to acquire Blacksand Technology LLC, West Valley City, Utah. The two companies have been collaborating on an investigation into the commercial development of spherical titanium metal powders.

"The combination of Hyperion and Blacksand Technology is transformational, bringing together two highly complementary organisations, supported by the world-class metallurgical engineering department at the University of Utah, to create a leader in sustainable low carbon titanium metal and powders," stated Anastasios Arima, CEO and Managing Director, Hyperion. "Hyperion's Titan Project in Tennessee will supply low carbon titanium mineral feedstock to produce low carbon, low-cost titanium metal and powders using the HAMR and GSD technologies. We aim to build on Blacksand's strengths in material science and innovation to scale and commercialise these breakthrough American technologies and make the US, once again, the leader in titanium metal."

Since the founding of Blacksand in 2013, it has developed the hydrogen assisted metallothermic reduction (HAMR) technology and developed over forty patents worldwide relating to titanium manufacturing, from the supply chain to specific technologies. Over the years, the company has seen a reported investment of around $12 million into these technologies from government agencies including the Advanced Research Projects Agency – Energy and the Office of Energy Efficiency and Renewable Energy of the US Department of Energy; the National Science Foundation; and the Naval Air Systems Command of the US Department of Defense.

Dr Z Zak Fang, Professor of the University of Utah and founder of Blacksand, added, "Blacksand is excited about the prospects of commercialising its suite of titanium technologies through Hyperion Metals. Hyperion recognises the potential of the breakthrough HAMR process based on a simple and elegant scientific principle to lead the titanium production industry away from the old, energy-intensive, and environmentally-challenging Kroll process. This is a historical opportunity to change how titanium is made with an energy-efficient, potentially zero-emission, and low-cost technology."

www.hyperionmetals.us
www.blacksandtechllc.com

EOS releases new high-strength, lightweight Al2139 aluminium alloy

EOS GmbH, headquartered in Krailling, Germany, has announced the addition of EOS Aluminium Al2139 AM, a new material specifically developed for Additive Manufacturing. The alloy is reported to offer high performance in elevated temperatures up to 200°C, good corrosion resistance and is the highest-strength AM aluminium alloy available from EOS. In its heat-treated state, Al2139 AM achieves a yield and tensile strength of around 500 MPa. Due to a single-step heat treatment procedure, companies can save up to 88% in active heat treatment time, meaning parts can be manufactured faster. Components produced using EOS Aluminium Al2139 AM can also be electropolished and anodised.

EOS Aluminium Al2139 cylinder head on display at the company's stand during Formnext 2021 (Copyright Metal AM)

The combination of lightweight and strength properties of EOS Aluminium Al2139 AM are said to make it suitable for a range of high-performance and demanding applications such as aviation, transportation, racing and the space industries, while also offering flexibility and improved material and production cost management to the contract manufacturing sector.

Sascha Rudolph, Senior VP EOS Metal Materials, stated, "At EOS, we are constantly striving to improve the performance of our customer's manufactured parts, whilst reducing the amount of material needed and streamlining production processes. EOS Aluminium Al2139 AM is a culmination of those efforts to put new materials innovations in the hands of manufacturers."

The EOS Aluminium Al2139 AM material and process parameters for the EOS M 290 are planned for release in the first quarter of 2022, with process parameters for other EOS Laser Beam Powder Bed Fusion (PBF-LB) machines released soon after.

www.eos.info

FreeFORM expands technology offering with addition of MIM services

FreeFORM Technologies, St Marys, Pennsylvania, USA, reports that it has expanded its offering to provide Metal Injection Moulding services, in addition to its metal Binder Jetting (BJT) capacity, thanks to the recent acquisition of two fully automated Arburg Allrounder 320 C injection moulding machines and a vacuum debinding and sintering furnace for MIM and sinter-based AM from Centorr Vacuum Industries.

Founded in 2020, FreeFORM has developed a strong presence in the metal BJT service bureau landscape. In the company's first twelve months of business, it delivered over 45,000 additively manufactured parts to more than twenty-five customers worldwide. "We have seen a great increase in customer and prospect RFQ activity for new and conversion products," stated Nathan Higgins, president of FreeFORM Technologies."FreeFORM strives to operate as a function of the customers' engineering teams, solving their most complex problems. Along with our customers, equipment manufacturers, and powder suppliers, we have helped customers launch products in several new binder jetted materials in 25% of the typical time for traditional manufacturing."

"Volume is a still a recurring question from our customers when it comes to Additive Manufacturing and some still prefer to manufacture high volumes of parts with traditional technologies like Metal Injection Moulding," Higgins continued. "Our goal at FreeFORM is to continue to build on the acceleration of the AM 2.0 movement, but as a customer first business the message was loud and clear, we needed to offer additional technology."

Chris Aiello, vice president of Business Development, FreeFORM Technologies, added, "When we were presented with the opportunity to acquire these assets and the transfer tooling that came along with them, it was a no brainer for us. MIM is a natural fit to complement our existing capacity, plus people know our team as 'MIM guys' from our past roles, so it feels right to add this offering. Over the past twelve months, we have had countless requests from customers to offer MIM. We had explored some alternatives, but, to Nate's point, the writing was on the wall – we needed to offer this to our customers."

www.freeformtech.com


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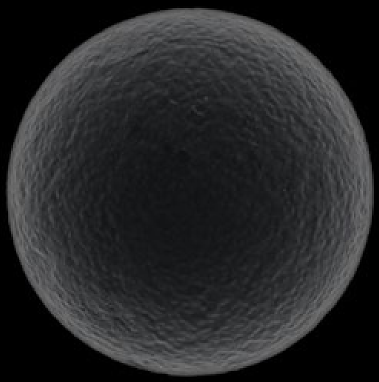

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WWW.CNPCPOWDER.COM

EOS and Grenzebach to strengthen partnership in development of automation processes

EOS GmbH, Krailling, Germany, and Grenzebach Group, headquartered in Hamlar, Germany, have reported a strengthening in their relationship in an effort to advance metal and polymer Additive Manufacturing through the development of efficient, safe and holistic automation processes.

"It is essential for us to further automate and network industrial 3D printing as intelligently as possible with different processes," Dr Marco Nock, Senior VP, Business Unit Systems and Innovation Management, EOS. "For years, we have been appreciating the exchange and cooperation with Grenzebach as our technology partner and now, we will take this next step together."

Since beginning the partnership, a portfolio has been developing which includes automation systems and transport solutions for the respective system platforms. In 2017, the innovation project NextGenAM was established, which aimed to realise the fully automated series production of quality metal components. An aerospace and automotive manufacturer from Baden-Württemberg adopted the automated solution, in which Grenzebach had been involved from the start as a consulting and solutions partner of EOS.

The portfolio was extended during the partnership and is still growing. More machines in the metal sector, such as the unpacking station, were handed over to Grenzebach. These developed solutions were then also applied to the industrial polymer AM sector. The companies, cooperating in both research and customer projects, develop individual configurations and derive process and production solutions to meet the respective requirements of customers. The partnership focuses on the highest possible utilisation of the industrial AM and the accompanying periphery, efficient and robust production processes and high levels of occupational health and safety.

Grenzebach has also extended its own portfolio for industrial AM in the past months; in addition to AM-machine-specific automation and transport solutions, the company developed automatic storage and bin picking & sorting solutions in an effort to further advance the automation of up-and downstream process steps.

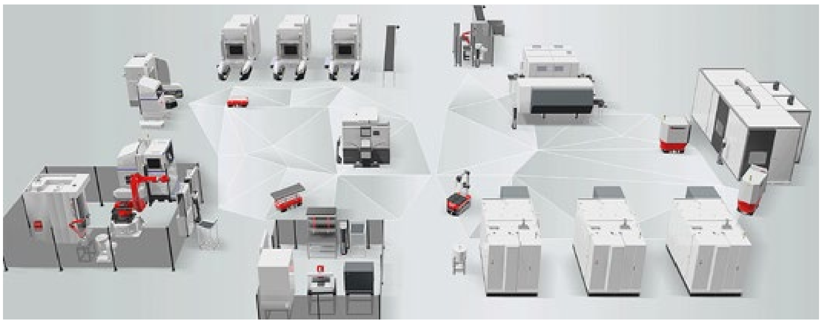
"We have already demonstrated our expertise with automated guided vehicles, robotics and efficient material flow in the automated transport of parts within process chains,", stated Oliver Elbert, Head of Additive Manufacturing at Grenzebach. "In the future, we will also contribute our know-how in further steps of the production process of additive manufacturing. There are still many processes which we have to automate on our way to a lights-out-factory."

The automation of AM has been noted as a clear growth area for the medium-sized Grenzebach Group. The close cooperation with partners such as EOS has been a key factor of success to Elbert.

He explained, "Only with strong partnerships in the market, in which everyone contributes their part, we are able to develop efficient solutions for industrial 3D printers users. We are happy to further deepen our partnership with EOS, which has grown over the years."

In the future, Grenzebach is expected to provide more machines in the direct and indirect environment of the EOS AM machines. It is hoped that this will open new opportunities and fields of interaction to address the specific industry and customer requirements more efficiently.

www.grenzebach.com
www.eos.info



Grenzebach's automation enables an optimal production flow and efficient utilisation of equipment (Courtesy Grenzebach)

Protolabs opens new €16 million AM centre in Germany

Protolabs Europe, headquartered in Telford, UK, reports that it has opened a new €16 million European Additive Manufacturing centre in Putzbrunn near Munich, Germany, boosting the company's Additive Manufacturing capacity by 60%. The new facility will enable customers to access faster lead times, with more than sixty industrial AM machines now offering metal and plastic parts through a range of AM technologies. The company has stated that the timing is ideal, with clients in the automotive, aerospace, electrical, industrial, medical and energy sectors looking to invest following the easing of lockdown.

"The new production facility expands our capacity and enables further growth for pioneering 3D printing technologies in the future," stated Bjoern Klaas, vice president and Managing Director of Protolabs Europe. "Our UK customers will enjoy an even greater range of services and this latest investment will undoubtedly help us meet our promise of delivering prototypes and low-volume production parts in just a few days."

Protolabs has also enhanced its commitment to the environment with several sustainable features included in the design of the Putzbrunn plant, building on its ISO 14001 certification and desire to save resources whilst reducing its CO_2 footprint. This is said to already be evident in energy consumption alone, which has been reduced by leveraging the capabilities of heat recovery and waste heat utilisation, as well as the intelligent linking of engineering processes.

The new location, which keeps noise emissions below 26 decibels, also includes charging facilities for electric and hybrid vehicles in its own parking garage and draws on a mix of green electricity.

"The opening of the 3D printing centre illustrates our long-term corporate strategy, which is geared towards fast-evolving technologies, rapidly shifting markets, environmental considerations and world-class employees," added Klaas.

"In doing so, we want to fulfil our social responsibility, as well as deliver an unparalleled service through digital manufacturing. This approach enables our customers to more rapidly develop their products, go to market faster, reduce manufacturing costs and achieve a flexible supply chain throughout the entire product lifecycle."

www.protolabs.co.uk

Protolabs has opened its new European Additive Manufacturing centre in Putzbrunn near Munich, Germany (Courtesy Protolabs)

Tritone DIM expands Moldjet product line

Tritone Technologies, Petach-Tikva, Israel, has announced the introduction of the Tritone® DIM, a mid-range metal AM platform. Powered by Tritone's patented Moldjet® technology, DIM aims to address the needs of consumer goods and consumer electronics manufacturers, service bureaux, R&D and educational departments to create end-use metal parts.

Moldjet technology is said to facilitate the shift from prototyping to industrial production, enabling the production of a wide variety of metal and ceramic parts with fine details and high surface quality. Key advantages of the technology are said to include a reduction in lead time by up to 80%, whilst retaining the ability to produce repeatable, on-demand parts which meet demanding industrial standards.

In the first stage of the Moldjet process, a mould is produced as a negative of the component geometry from a wax-like polymer with inkjet-like print heads. This layer of the mould is then filled with water-based metal powder paste in a slot-die process. The process continues layer-by-layer, allowing undercuts or even internal channels to be possible without the use of support structures. Finally, the surrounding mould is removed, allowing the 3D-shaped green part to be taken for heat treatment and sintering.

"Our propriety technology is a game-changer in the AM industry," stated Omer Sagi, VP Products and Business Development at Tritone. "Tritone's solution can facilitate any shape, design and complexity for fast go-to-market industrial production. After the initial success of our Dominant system, we are proud to expand our market reach with the DIM system. The market is ready to shift gear from prototyping to production of high-quality metal parts, and we are proud to be at the forefront of this emerging revolution."

www.tritoneAM.com


E-Plus-3D®
Tailored Metal
Additive Manufacturing
Solution to Large Scale Parts
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Frame
470x400x499mm³
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Φ394x341mm³
Full-size Nozzle
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info@eplus3d.com
www.eplus3d.com
contact us

Optomec extends range with two new AM machines

Optomec Inc, Albuquerque, New Mexico, USA, showcased two new Additive Manufacturing machines at Formnext 2021: the HC-TBR, a compact metal AM machine that uses LENS® Directed Energy Deposition (DED) to build or repair AM metal parts; and the Aerosol Jet®HD2 3D electronics AM machine for 3D semiconductor packaging/assembly.

The HC-TBR machine is capable of processing reactive metal alloys such as titanium and aluminium at high volume in an oxygen-free chamber, to ensure superior mechanical properties. Using advanced laser optics, the machine can remotely change the size and power profile of its laser beam, enabling significant reductions in print times, which the company states is a first for the industry. The machine was designed in response to manufacturers in several sectors that are seeking lower cost methods of producing and repairing titanium components, as the industrial use of titanium continues to grow worldwide.

The Aerosol Jet HD2 uses Optomec's patented Aerosol Jet solution to produce high resolution circuitry (with features as small as 10 microns), including a unique ability to dispense conformal 3D interconnects between die, chips, components and substrates. This interconnect approach is all the more powerful due to its improved performance at high signal frequencies, enabling longer range and reduced power consumption in emerging segments such as 5G communications, automotive radar and defence applications. As a primary application, the Aerosol Jet HD2 can serve as a drop-in replacement for the decades-old method of connecting electrical components with wire bonds, which suffer from several critical deficiencies including space inefficiency, high scrap and poor signal performance.

Optomec's patented Aerosol Jet Systems for additively manufactured electronics, and LENS and Huffman brand AM machines for metal component production and repair, are used by industry to reduce product cost and improve performance. Together, these AM solutions work with the broadest spectrum of functional materials, ranging from electronic inks to structural metals and even biological matter.

The company has reportedly delivered more than 500 of its proprietary Additive Manufacturing systems to more than 200 marquee customers around the world, for production applications in the electronics, energy, life sciences and aerospace industries.

www.optomec.com

HC-TBR (left) and the Aerosol Jet HD2 3D Electronics Printer (Courtesy Optomec/Business Wire)

MPIF names Rodney Brennen its new president

The Metal Powder Industries Federation (MPIF) has elected Rodney Brennen, vice president/CFO, Metco Industries, Inc, as the 31st president of the MPIF, succeeding Dean Howard, PMT, North American Höganäs Co, a subsidiary of Höganäs AB.

Brennen's two-year term began at the conclusion of the MPIF's annual Powder Metallurgy Management Summit and 76th Annual MPIF Business Meeting, October 23–25, 2021, in Nashville, Tennessee, USA. Brennen has worked for Metco Industries for more than twenty-five years, starting as Finance and Personnel Manager and progressing to his current position as vice president/CFO. He most recently served as president of the Powder Metallurgy Parts Association. He is active in APMI International, a past chairman of the West Penn Chapter (1999-2001), and currently serves on the APMI Board of Directors. He received the Distinguished Service to Powder Metallurgy Award in 2021.

Two of the federation's six associations also instated new presidents following the Summit. Nicola Gismondi, PMT, vice president, Sales & Marketing, MPP, has been elected president of the Powder Metallurgy Parts Association (PMPA) and will serve a two-year term.

Christopher Adam, PMT, president & CEO, Valimet Inc, has been elected president of the Association for Metal Additive Manufacturing (AMAM) and will also serve a two-year term.

www.mpif.org

Australia's RMIT adds AML3D's Arcemy AM machine

AML3D Limited, Edinburgh, Australia, has sold an Arcemy® Additive Manufacturing machine to the RMIT Centre for Additive Manufacturing, part of Australia's Royal Melbourne Institute of Technology University (RMIT), for approximately AUS $400,000. Once installed and commissioned, the new machine is expected to be used with a number of metal alloy grades for post-doctorate research, education and industry-related applications at the RMIT.

The Arcemy machine uses a process that AML3D calls WAM®, also known as Wire Arc Additive Manufacturing (WAAM), a wire-based form of Directed Energy Deposition (DED). It is capable of additively manufacturing all metallic alloys up to dimensions of 1.5 m^3 and mass of ~750 kg with a deposition rate of up to 7-8 kg/hr, depending on the material being used. Arcemy machines are certified across a wide range of welding wire feedstock-based metals, which is said to make them more flexible than powder-based solutions.

"It's encouraging to see Universities and Research institutes seeing the value in our Arcemy printing modules and educational research into the WAM process," stated Andy Sales, AML3D's Managing Director. "To be able to supply the RMIT Additive Manufacturing Centre with our sophisticated integrated wire-based Arcemy 3D printing unit, under the guidance of Prof Milan Brandt and industry expert Alex Kingsbury is exciting and endorsing. There is an expectation that we will work closely with RMIT in the future around specific R&D programmes that will benefit both parties in research, industry application and student based learning and research."

AML3D has sold an Arcemy AM machine to the RMIT Centre for Additive Manufacturing for R&D use (Courtesy AML3D)

Prof Brandt, the Centre Director, commented, "We are excited to be working closely with AML3D on delivering this new 3D printing technology to Victorian organisations. The equipment funded through the Victorian Higher Education State Investment Fund complements our current range of 3D printing technologies and opens the opportunities for working closely with Victorian and more broadly Australian organisations on delivering new products and processes based on this technology as well as training the next generation of engineers in digital manufacturing."

www.rmit.edu.au/research/centres-collaborations/centre-for-additive-manufacturing

www.aml3d.com

Amplify Additive expands orthopaedic capacity with new EOS M290

Amplify Additive, Scarborough, Maine, USA, has expanded its orthopaedic Additive Manufacturing capacity with the addition of an EOS M290 Laser Beam Powder Bed Fusion (PBF-LB) machine. The company now offers both laser and electron beam (PBF-EB) services, currently employing a GE Additive Arcam EBM Q10plus, and now the EOS M290, for orthopaedic solutions.

"The original vision for Amplify was to be technology-neutral with regards to leveraging Additive Manufacturing for the design and manufacturing of 3D printed titanium orthopaedic implants," stated Brian McLaughlin, CEO and founder. "While we are firm believers that EBM [PBF-EB] technology is undoubtedly the best technology for specific applications within the orthopaedic market, to be a supplier who takes a solutions-based approach instead of a technology approach, it was inevitable that we would eventually have Laser Powder Bed Fusion here at Amplify."

He continued, "One of the challenges in choosing which laser platform to use is that machine selection determines who you can potentially work with, given the current regulatory approach for Additive Manufacturing. EOS is by far the largest supplier with the most history in the US market when it comes to 3D printed titanium implants, and that made our choice easy."

Customers often have uncertainty about how best to implement Additive Manufacturing, explains McLaughlin. "We're able to use our expertise on both sides of the aisle, both clinical and engineering, to add value and offer organisations a solution to overcome those hurdles. We implicitly understand both sides of the conversation. The orthopaedic community is a beacon for using Additive Manufacturing to drive innovation, from the concept stage to the volume production of implants. Continued education about our process of Additive Manufacturing with EBM and Laser will only empower surgeons and engineers to push boundaries further in improving patient outcomes."

www.amplifyadditive.com

Freemelt receives machine order from the Polytechnic University of Turin, granted US patent approval

The Polytechnic University of Turin has ordered a Freemelt ONE AM machine for materials development (Courtesy Freemelt)

Freemelt, Mölndal, Sweden, has received an order for a Freemelt ONE Additive Manufacturing machine from the Polytechnic University of Turin in Italy for the development of new materials. The order, valued at SEK 3.5 million, includes the new ProHeat™ technology and the university will also perform advanced testing and develop methods around the use of ProHeat on behalf of Freemelt.

The Polytechnic University of Turin is a leading university in material science with previous AM development of material processes that have enabled successful industrial production.

"The research activities of the Interdepartmental Centre for Integrated Additive Manufacturing of Politecnico di Torino covers the full process chain needed for producing additively manufactured parts: the design for Additive Manufacturing, the development of new materials with a relevant background on the gamma titanium aluminides production by EBM [Electron Beam Powder Bed Fusion; or, PBF-EB], as well as big experience in the simulation of AM processes and the definition of new and innovative thermal treatments and component finishing processes," stated Sara Biamino, Professor in Material Science and Technology at the Polytechnic University of Turin. "Now, we are very proud to announce the acquisition of a Freemelt ONE that we are sure will contribute to further improve our capabilities."

Ulric Ljungblad, CEO and co-founder of Freemelt, commented, "This is an important order for us and a confirmation that customers with great knowledge and ambition in materials development value our product. We are also excited about the ProHeat evaluation that will be performed as this technology provides great possibilities for the future of 3D printing processing. Furthermore, this is our first order in Italy establishing Freemelt as a supplier of advanced 3D printing technology in yet another country in Europe."

Patent approval

In addition to the machine order, Freemelt reports that it has received patent approval for application number US17/050924 from the United States Patent and Trademark Office (USPTO). The patent provides protection regarding a self-sealing build compartment for Additive Manufacturing metal powder, which reputedly enhances the certainty of contamination-free AM with Freemelt's method. Protection under this patent extends in the United States until April 25, 2039. In the same patent family, applications in Europe, China and Japan are still awaiting approval.

Ljungblad stated that he found it gratifying that Freemelt now holds an approved patent and that this is expected to be an important moment for the future of Freemelt on the American market.

www.freemelt.com

www.polito.it

Norsk Titanium shortens part development time with release of RPD Builder

Norsk Titanium AS, Hønefoss, Norway, has announced the successful deployment and validation of RPD Builder™, an internally developed computer-aided manufacturing (CAM) tool expected to significantly shorten part development timelines. The software has been developed over the past three years and incorporates the full knowledge base of Norsk Titanium's process metallurgy and machine controls into a single design toolkit.

"This is a tremendous accomplishment for Norsk Titanium," stated Nicholas Mayer, Norsk Titanium's vice president of Commercial. "RPD Builder is a significant enabler as we move into more industrial manufacturing and engineering services markets. It will give our customers added flexibility and allow them to explore part design options independent from our manufacturing engineering team."

Norsk Titanium's metal Additive Manufacturing machines incorporate a propriety Rapid Plasma Deposition® (RPD®) process, a form of plasma-based Directed Energy Deposition (DED). RPD Builder is intended to enable users to rapidly translate customers' final part geometries into optimised RPD Form designs. It ultimately produces the code needed for any of Norsk Titanium's Merke IV® RPD machines to additively manufacture the part preform, regardless of location.

Norsk Titanium's manufacturing engineers have already employed the software on multiple part development efforts, reportedly reducing development time to as little as two days.

"Our Material Process & Product team has evaluated the microstructure of the deposited preforms and validated that the material produced with the RPD Builder is consistent with our proven process," added Odd Terje Lium, Norsk Titanium's vice president of Engineering. "We were able to validate that the software is capable of producing complex geometries on multiple machines in both our development and production facilities."

Initial applications of RPD Builder are expected to come as Norsk Titanium expands into markets beyond commercial aerospace. The CAM tool will be deployed under licence to customers who desire more insight into part development than Norsk Titanium's current built-to-manufacture finished products.

www.norsktitanium.com

BOFA upgrades 3D PrintPRO 4 to offer extended filtration and capacity

BOFA International, Ltd, a global fume and dust extraction solutions provider headquartered in Poole, Dorset, UK, is redesigning and improving its 3D PrintPRO 4 technology, offering wider filtration airflow ranges and expanded filtration capacity. The enhanced 3D PrintPRO 4 is an industrial machine that is suitable for larger manufacturing processes including Material Extrusion (MEX) processes such as Fused Filament Fabrication (FFF), Powder Bed Fusion (PBF), Vat Photopolymerisation (VPP), digital light processing, Binder Jetting (BJT) and material jetting.

The updated 3D PrintPRO 4 is suitable for technologies such as Fused Filament Fabrication, Powder Bed Fusion, Vat Photopolymerisation (Courtesy BOFA International)

The upgraded unit has multi-stage gas filtration with a deeper carbon bed to capture a greater volume of potentially harmful fume, thereby extending filter life and enabling safe, odourless Additive Manufacturing for longer. This is complemented by a larger HEPA filter, enabling multiple AM machines to be hooked up to a single BOFA unit, optimising investment in filtration technology to help keep workplaces free from airborne contaminants and equipment clear of particulate residue. Airflow rates of 5 m^3/min in the upgraded technology are double that of the original 3D PrintPRO 4, enabling the unit to cater for a greater range of industrial AM machines, including large format machines.

Operating pressures in the new 3D PrintPRO 4 have been tripled to 96 mBar, which allows the unit to overcome greater system resistance, reportedly enabling effective performance in complex installations and multiple AM machine architectures. The redesigned 3D PrintPRO 4 has been tested to UKCA and CE as well as UL and cUL standards.

Haydn Knight, Sales & Marketing Director at BOFA, stated "The 3D printing market is evolving at a rapid pace and the enhancements to our 3D PrintPRO range match the industry trend towards faster printing capability and larger build chambers. Our filtration system options for this market are improving all the time, underlining our leading position in meeting the needs of companies investing in the benefits of industrial Additive Manufacturing processes."

www.bofainternational.com

Aconity3D and Equispheres report faster speeds for metal AM

Equispheres, Ottawa, Ontario, Canada, and Aconity3D, Herzogenrath, Germany, have reported breakthrough speeds in aluminium part Additive Manufacturing using an Aconity3D 1 kW MIDI Laser Beam Powder Bed Fusion (PBF-LB) machine and Equisphere's aluminium powder. Aconity3D has been testing Equispheres powder to produce a part of the AconitySCAN, a key component of its AM machines, in hopes of producing the parts quicker and at a lower cost than the company has found achievable with standard powder. To date, the results achieved are said to have demonstrated that the desired part can be produced in over 60% less time (i.e., from fifty-three hours down to seventeen and a half hours) with no impact on mechanical properties.

"This dramatic reduction in production time reduces the cost to produce the part by greater than 50%. More importantly, it enables Aconity3D to produce our printers more quickly and meet the growing demand for our systems," stated Yves Hagedorn, Managing Director of Aconity3D.

Evan Butler-Jones, Director of Applications Engineering at Equispheres, explained that this feat was achieved through the use of highly spherical, uniform Equispheres powder, which is able to absorb the energy from the 1 kW laser without disturbing the melt pool, something he has stated isn't achievable with standard aluminium powders. "We are pleased to partner with Aconity3D on this initiative," he added. "Combining their expertise with AM systems and our expertise in powders provides a powerful solution to the market."

Aconity3D intends to conduct additional testing with Equispheres powder in an effort to further optimise its process and reduce costs. In addition to using the powder for their internal part production needs, the companies are said to be finalising an agreement to enable Aconity3D to provide Equispheres powder directly to its own customers as a starter kit.

"We want our customers to have the best production experience when they utilise our specialised printer equipment. The best way to showcase our devices is to equip them with the best powder," Hagedorn concluded.

www.aconity3d.com
www.equispheres.com

BEAMIT Group develops AM process for nickel-base superalloy René 80

The BEAMIT Group, Fornovo di Taro, Italy, reports that it has developed an Additive Manufacturing process for nickel-base superalloy René 80 RAM1, as a result of the group's efforts to identify new alloys for use in the energy industry.

In recent years, AM has become a trusted technology in the energy industry due to its ability to produce components, such as combustor gas turbines, which offer better combustion efficiency and reduce the environmental impact of energy production, explains BEAMIT.

René 80 has a high melting point and excellent oxidation resistance at high temperatures, making it particularly suited to applications in the energy industry for turbines and valves, and for the aerospace industry. Additionally, when processed with AM technologies rather than conventional technologies, René 80 is reported to be one of the highest performing alloys at ambient temperature.

The first step in developing the AM process for René 80 was processing the alloy: the chemical composition of nickel superalloy powder is very complex, and a few critical issues often arise during the Additive Manufacturing phase. The powder was modified by Elementum 3D, Erie, Colorado, USA, using its patented RAM technology.

Once the alloy's chemical composition had been modified, BEAMIT technicians developed and optimised the Laser Beam Powder Bed Fusion (PBF-LB) process to achieve good density and a crack-free microstructure.

BEAMIT explained that heat treatments are a key part of ensuring excellent performance in this case. Thorough research was conducted to identify the most suitable treatment, and also to eliminate any cracks in the components.

"René 80 is proving that our one-stop-shop strategy succeeds throughout the entire value chain, including when researching and developing new materials. Integrating special processes enables us to devise an otherwise unattainable solution with extraordinary results," stated Andrea Scanavini, BEAMIT Group General Manager.

"The tougher the technological challenges, the more process integration and the innovation of post-processing, made available to highly skilled metallurgists, not only make the difference but become the only way forward," he continued. "René 80 is one of our first demonstrations of this concept. And we are not done yet because other new advances are already in the developmental phase."

The parameters for René 80 RAM1 treated with Hot Isostatic Pressing (HIP) and HIP quenching were characterised and compared with as-built René 80. With the optimised HIP-Q cycle, BEAMIT recorded a 20% increase in the mechanical properties compared with the aged condition of René 80 produced with conventional technologies. Furthermore, elongation up to 8% was achieved with a 37% increase compared to casting.

The group states that the advantage of the process parameterised lies in the HIP-Q phase. The treatment can be performed with Quintus technology and enables HIPing to be followed by rapid quenching in argon to produce a high-performance material with just a one-step heat treatment and ensure a shorter lead-time than treatments using conventional methods.

Finally, tests were conducted at high temperatures and to gauge cracking resistance which confirmed a yield strength of 750 MPa at around 900°C.

Jacopo Sisti, BEAMIT Group Materials and Special Processes Manager, concluded, "It was a challenge to actually print an alloy that performs so well at high temperatures, but we fine-tuned the AM process and succeeded – plus we achieved high density. The turning point came with the innovative HIP-quenching heat treatment: we avoided the formation of cracks in the material which meant that we delivered better static mechanical properties than the alloy produced with conventional technologies."

www.beam-it.eu

Xact Metal launches new XM200G metal AM machine

Xact Metal, State College, Pennsylvania, USA, has launched the XM200G, a highly configurable metal Additive Manufacturing machine. With single- or dual-laser options, the XM200G is reported to offer metal Laser Beam Powder Bed Fusion (PBF-LB), with industrial speed and performance, at a more affordable price point. The XM200G is based on the design of the Xact Metal XM200C metal AM machine, but uses a high-performance galvanometer system. This new architecture allows faster manufacturing times and supports multiple lasers.

Xact Metal has launched the XM200G family of metal AM machines (Courtesy Xact Metal)

"With pricing beginning at a US MSRP [manufacturer's suggested retail price] of $90,000 dollars, the XM200G family is ideal for printing parts where high-performance applications and print speed are critical," stated Juan Mario Gomez, CEO of Xact Metal. "The introduction of the XM200G is another example of how Xact Metal continues to combine the requirements of metal Powder Bed Fusion and breakthrough technology to establish a new level of price and performance for Additive Manufacturing."

To increase build speeds, the XM200G provides the option of using two lasers with either a 100% overlapping work area (100 µm spot size) or a 66% overlapping work area (50 µm spot size). With a large 150 x 150 x 150 mm build volume, the XM200G can be configured to match different applications, and has options for a 100, 200 or 400 W fibre lasers, a water-cooled galvanometer, and a glovebox to ease powder handling with an integrated powder handling system.

"XM200G printers tailor to customers starting their entry into metal 3D printing in various applications, including product development, tooling manufacturing, metal powder bed research and educational," Gomez continued. "Xact Metal aims to further expand the use of metal 3D printing in multiple industries including aerospace, automotive, and general manufacturing."

Xact Metal also announced that its XM200C metal AM machine is now available with a US MSRP of $65,000. "We are very excited to offer a starting MSRP of $65,000 for our XM200C metal 3D printer to allow more customers to benefit from metal laser Powder Bed Fusion technology. This is another example of how Xact Metal continues to combine the requirements of metal powder bed fusion and breakthrough technology to establish a new level of price and performance for Additive Manufacturing,"Gomez concluded.

www.xactmetal.com

Authentise and Riven integrate software for advanced AM production

Authentise, London, UK, and Riven, Berkeley, California, USA, have announced the integration of the Riven 3D reality platform, Warp Adapted Model (WAM™), with the Authentise Manufacturing Execution System (aMES). Through the integration, scan data from Riven's sensors will be automatically inserted into the traceability report of the part in aMES. Riven's software will also receive critical information such as the as-designed CAD file, process, and material information directly from Authentise. The rapid identification of divergence from Riven's WAM will be viewable in Authentise. The resulting full contextual data capture of all parts provides a platform for further analysis by Riven, Authentise and users alike. In the future, WAM compensation will automatically trigger new orders in aMES.

"Integrating full-part 3D data into the Authentise aMES platform will greatly accelerate new product introduction for parts made via Additive Manufacturing," stated Andre Wegner, CEO of Authentise. "Riven's WAM technology is levelling up part accuracy across all AM production techniques. I am very excited to see existing AM systems now able to produce production parts and meet tolerance specs that were previously impossible. Authentise customers will see immediate benefits – especially for setting up and managing series-production orders with Authentise."

James Page, founder and CTO of Riven, commented, "For additive to reach its full potential, OEMs and service bureaux need to have confidence that production parts will be delivered quickly and meet specs. Authentise's open platform and workflow automation are an excellent complement to Riven's push-button easy capture, analysis and streamlined data aggregation. Data lakes based on capture of complete as-manufactured parts fuel Riven's next-generation predictive, machine learning technology, enabling even higher part quality and reduced time to production deliveries for Authentise customers."

www.authentise.com
www.riven.ai

MX3D's wire-based DED process certified by Lloyd's Register

Lloyd's Register has awarded MX3D, Amsterdam, the Netherlands, certification for its Directed Energy Deposition (DED) facility, incorporating the M1 Metal AM system, in accordance with the requirements of the LR-TWIO 'Guidance notes for Additive Manufacturing certification'. The scope of the qualification included assessment of control relating to feedstock, equipment, personnel, processes and build control covering multiple materials such as aluminium alloys, copper alloys, carbon and stainless steel alloys.

MX3D has seven years of experience with robotic Wire Arc Additive Manufacturing (WAAM), a wire-based DED process. The M1 Metal AM machine runs on the company's proprietary MetalXL software and comes with a control system that monitors and logs all relevant building parameters. It also has automated calibration routines built in, to minimise downtime during production.

"This is huge!" stated Gijs van der Velden, co-founder and CEO. "The certification will allow us to print with qualified Deposit Parameter Sets (DPSes) and help our customers to print certified end parts. After showcasing multiple industrial use cases – like an optimised robotic arm, near-net-shape propellers and clamps for the oil & gas industry – the last step needed for implementation in the businesses of our customers was this external validation of our process."

"We can now print materials using processes qualified by Lloyd's Register 3.1 or 3.2 material certificates (3.2 certificates require third-party inspection), which enables the printed parts to be certified," he continued. "Furthermore, our M1 Metal AM machine customers can benefit from fast-track qualification of their machine and procedures, as an additional service."

David Hardacre from Lloyd's Register, who led the certification procedure, added, "Having supported MX3D from the start of this project, we're proud to be part of this latest success. The benefits of AM can be enormous and, as the focus shifts to manufacturing for safety-critical applications, the ability to meet industry standards and regulations will be key to fulfilling the technology's potential."

"This achievement is a significant step, not only for MX3D, but for the AM industry as a whole, demonstrating how the qualification of AM processes leads to products that can be certified for use in demanding applications within highly regulated industries," he concluded.

www.mx3d.com

The M1 Metal AM machine uses the MetalXL software (Courtesy MX3D)

US Army Research Lab in partnership to develop large-scale Friction Stir AM

The US Army Research Laboratory (ARL) has partnered with Solvus Global, Pacific Northwest National Laboratory (PNNL), and Bond Technologies to develop a new capability in large-scale Additive Manufacturing, in an effort to ensure supply chain security and military readiness in the production of metal parts with reduced costs and lower scrap rates. The partnership has focused on Friction Stir Additive Manufacturing (FSAM), said to provide cost-effective, rapid turn-around on large parts greater than 0.03 m^3 (1 ft^3) in volume.

FSAM technology is reported to compete favourably with traditional forging and casting practices due to its ease in joining large, geometrically critical complex parts. Fabrication of titanium castings with FSAM reportedly allows for high-performance, low-volume production of crucial armour components for use by the US Department of Defense (DoD).

Development of FSAM technology at the Solvus Global Center for Scaled Innovations in Manufacturing has created a Friction Stir Welding system in a combination of five selected AM techniques:

- Friction Stir Assembly
- Additive Friction Stir
- Plate Stacking
- Hybrid Friction Stir
- Friction Stir Surfacing

PNNL torque-based temperature control technology is integrated into the machine to enable control of processing temperature which, in turn, may enable improved properties and processes robustness. The machine is said to be able to maintain constant forge force, processing temperatures and tool tilt relative to complex weld paths, reportedly leading to unprecedented control and repeatability for the technology.

Bond Technologies has brought equipment concepts to fruition with the development of the Friction Stir Welding system. The GL7 solid-state manufacturing centre is reportedly capable of high-rate AM friction stir deposition using controls and motion control systems. The system is capable of operating with metals including aluminium, Inconel, steels, and titanium.

www.arl.army.mil
www.pnnl.gov
www.bondtechnologies.net
www.solvusglobal.com


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Powder Recovery
solukon.de

GF AMotion Center invests in powder recycling solution for DMP Factory 500

GF's AMotion Center has invested in powder recycling technology for the DMP Factory 500 (Courtesy GF)

GF's AMotion Center, located in Novazzano, Switzerland, reports that it has invested a six-digit amount in euros on new powder recycling technology. The new module optimises the manufacturing process and is intended to upgrade the DMP Factory 500.

The Powder Recycling Module (PRM) is the most recent of six components of the manufacturing system. It recycles the powder which was not fused by the lasers during the building process. The system fully automatically sieves surplus material allowing it to be reused in the next process step working in parallel with the Printer Module (PTM) without negatively impacting productivity. The recycling process is performed under an inert atmosphere in order to ensure the highest possible powder quality and mitigate the health & safety risks for operators.

The manufacturing solution consists of six function-specific modules: the Removable Print Module (RPM) is responsible for the powder and parts transport between the AM machine, Depowdering Module (DPM) and PRM and thus ensures to always keep under control the raw material quality. The PTM is designed to withstand 24/7 production cycles with maximum AM machine uptime and performance.

The DPM automatically depowders the parts on the build platforms and the Transport Module (TRM) enables efficient transport of the RPMs reducing production time. The Parking Module (PAM) serves as storage for RPMs in a secured environment until they are ready for further processing. This optimally protects the powder inside the RPM from possible external influences such as oxidation.

The DMP Factory 500 modular AM platform is designed for the production of high-quality metal parts up to a dimension of 500 × 500 × 500 mm and is used to streamline workflows at what are said to be the lowest possible operating costs. The metal AM system was developed by GF Machining Solutions in partnership with 3D Systems and is being used at the GF AMotion Center for the production of parts for the aerospace and the energy market.

www.gfcs.com

Optomec delivers $1 million AM machine to aviation MRO supplier

Optomec Inc, Albuquerque, New Mexico, USA, has delivered a multi-functional Additive Manufacturing machine to a leading supplier to the aviation engine maintenance, repair and overhaul (MRO) market.

The user is an existing customer with more than five Optomec AM machines currently being used in production to repair a range of turbine components from aircraft engines, as well as industrial gas turbines. The new machine combines two turbine repair process operations that are typically done manually, which is said to not only reduce the cost of engine overhauls, but improve the quality and consistency of these flight-critical procedures.

Optomec users have performed production repairs on more than 10 million components over time (Courtesy Optomec)

Optomec's Directed Energy Deposition (DED)-based metal AM repair solutions are currently used in high-volume production in approximately 100 MRO installations worldwide; together, Optomec users have performed production repairs on more than 10 million components over time.

The global fleet of 25,000 commercial aircraft and 50,000 military aircraft have a mandated time between overhaul (TBO) of around 5,000 flight hours, creating a large and growing demand for automated repair equipment. Optomec AM systems are currently certified for aviation repair in fifteen countries.

"There are really three advantages to using the Optomec AM process for repairing turbine components, "stated Jamie Hanson, VP of Business Development, Optomec. "First of all, it saves time and cost relative to manual repairs. Secondly, it requires far less heat input, so the base metal is far less affected by the repair. Finally, because the adaptive AM process adds less repair metal, the downstream machining costs are drastically reduced."

www.optomec.com

University of Queensland purchases AML3D Arcemy machine

AML3D Limited, Edinburgh, Australia, has sold an Arcemy® machine to the University of Queensland (UQ) for approximately AUS $400,000. Arcemy units are certified across a wide range of welding wire feedstock-based metals, which is said to make them more flexible than powder-based Additive Manufacturing machines. The machine uses a process the company calls WAM®, also known as Wire Arc Additive Manufacturing (WAAM), a wire-based form of Directed Energy Deposition (DED).

"We are thrilled to be able to supply UQ with what we believe is the world's most sophisticated integrated wire-based 3D printing unit," stated Andy Sales, Managing Director, AML3D. "There is an expectation that we will work closely with UQ in the future around specific R&D programs that will benefit both parties in research, industry application and students' base learning and research."

AML3D will work with the university in the installation and commissioning of this unit, which is expected to be used for education and research and development at UQ.

www.aml3d.com
www.uq.edu.au

Oerlikon delivers 1000th additively manufactured bicycle component to Urwahn

Oerlikon Group, Pfäffikon, Schwyz, Switzerland, reports that its Additive Manufacturing team in Barleben, Germany, has now surpassed the milestone of delivering 1,000 AM components to bicycle manufacturer Urwahn Engineering GmbH, Magdeburg, Germany. Oerlikon has produced some 150 sets of seven unique components for a bicycle, based on a completely new design developed by Urwahn Engineering founder Sebastian Meinecke.

The partnership between the companies began several years ago when Meinecke brought his idea to the Oerlikon AM team. From concept to creation, both partners determined the materials, processes and the right machines to develop this unique next-generation bike.

Oerlikon's AM team has produced the 1000th AM bicycle part for Urwahn Engineering GmbH (Courtesy Oerlikon Group/Urwahn Engineering GmbH)

"The collaboration with the Oerlikon team has been great," stated Meinecke. "With their knowledge of materials and technology, we were able to develop a process chain that enabled us to offer new and unique features such as fully integrated electric systems for the product. And this is just the beginning. I am excited to see what else we can innovate together by taking advantage of new materials and Additive Manufacturing."

In addition to its unique shape, which uses rear wheel elastic suspension to ensure a comfortable ride, the frame has integrated LED lighting and a GPS tracking system as well as other features, which would not be feasible to make with conventional production processes. To protect the frame and add another innovative dimension, a protective Balinit Croma Plus coating, from the Oerlikon Balzers brand, is applied.

Hendrik Alfter, General Manager of Oerlikon's European production, commented, "This is the kind of project that sparks our creativity because we started with a completely white board. Sustainable mobility and transportation options, including cycling, are megatrends as people steer toward environmentally friendly options to stay mobile. We see great opportunity in this market."

www.oerlikon.com/am
www.urwahnbikes.com

Addman Engineering increases production with second Velo3D machine

Addman Engineering, headquartered in Bonita Springs, Florida, USA, has purchased a second Sapphire metal Additive Manufacturing machine from Velo3D, Campbell, California, USA, following the purchase of its first Sapphire machine in May. This second acquisition is expected to allow Addman Engineering to offer more comprehensive end-to-end manufacturing solutions at its Indianapolis facility, Indiana, and to improve the range of services offered to clients in the aerospace sector and increase production capacity at the Bonita Springs facility, while improving quality control. The Laser Beam Powder Bed Fusion (PBF-LB) machine will primarily be used to additively manufacture Inconel 718 parts for aerospace clients.

Addman Engineering reports that it has ordered additional Velo3D machines which are scheduled for delivery in 2022. The two Sapphire XC machines on order will complement the four existing Additive Industries MetalFAB1 AM machines at the Indianapolis production facility to offer new manufacturing capabilities, along with improvements in capacity and efficiency. Addman Engineering's Bonita Springs facility will remain its innovation centre.

Bob Markley, who is one of the original founders of 3rd Dimension as well as an executive vice president at Addman Engineering, stated that the purchase of the Sapphire machines shows that the company is committed to "pushing the boundaries of possibility."

www.velo3D.com
www.addmangroup.com

Titanium alloy for AM developed by City University of Hong Kong researchers

Researchers from the City University of Hong Kong (CityU) have successfully developed a super-strong, highly ductile and super-light titanium-base alloy using Additive Manufacturing. Their findings have been published in a paper, 'In situ design of advanced titanium alloy with concentration modulations by additive manufacturing', in the scientific journal *Science*.

The research team was led by Professor Liu Chain-Tsuan, University Distinguished Professor in the College of Engineering and Senior Fellow of CityU's Hong Kong Institute for Advanced Study (HKIAS). Dr Zhang Tianlong, a postdoc in the Department of Materials Science and Engineering (MSE), conducted the experiments. President Way Kuo of CityU also contributed to the published paper. Their findings anticipated opening up a new pathway to design alloys with unprecedented structures and properties for various structural applications.

Dr Zhang notes that most people consider AM as a revolutionary technology that can produce machine parts to complex shapes within just one step. "However, we unveiled that it has important potential in designing materials, rather than simply designing geometries," he stated.

Metallurgists may think that a lack of uniformity in alloy components is undesirable because it leads to bad properties, such as brittleness. One of the key issues in the AM process is how to eliminate this inhomogeneity during the fast cooling of AM parts. But Dr Zhang's previous modelling and simulation study found that a certain degree of heterogeneity in the components can actually produce unique and heterogeneous microstructures that enhance the alloy's properties.

"The unique features of Additive Manufacturing provide us with a greater freedom in designing microstructures," Dr Zhang added. "Specifically, we have developed a partial homogenisation method to produce alloys with micrometre-scale concentration gradients with the aid of 3D printing, which is unachievable by any conventional methods of material manufacturing."

The research team's proposed method involves the melting and mixing of two different alloys: titanium alloy powders and stainless steel powders, using Laser Beam Powder Bed Fusion (PBF-LB). By controlling parameters like laser power and scanning speed during the AM process, the team successfully created the non-uniform composition of the elements in the new alloy in a controllable way.

"In addition to the use of Additive Manufacturing, the composition of the two-powder mixture is another key to creating the unprecedented lava-like microstructures with a high metastability in the new alloy," said Professor Liu. "These unique microstructures give rise to the supreme mechanical properties, allowing the alloy to be very strong but ductile, and lightweight."

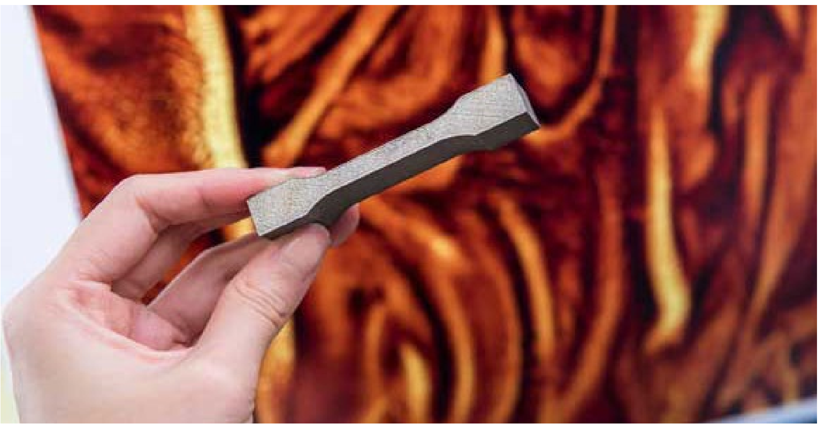
While AM stainless steel generally has a density of 7.9 g/cm^3, the new alloy is only 4.5 g/cm^3, resulting in around 40% lighter weight. In their experiments, the titanium alloy with lava-like microstructures exhibited a high tensile strength of approximately 1.3 GPa with a uniform elongation of about 9%. It also had an excellent work-hardening capacity of over 300 GPa, which guarantees a large safety margin prior to fracture and is useful in structural applications.

"These excellent properties are promising for structural applications in various scenarios, such as the aerospace, automotive, chemical, and medical industries," commented Professor Liu. "As the first team to use 3D printing to develop new alloys with unique microstructures and properties, we will further apply this design idea to different alloy systems to further explore other properties of the new alloys."

Other researchers who participated include Dr Luan Junhua, Dr Wang Anding and Dr Kong Haojie. Other collaborators are Professor Huang Zhenghua from Guangdong Academy of Sciences and Dr Wang Dong from Xi'an Jiaotong University.

The research was supported by CityU, HKIAS, the National Key Research and Development Program of China, the National Natural Science Foundation of China, Guangdong Academy of Sciences, and the US National Science Foundation.

www.cityu.edu.hk



An additively manufactured sample part in the titanium alloy developed by researchers from the City University of Hong Kong (Courtesy City University of Hong Kong)

Ti-MIM specialist Element22 adopts Headmade's Cold Metal Fusion AM process

Titanium Metal Injection Moulding specialist Element22, Kiel, Germany, has purchased a Formiga P110 SLS machine from EOS as part of its implementation of the Cold Metal Fusion (CMF) Additive Manufacturing process developed by Headmade Materials, Würzberg, Germany.

"We are innovation drivers and always on the lookout for better, more effective solutions," stated Matthias Scharvogel, CEO of Element22. "During technology screening, we came across the Cold Metal Fusion technology. The projects that we have already been able to realise with Headmade Materials in the past few months then completely convinced us."

Cold Metal Fusion is based on integrating metal powder into a functional binder system (Courtesy Element22)

CMF technology has recently been demonstrated in titanium series components for high-end bicycles, which, among other things, offers new possibilities in frame construction. New part designs and functional integrations can be implemented, while production costs can be reduced. The demand for additively manufactured titanium components also comes from other sectors such as medical, aerospace and other high-end consumer goods. Utilising the CMF technology, Element22 now also serves these sectors.

When processing the titanium feedstock from Headmade Materials on the EOS Formiga P110, the included polymeric binder is melted layer by layer to form strong green parts. These are then debound and sintered to produce components which are reportedly comparable to MIM parts.

Christian Fischer, Managing Director, Headmade Materials, concluded, "We are pleased about the expansion of our partnership with Element22 and that the titanium specialist is relying in-house on our Cold Metal Fusion technology to move into industrial titanium 3D printing. This also underlines our technology leadership in sinter-based titanium 3D printing."

www.headmade-materials.com
www.element22.de

Read more on Headmade Materials in *PIM International* (Vol. 15 No. 4). https://bit.ly/3DUXge5

MacLean Additive buys SLM 280 3.0 Production Series machine for serial AM

SLM Solutions, Lübeck, Germany, and MacLean Additive, an Additive Manufacturing and materials start-up division of automotive supplier MacLean Fogg Component Solutions based in Mundelein, Illinois, USA, have announced the purchase by MacLean Additive of an SLM®280 3.0 Production Series PBF-LB machine.

MacLean Additive is the home of the Formetrix L-40 steel powder, an engineered, patented, high-performance steel alloy designed for AM to provide a combination of hardness, ductility, and toughness. Durable tooling manufactured with Formetrix L-40 powder have been serially produced via SLM Solutions machines and are deployed across multiple industries and processes.

"Some of the most innovative use cases for Formetrix L-40 powder were developed and printed using SLM machines," stated Greg Rizzo, vice president and General Manager of MacLean Additive. "This proven performance made SLM machines the perfect fit for our initial production product lines."

The new SLM AM machine will be used to additively manufacture hundreds of identified Formetrix L-40 AM tools annually, with technical and economic benefits exceeding those of traditional tooling. It is scheduled to be delivered to one of MacLean Additive's design and manufacturing centres in the Detroit metropolitan area.

Sam O'Leary, CEO of SLM Solutions, commented, "We're excited to partner with MacLean Additive on the industrialisation and growth of their 3D metal printing product lines. Success with another innovative powder like Formetrix L-40 tool steel adds to the already impressive list of materials validated and proven on SLM machines. We look forward to the mutual growth of Formetrix L-40 powder usage and the rapid adoption of SLM Solutions' technology."

www.macleanfoggcs.com
www.slm-solutions.com

The SLM 280 3.0 Production Series AM machine is expected to scale up AM capabilities using MacLean's proprietary Formetrix L-40 steel powder (Courtesy SLM Solutions)

BCN3D releases Metal Pack to enable simpler entry into metal Additive Manufacturing

Additive Manufacturing solutions provider BCN3D, Barcelona, Spain, showcased the new Metal Pack for its line of Epsilon AM machines at Formnext 2021. This upgrade is intended to open a new range of applications for BCN3D customers, especially for spare parts, functional prototyping, and tooling. It is mainly aimed at the pharmaceutical, food, automotive, aerospace, and manufacturing sectors.

The Metal Pack includes both Ultrafuse® 316L and 17-4 PH filaments from Forward AM, part of BASF 3D Printing Solutions GmbH, headquartered in Heidelberg, Germany. It also includes a new exclusive hotend for metal, as well as specific accessories, said to enable a smooth printing experience. Following the build process, BCN3D added that debinding and sintering stages can be undertaken externally through the current Forward AM authorised network of service suppliers.

"Ultrafuse Metal Filaments portfolio has been developed based on BASF's decades of know-how coming from the Metal Injection Moulding (MIM) industry," stated Firat Hizal, Head of Metal Systems Business Group at BASF. "Filaments are designed for ultimate ease of handling and can be used on any open-source Fused Filament Fabrication (FFF) printer. We are very happy that both Ultrafuse 316L and 17-4 PH are validated by BCN3D and BCN3D decided to enable its userbase by introducing this bundle."

Eric Pallarés, CTO, BCN3D, added, "The whole AM industry is chasing metal 3D printing. But the truth is that, nowadays, affordable available solutions, if any, are very scarce. With the release of the Metal Pack at BCN3D, we are excited to leverage BASF's decades of experience in MIM technology applied to metal extrusion and post-processing. In combination with our existing 3D printing ecosystem, it becomes an end-to-end and accessible solution for functional prototyping. Our customers will be able to take the best advantage of 3D printing by obtaining industry-grade metal parts, within days and hassle-free."

The first units of the Metal Pack are scheduled to ship in January 2022.

www.bcn3d.com
www.forward-am.com

Parts additively manufactured using the Metal Pack on one of BCN3D's Epsilon AM machines, showing as built part left, sintered part (centre) and post-processed part (right) (Courtesy BCN3D)

Wohlers releases report on post-processing of AM parts

Wohlers Associates, Inc, Fort Collins, Colorado, USA, has released a new report titled 'Post-Processing of AM and 3D-Printed Parts' discussing the many time consuming and often expensive steps in post-processing parts made by Additive Manufacturing, including support material removal, the finishing of surfaces, colouring and coating, and heat treatment.

Organisations involved with AM have vast amounts of post-processing knowledge and experience, yet little systematic documentation is available, explains Wohlers Associates. This has led to companies 'reinventing the wheel' and spending time and money unnecessarily to complete jobs. The company states that the methods and techniques described in this report can reduce the trial-and-error that so many organisations use.

Post-processing is one of three major phases of producing AM parts and, according to research conducted for *Wohlers Report 2021*, it accounts for nearly 27% of the cost of production. The study involved input from 124 service providers in twenty-seven countries.

When calculating the cost of post-processing, it is critical to consider the entire end-to-end workflow, explains Wohlers Associates. Bottlenecks are a challenge, especially when scaling into production quantities. The post-processing steps for metal Powder Bed Fusion (PBF) include the removal of powder, thermal stress relief and the separation of parts and support material from the build plate. They also include the removal of supports from parts, media blasting, and machining and grinding.

Some parts may require Hot Isostatic Pressing (HIP), additional heat treatment, anodising, and inspection. If post-processing is not scaled and streamlined accordingly, bottlenecks will occur, especially with large quantities.

www.wohlersassociates.com

JAMPT aims for critical role in Japan's adoption of AM

Specialist service bureaux in Japan often act as the first step on the Additive Manufacturing journey for manufacturers, allowing companies to visualise operations before introducing an in-house system. One such bureau is Japan Additive Manufacturing & Processing Technology (JAMPT), based in Tagajō in the Miyagi Prefecture. JAMPT was one of the country's first specialist metal AM service bureau to provide technological services, from metal powder development and prototyping to mass production. The company works closely with aerospace, defence, medical equipment, and automotive sector manufacturers who are planning to deploy metal AM technology.

As the use of metal AM grows internationally, JAMPT's Plant Manager Shoichi Sato believes that some industries in Japan are still catching up. "While aerospace companies in the US and other countries are installing metal additive components into aircraft engines, here in Japan, we are still often faced with helping and educating companies how to identify the possible benefits of the technology," stated Sato. "If you take a snapshot of Japanese industry, it is the defence industry – thanks to support from the Acquisition, Technology & Logistics Agency (ATLA), part of the Japanese Ministry of Defense – that is currently progressing further than other industries, in terms of the technological and practical use of Additive Manufacturing. However, there are encouraging developments underway in the medical equipment industry and the automobile industry, and the number of successful cases and new requirements are progressively growing, little by little."

"In terms of the adoption of metal additive here in Japan, it has become clear that there are specific issues in each industry. Identifying and then solving them will lead to the growth of the Additive Manufacturing market. We think we have a good opportunity here at JAMPT, to play an important role and contribute to the additive manufacturing industry as it develops," Sato added.

JAMPT supports many companies across a wide variety of industries and is also engaged in R&D to improve the quality of AM products. In addition, JAMPT has acquired JIS Q 9100 certification – a quality management system required by manufacturers in the aerospace and defence industries in Japan, equivalent to the AS 9100 standard used in North America and the EN 9100 standard in Europe.

In the automotive sector, JAMPT has formed a technical partnership with the research institute Tokyo R&D Co., Ltd., to provide a Design for Additive Manufacturing (DfAM) support programme for automobile manufacturers. The partnership provides various services, including proposals for the use of AM in automotive, as well as services for other industries, such as structure and strength analyses to manufacture lightweight jigs, tools, and thermal fluid analyses for the thermal management of coils and heatsinks.

Sato concluded, "As the adoption of metal 3D printing among our various manufacturing communities grows, the demand for specialist metal 3D printing service bureaus in Japan is increasing. If you are getting started, encountering challenges with Additive Manufacturing, please contact us. Let us seek solutions together using our metal additive technology and apply the expertise and know-how that we have developed."

JAMPT was established through a joint investment between Koiwai Co., Ltd.; Tohoku University Venture Partners Co., Ltd. (THVP-1 fund), and the Sojitz Corporation. Koiwai's activities involve the advanced technical and functional aspects of metal AM, process control and quality control during the development, manufacturing, test production, and mass production of metal powders. Professor Akihiko Chiba of the Institute for Materials Research at Tohoku University, offers support from an academic point of view, while Sojitz manages and operates the business using its global network, information collection and analysis capabilities.

JAMPT runs a total of seven Electron and Laser Beam Powder Bed Fusion (PBF-EB and PBF-LB, respectively) machines, with GE Additive's Concept Laser M2 the most recent addition.

www.jampt.jp/en

Fraunhofer IPT and partners produce greener hydrogen combustion chambers

In a joint research project, FH Aachen – University of Applied Sciences and the Fraunhofer Institute for Production Technology IPT, Aachen, Germany together with Präwest Präzisionswerkstätten GmbH & Co KG., Bremen, have used Additive Manufacturing to produce a hydrogen combustion chamber which is said to significantly reduce nitrogen oxide emissions.

The design of the hydrogen combustion chamber supports the MicroMix combustion process (MMX), developed by Prof Dr Harald Funke at the Faculty of Aerospace Engineering at FH Aachen, which was awarded the FH Aachen Research Prize 2021. This combustion process relies on a large number of smaller flames compared to conventional combustion processes with a few large flames. The MMX combustion chamber is designed in such a way that the gas mixes with the supplied air and burns with less NOx emissions. Another reported advantage of the small flames in the chamber is higher safety against flashback, making such combustors in appropriate scaling suitable for aerospace applications.

The production of MMX combustion chambers is technically quite challenging, because the manufacturing tolerances are small: the operation of such a combustion chamber with the volatile hydrogen gas requires that the system remains permanently leak-tight. In addition, all the functional elements inside the chamber, such as the air baffles, must be precisely aligned with each other to ensure the desired flow characteristics of the incoming and outgoing gases. However, subtractive manufacturing alone would make components of this kind very costly. This led the project partners to choose Laser Beam Powder Bed Fusion (PBF-LB) AM.

After manufacturing the combustion chamber and the separation of the platform on which it was built, only a few subtractive post-processing steps were required (e.g., the filigree, movable air baffles are manufactured in a milling process and the holes for the hydrogen outlet are added subsequently). By combining the individual manufacturing steps, the partners were able to compensate for the weaknesses of the existing manufacturing processes and to link them into a synergetic process chain.

www.ilt.fraunhofer.de
www.fh-aachen.de
www.praewest.com

The micro-mixing combustion head, a component of the MMX combustion chamber (Courtesy Fraunhofer IPT)

Authentise leads UKRI funded project to increase AM efficiency

A consortium led by Authentise Ltd, London, UK, has been awarded a competitive grant by the UK Research and Innovation's (UKRI) Transforming Foundation Industries challenge, delivered by Innovate UK. The team of companies aims to develop and validate scalable digital tools to identify, create and enforce rules that reduce direct and indirect energy consumption and increase material efficiency in metal and ceramic Additive Manufacturing.

The consortium includes ICD, a metal powders and components provider; the Materials Processing Institute, which will provide research services for the foundation Industries; TWI, the membership-based research and technology organisation; and photopolymer and LCD-based AM brand Photocentrics.

"Continuing studies and analysis will only achieve so much," stated Andre Wegner, CEO of Authentise. "Digital tools that can monitor, analyse, predict and alert a range of impact and deviations in standard operating procedures are fundamental to improve manufacturing processes, increase repeatability and reduce the resource intensity of the process. Additive Manufacturing rightfully has a reputation as a clean technology, but there is so much more to be done."

During the £1.7 million Scalable AM Rule Creation & Dissemination (SAMRCD) project, Authentise intends to develop tools that will enable users to identify operating rules through literature, standards, experiments, and deep learning, and to enforce these rules on future production to ensure more efficient and repeatable products.

To achieve this, the partners will integrate direct data capture from across the materials and production value chain. Photocentric and TWI will test these tools in metal and ceramic AM studies that aim to reduce energy and material used in production. The material and related production data will be supplied by ICD, with results validated by the Materials Processing Institute.

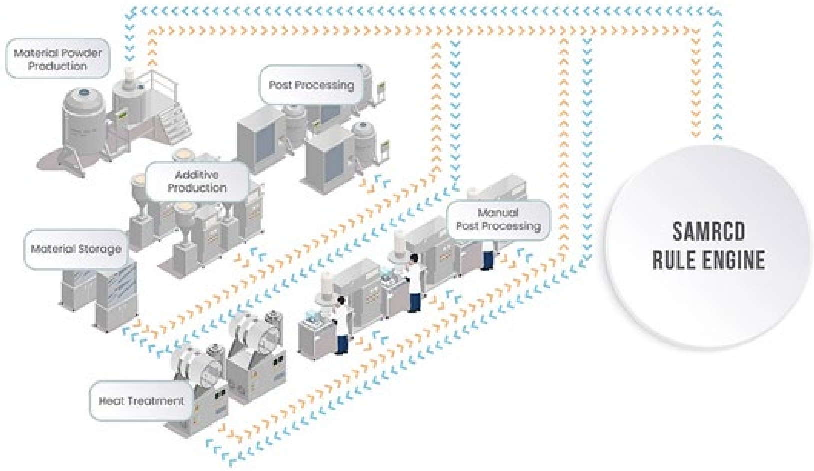
"This is the first time that the impacts of actions are considered across the entire value chain, from material production to final part," stated Carl Hauser, Section Manager – Laser Additive Manufacturing of TWI. "The SAMRCD team includes partners from across that spectrum. Together, we are able to increase the scope of in-process control from very specific in-machine processes to end-to-end monitoring. Changing material production parameters slightly may have a material impact on part production success, for instance. Thanks to SAMRCD, we won't only know that, but will be able to take direct action."

Paul Holt, CEO, Photocentric, added, "We're delighted to have been selected for this highly competitive programme by UKRI's Transforming Foundation Industries challenge. The launch of SAMRCD could not come at a more poignant time given the current headwinds facing foundation and manufacturing industries, with energy costs soaring and cost of materials increasing as supply chains compete for key metals."

Bruce Adderley, director of UKRI's Transforming Foundation Industries challenge, explained, "Collaboration is the lynchpin for innovation across these industries, as the opportunities for mutual benefits, re-use of by-products and the exchange of knowledge and skills will be essential for ensuring their journey towards improving their efficiency and productivity to meet new market challenges."

"We have seen from the quality of applications just how new technology and a commitment to combined thinking can work together to address some of the key issues affecting the sector. The development of the tools proposed within the SAMCRD project would make a profound impact in energy reduction and accelerate additive manufacturing as a viable sustainable production process as part of the UK's manufacturing capabilities," Adderley concluded.

www.authentise.com
www.icdgroup.com
www.mpiuk.com
www.photocentricgroup.com
www.twi-global.com



The partners will integrate direct data capture from across the materials and production value chain (Courtesy SAMRCD)

Desktop Metal qualifies 420 stainless steel, nickel alloy IN625 and D2 tool steel for its Production System

Desktop Metal, Inc., Boston, Massachusetts, USA, has qualified 420 stainless steel, nickel alloy IN625 and D2 tool steel for use in its Production System™ Additive Manufacturing platform. The high-speed Binder Jetting (BJT) machine is based on the company's bi-directional Single Pass Jetting™ (SPJ) technology.

420 stainless steel

A martensitic heat-treatable stainless steel, 420 stainless steel is characterised by its high strength and hardness, as well as its corrosion resistance when exposed to the atmosphere, foods, fresh water, and mild acids when in a fully hardened condition. It is a common material used extensively across a variety of applications such as surgical and dental instruments, ball bearings, gear shafts, pump and valve components, fasteners, gauges, hand tools, and high-end cutlery.

"Engineers continue to seek out metal Additive Manufacturing as a leading option to drive innovation in design and manufacturing," stated Jonah Myerberg, CTO and co-founder of Desktop Metal. "We believe our qualification of 420 SS and other high-strength alloys will accelerate the deployment of our AM 2.0 solutions among customers looking to successfully mass-produce critical parts at scale."

The company's materials science team has qualified and fully characterised 420 stainless steel additively manufactured on the Production System and found that it meets MPIF 35 standards for structural Powder Metallurgy parts set by the Metal Powder Industries Federation (MPIF). Producing 420 stainless steel parts on the Production System platform eliminates the use of tooling and minimises material waste, as well offering shorter production times and part cost compared to conventional manufacturing methods.

Nickel alloy IN625

IN625 is a nickel-chromium superalloy characterised by its high strength, resistance to corrosion and oxidation, excellent weldability, and ability to withstand extreme, elevated temperatures for parts under load. As such, IN625 is a critical material in high temperature aerospace applications, while its corrosion resistance under a range of temperatures and pressures makes it well suited to applications across marine, power generation, and chemical processing.

Cams used in oil and gas or chemical processing applications convert rotary motion into reciprocating linear motion in a machine. D2 tool steel is critical for this application because of its hardness and corrosion resistance (Courtesy Desktop Metal)

"As Desktop Metal continues to drive our internal R&D efforts to qualify more materials for the Production System platform, we are excited to offer customers an all-inclusive Binder Jetting solution to print fully characterised IN625 with excellent properties," added Myerberg.

Jason Harjo, Director, Mechanical & Electrical Design (Americas), Koch Engineered Solutions, added, "As a transformative combustion equipment company, we are very excited about the release of IN625 for its high temperature and corrosion-resistant properties in flaring and sulfur incineration applications. This will give us much more flexibility in innovative, Additive Manufacturing designs for some of our most difficult applications."

Desktop Metal's materials science team has qualified and fully characterised IN625 manufactured on its Production System technology in accordance with ASTM testing requirements. IN625 parts additively manufactured on the Production System platform were reported to eliminate the use of tooling and minimise material waste at a significantly decreased production time and part cost compared to conventional manufacturing methods.

D2 tool steel

D2 is used for a wide variety of cold work tools that require a combination of wear resistance and moderate toughness, such as coining and sizing tools, blanking and forming dies, shear cutting tools, gauges, burnishing tools, and other wear parts.

"Our materials science team is constantly working to develop new materials and processes to make 3D printing accessible to all industries and applications," explained Myerberg. "We are responding to the demand from our customers across manufacturing and industrial industries for materials like D2 tool steel that enable the production of critical forming and cutting tools and in various other applications where high hardness is valued."

One such application is rotating cams, used in oil and gas or chemical-processing applications to convert rotary motion into reciprocating linear motion in a machine. Typically, these parts require multiple manufacturing steps, beginning with CNC machining and following on with broaching of the spline on a separate machine. BJT enables the production of cams in a single build step, reducing both the cost and lead time of the part, while also supporting the production of numerous cam sizes in a single build to accommodate different machines, all without any fixturing or tooling required.

D2 tool steel is critical for this application because of its hardness and corrosion resistance, which ensures a longer lifetime as the cam mechanically interacts with a sliding pin. In addition, because these components are often integrated into machines operating in harsh environments, the corrosion resistance provided by D2 ensures that the parts will perform as intended and not deteriorate.

Desktop Metal's materials science team has qualified and fully characterised D2 tool steel additively manufactured on Production System technology in accordance with ASTM testing requirements.

www.desktopmetal.com

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- Scan to Solid Body
- Designing for the printing process

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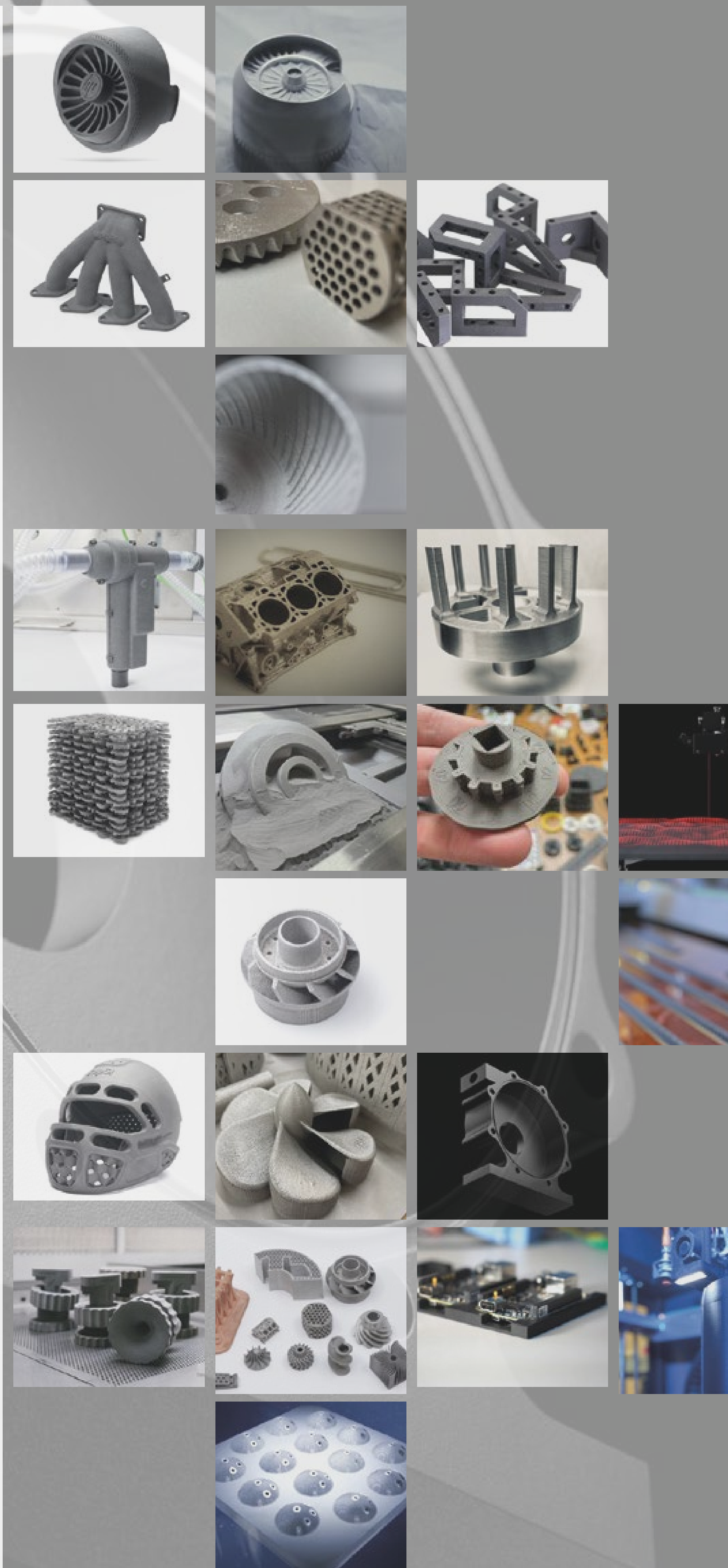

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WWW.ADDTEC3DM.COM

Edelstahl-Mechanik adds Meba saw for build plate separation

Edelstahl-Mechanik GmbH, Göppingen, Germany, an engineering company offering a wide range of production technologies, including Additive Manufacturing, has installed a MEBA3D 335 band saw from MEBA Metall-Bandsägemaschinen GmbH, Westerheim, Germany, specifically for the removal of AM parts from the build plate. The MEBA3D 335 is based on the straight-cut model MEBAeco 335, which is equipped with feed monitoring and a frequency-controlled ball screw drive. The saw includes a special clamping device for holding metal build plates; the build plate can be moved as desired via linear guides and can be precisely aligned.

The MEBA3D 335 works with a two-column guided saw frame. The machine allows very fine adjustment of cutting and feed speed and, in combination with the right selection of band saw blades for the respective material to be separated, even filigree parts can be separated with precision.

"The practical clamping system and the precise work of the band saw are convincing throughout. Compared to alternative solutions for separating the components, the Meba saw is not only time- and resource-efficient, but also cost-effective. In addition, the components have a very high quality in the end," stated Josef Eisele, Managing Director of Edelstahl-Mechanik.

In addition to its reputed ease of handling, the MEBA3D saw is also said to easily meet the occupational health and safety criteria. Equipped with a protective enclosure and an industrial vacuum cleaner for removing coarse dust, the saw provides a clean working environment wherein the machine operator does not inhale powder or get it on their skin.

The MEBA3D 335 can also be used for standard sawing work. "We needed a solution to remove the 3D-printed parts from the base plate. As a further positive side effect, the saw can also be used for standard sawing tasks and is, therefore, the perfect complement to the 3D printer in the overall package," Eisele concluded.

www.edelstahl-mechanik.de
www.meba-saw.com

The MEBA3D 335 is equipped with a special clamping device for holding the build plates (Courtesy Meba)

Digital Metal and Etteplan partner to advance transition to AM

Digital Metal, part of Sweden's Höganäs Group, and global engineering company Etteplan, Espoo, Finland, have announced that they will enter a strategic partnership to offer guidance to existing and new customers looking to make the transition to Additive Manufacturing.

The companies aim to provide design optimisation solutions for Digital Metal's Binder Jetting (BJT) processes and to offer manufacturing companies the full benefit of the technology – from idea to complete component with volume production in mind.

"Together with Etteplan we will be able to offer a stronger value proposition, covering a complete design and manufacturing process, to our customers," stated Christian Lönne, CEO at Digital Metal. "The partnership gives us access to a world-class design team that complements our business very well."

Etteplan provides software and embedded solutions, industrial equipment and plant engineering and technical documentation solutions. In 2020, it had a turnover of approximately €260 million and employs over 3,500.

The companies explain that by combining Digital Metal's expertise in BJT with Etteplan's knowledge in the design of components for AM, their goal is to accelerate the transition from traditional manufacturing to Additive Manufacturing.

Riku Riikonen, SVP, Engineering Solutions, Etteplan, commented, "Etteplan has invested heavily in Additive Manufacturing and has been involved in groundbreaking engineering already for a long time. We look forward to exploring and create synergies together with Digital Metal. The partnership will strengthen both Etteplan's as well as Digital Metal's offerings towards existing and future customers."

www.digitalmetal.tech
www.etteplan.com

PostProcess and AddUp partner to streamline AM processes

PostProcess, headquartered in Buffalo, New York, USA, has partnered with AddUp Group, based in France, with a goal of delivering streamlined processes to additive users. AddUp offers a catalogue of multi-technology production systems and on-demand part manufacturing. The alliance with PostProcess brings post-build technology both in house and to users with software-driven, scalable surface finishing.

AddUp's FormUp 350 was launched in May (Courtesy AddUp)

Both companies share the vision that AM will not scale sustainably unless the entire process flow from design to finished part is digitised and automated. This requires industry collaboration among the ecosystem players. With this partnership, AddUp and PostProcess lay the foundation for scaling affordably and safely the production of AM parts by not only reducing the cost of post-processing, but also improving safety and traceability through digitisation and automation.

Work has started with an initial focus on parts additively manufactured by AddUp and post processed with the PostProcess DECI Duo™ automated metal surface finishing solution. AddUp will also implement the DECI Duo solution in two of its facilities in France and the USA.

Medhi Offroy, Post-processing Methods Engineer at AddUp Group, stated, "We found in PostProcess Technologies the perfect match for a partnership. Digital integration in the post-processing of Additive Manufacturing is the point we were looking for to improve the value chain. The DECI Duo solution is really interesting to reduce surface roughness on delicate metal 3D printed parts. Now we can reach inaccessible surfaces in a quick execution time."

AddUp's AM machine, the FormUp®350 New Generation – launched in May – is able to produce metal parts not only with medium particle size powder, but also with fine powder, which improves the final result of surface roughness reduction.

"We found different applications in every field we work with to apply the combination of the FormUp 350 and the DECI Duo to meet the most challenging requirements of our customers," stated Frank Moreau, AddUp CEO.

Bruno Bourguet, Managing Director, PostProcess Technologies International, concluded, "When considering the potential of Additive Manufacturing's impact, the need to connect the ecosystem and enable processes through digitalisation is paramount. This relationship does both of those things. We are delighted to partner with an esteemed name in the global metal 3D printing space and look forward to jointly help customers globally."

www.addupsolutions.com
www.postprocess.com

TÜV SÜD offers certification for new ISO/ASTM standard

TÜV SÜD, Munich, Germany, now offers certification of industrial Additive Manufacturing sites in accordance with the new ISO/ASTM 52920 standard. The standard describes quality assurance requirements and forms part of the ISO/ASTM 52900 series, which outlines fundamental AM principles.

"Using the new standard, component manufacturers can streamline supplier audits to an enormous extent," stated Simon Schlagintweit, Lead Auditor Additive Manufacturing, TÜV SÜD. "This facilitates the auditing process and ensures the quality of industrial-scale Additive Manufacturing throughout the supply chain."

Even the smallest deviations in feedstock or machine calibration may adversely affect component stability. Given this, ISO/ASTM 52920 defines both quality-related factors in the process chain and processes at manufacturing sites. The standard is divided into three aspects: 'Qualification of the additive system operations', 'Quality assurance' and 'Verification of the part requirements', while sub-aspects include data preparation, system setup and post-processing.

The new standard adopts an integrated, rather than a product-specific approach, suitable for regulated sectors, including the automotive, rail, aerospace and medtech industries. It applies to all methods included in the scope of the ISO/ASTM 52900 standard and was developed in a collaboration between the ISO/TC 261 Additive Manufacturing and CEN/TC 438 Additive Manufacturing Processes Technical Committees of the French standardisation institute, Association française de normalisation (AFNOR). In Germany, the Additive Manufacturing working committee of the DIN Standards Committee Technology of Materials was involved in the development.

TÜV SÜD provides AM quality assurance support, including knowledgeable personnel, implementation of defined manufacturing processes and handling of special feedstock, as well as issues such as standardisation, delivery periods and reproducible quality.

www.iso.org/standard/76911.html
www.tuvsud.com

Australian Army succeeds in producing AM armoured vehicle parts in the field

SPEE3D, Melbourne, Australia, reports that the Australian Army has proven it is possible to additively manufacture and replace armoured vehicle parts in the field, having done so during Exercise Koolendong, an annual bilateral military exercise between the Australian Army and the Marine Rotational Force – Darwin. Various parts for the M113 Armored Personnel Carrier were replaced with metal parts additively manufactured on-site, using SPEE3D's cold-spray AM WarpSPEE3D metal AM machine. Parts were identified, additively manufactured, certified and subsequently installed on vehicles.

The Australian Army is rapidly developing its metal manufacturing capability and, with the WarpSPEE3D, is said to be able to create significantly faster and more cost-effective metal part production than any other process. The machine can additively manufacture large metal parts up to 40 kg at a record rate of 100 g per minute.

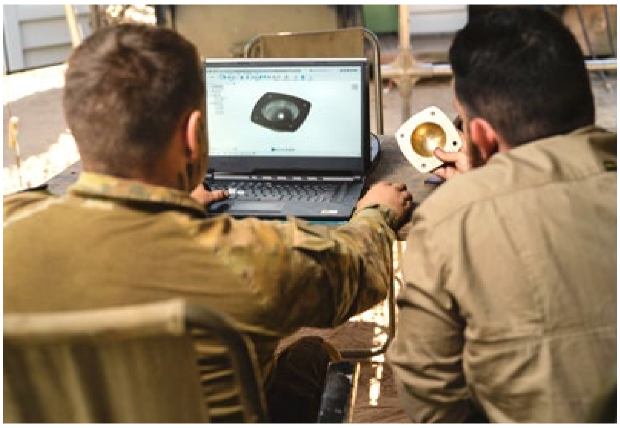
SPEE3D has been working closely with the Australian Army and Royal Australian Navy to bring this capability to the Australian Defence Force with world-first field trials designed to test the feasibility of deploying metal AM as a capability, both in barracks and in the field. A number of field trials in 2020 resulted in over fifty case studies of printable parts and demonstrated that SPEE3D's WarpSPEE3D machine was robust enough to operate in remote Australian bushland. The programme was extended in 2021 to verify initial results.

Throughout 2021, SPEE3D states that it has been helping train the Australian Army's first military Additive Manufacturing Cell (AMC) technicians who specialise in the production of metal AM parts, from design, building, machining, heat-treatment, through to certification. In the remote bushland of Bradshaw Training Area in the Northern Territory, the AMC and SPEE3D recently tested the WarpSPEE3D as part of its toughest trial yet. The machine was transported in a round trip over 1200 km, over rough terrain, to operate in hot and dusty conditions for three weeks.

During the trial, the AMC produced more than a dozen different replacement parts for the M113 Armored Personnel Carrier, a vehicle that has been used by the Australian Army for over forty years. The trial aimed to prove metal AM can produce high-quality, military-grade parts that can be validated and certified for use in the field. One of the parts produced was an M113 wheel bearing cover, a part which is often damaged by trees when driven through bushland. The two-kilogram wheel bearing cover was additively manufactured in just twenty-nine minutes at a cost of $100. The team was able to additively manufacture, heat treat, machine, test and validate the parts in the field as well as redesign and fortify some parts, reducing the risk of future damage.

Byron Kennedy, SPEE3D's CEO, commented "This is a great example of how expeditionary metal 3D printing can improve defence readiness. Field trials conducted in 2020 proved SPEE3D technology was deployable. This year's trial extension was bigger, longer, and more remote, making it the world's toughest and longest metal 3D printing trial so far."

www.spee3d.com

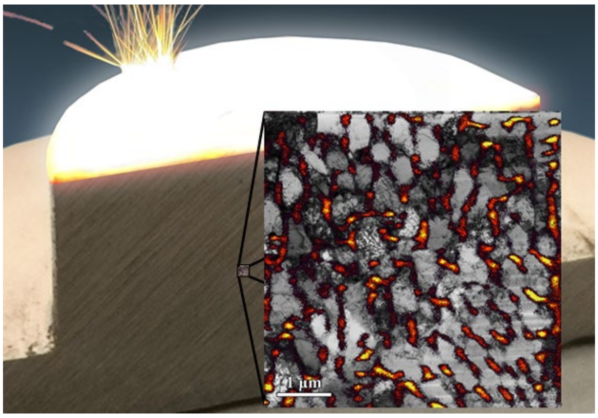


The additively manufactured wheel bearing part took just twenty-nine minutes to build (Courtesy SPEE3D)

Synchrotron X-ray techniques could lead to improved AM steel

A new study led by researchers from Stony Brook University, New York, USA, sheds light on the connection between the corrosion behaviour and underlying materials structure in additively manufactured 316L stainless steel using Laser Beam Powder Bed Fusion (PBF-LB) technology. Using multimodal synchrotron X-ray techniques, the team reported new connections between build parameters and the defect state in the material. This enables the researchers to map pathways for engineering an even better corrosion-resistant additively manufactured alloy.

The findings, published in the November issue of peer-reviewed journal *Additive Manufacturing*, could enable the future production of a highly corrosion-resistant stainless steel by engineering its defects at the nanoscale. The research also demonstrated that multimodal synchrotron techniques are becoming essential tools in establishing correlations between the AM process, underlying structure of the material and its realised performance.



The research into additively manufactured 316L revealed a heterogeneous, correlative distribution of crystal defects in the bright-field transmission electron micrograph (grey) and alloying elements in the superimposed X-ray fluorescence map (colour) (Courtesy Dr W Streit Cunningham and Prof Jason Trelewicz, Stony Brook University)

"The major focus of our study was to understand the corrosion behaviour of laser additively manufactured 316L stainless steel in the context of microstructural defects that form due to the rapid solidification rates inherent to this 3D printing process," stated Jason Trelewicz, co-author and associate professor of Materials Science and Engineering at the College of Engineering and Applied Sciences and the Institute for Advanced Computational Science, both in Stony Brook. "We show that while uniform surface corrosion of the printed 316L is similar to a traditional 316L alloy, the printed material exhibits an increased susceptibility to pitting, particularly in the samples with the greatest defect density uncovered from our synchrotron measurements."

The team, consisting of research scientists and students in Professor Trelewicz's group, the Engineered Microstructures and Radiation Effects Laboratory, working with collaborators at Brookhaven National Laboratory, conducted the synchrotron X-ray experiments at Brookhaven's National Synchrotron Light Source II (NSLS-II) in Upton, New York.

The 316L samples were additively manufactured at the Pennsylvania State University by collaborator Professor Guha Manogharan. The team performed correlative electron microscopy at the Center for Functional Nanomaterials (CFN) at Brookhaven and corrosion measurements were performed at Stony Brook University.

Beyond the development of novel additively manufactured materials, Trelewicz says the findings highlight the critical role correlative synchrotron X-ray and electron microscopy measurements can play in building a detailed picture of volume-averaged microstructural trends in materials developed by PBF-LB Additive Manufacturing.

www.stonybrook.edu
www.bnl.gov

UKRI fellowship scheme funds research into metal AM for electrical machines

In late September, UK Science Minister Amanda Solloway announced a cash boost of £4.5 million to the University of Bristol. The investment, delivered through UK Research and Innovation (UKRI)'s flagship Future Leaders Fellowships scheme, will enable scientists and researchers in Bristol and across the UK to fund vital equipment and researcher wages to help drive studies forward more quickly.

"I am delighted that UKRI is able to support the next generation of research and innovation leaders through our Future Leaders Fellowship programme," stated Professor Dame Ottoline Leyser, UKRI Chief Executive. "The new fellows announced today will have the support and freedom they need to pursue their research and innovation ideas, delivering new knowledge and understanding and tackling some of the greatest challenges of our time."

Ninety-seven of the UK's top researchers will be backed with £113 million to help bring their ideas from lab to market, and provide bold solutions to tackle major global issues ranging from climate change and chronic disease to hate speech.

"Ending our contribution to climate change will mean harnessing the talents of innovators across the UK, not least in the South West of England," Solloway added. "I'm delighted that this fantastic work by researchers at the University of Bristol will help us take another step towards that goal, thanks to £4.5 million of government funding."

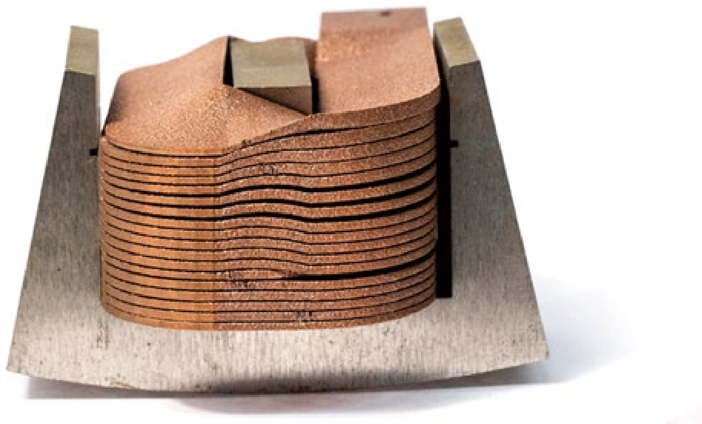
The researchers being funded at the University of Bristol include Dr Nick Simpson, who will lead a comprehensive research programme into metal Additive Manufacturing for electrical machines. Step changes in e-machine performance are central to the success of future More-Electric and All-Electric transport initiatives, and play a vital role in meeting the UK's net-zero emission target by 2050. E-machine technology roadmaps from the Advanced Propulsion Centre (APC) and Aerospace Technology Institute (ATI), however, seek continuous power-density of between 9 and 25 kW/kg by 2035, in stark contrast to the 2-5 kW/kg available today.

E-machine power-density is ultimately limited by the ability to dissipate internally generated losses, which manifest as heat, and the temperature rating of the electrical insulation system. The electrical conductors (windings) are often the dominant loss source and are conventionally formed from electrically insulated copper or aluminium conductors. Such conductors are manufactured using a drawing and insulation technique, which, aside from improvements in materials, has seen little change in the past century. Exploring alternative manufacturing methods could allow a reduction in losses, enhanced heat extraction and facilitate increased temperature ratings, ushering the necessary step changes in power-density and e-machine performance.

The design freedom offered by AM provides many sought-after opportunities to simultaneously reduce winding losses and packaging volume, improve thermal management and enable the use of high-temperature electrical insulation coatings. The design of these windings requires the development of new multi-physics design tools accounting for electromagnetic, thermo- and fluid-dynamics, mechanical and Design for AM (DfAM), of which establishing how to use build supports and post-processes to improve component surface quality and facilitate application of electrical insulation coatings is an important aspect. To this end, Dr Simpson has conducted initial studies in collaboration with academic and industrial partners focusing on shaped profile windings which have demonstrated the potential benefits of metal AM in e-machines and the drastic expansion of design possibilities to be explored.

Dr Simpson intends to expand on this initial work through the new fellowship, which will provide flexible funding over a four and three-year term to support The Electrical Machine Works, a comprehensive research programme reminiscent of a skunk works project. This will draw together UK industry and academic expertise in AM, material science and multi-physics e-machine design to establish an internationally leading platform in this important emerging field.

It is intended that the fellowship and associated platform, The Electrical Machine Works, will facilitate



Currently, all AM research is being performed with CuCrZr and pure copper on Laser Beam Powder Bed Fusion (PBF-LB) machines (Courtesy Dr Nick Simpson)

Research is intended to expand to include AlSiMg and pure aluminium (Courtesy Dr Nick Simpson)

interdisciplinary collaboration with both industry and academia, catalysing high-quality academic outputs disseminated through appropriate conference and journal publications, and the generation of intellectual property (IP), helping to keep the UK competitive in power electronics machines and drives – perhaps even at the forefront.

If successful, in time, The Electrical Machine Works may become a centre of excellence for AM in e-machines, contributing to a future skills and people pipeline and aiding in the raising of technology readiness levels in line with national priorities as expressed by the UK's Industrial Strategy, Advanced Propulsion Centre (APC), Aerospace Technology Institute (ATI) and Industrial Strategy Challenge Fund (ISCF) Driving the Electric Revolution (DER) and Future Flight (FF) initiatives.

Currently, all research is being performed with CuCrZr and pure copper on Laser Beam Powder Bed Fusion (PBF-LB) machines, but is intended to expand to include AlSiMg and pure aluminium, with later investigations planned into the suitability of Binder Jetting (BJT) and photopolymerisation.

The government has committed over £900 million to its Future Leader Fellowship initiative over three years. The projects being backed today will be an important part of the government's ambition to cement the UK's status as a global leader in science, research and innovation, as set out through the publication of the Innovation Strategy in July. The latest funding forms part of the government's commitment to increase public spending in R&D by £22 billion by 2024 to 2025, putting the UK on track to reach 2.4% of GDP being spent on R&D across the UK economy by 2027.

Solloway concluded, "We are putting science and innovation at the heart of our efforts to build back better from COVID-19, empowering our scientific leaders of tomorrow to drive forward game-changing research and helping to secure the UK's status as a global science superpower."

www.bristol.ac.uk
www.ukri.org

MPIF announces winner of 2021 Metal AM Outstanding Technical Paper Award

'Electrostatic Charging and its Impact on Powder Flowability', by Louis-Philippe Lefebvre, Roger Pelletier and Cindy Charbonneau, of the National Research Council Canada, has been selected for the 2021 Metal AM Outstanding Technical Paper Award. The paper was chosen after a critical evaluation of the highly qualified manuscripts presented at the AMPM2021 conference.

The Metal AM Outstanding Technical Paper Award was established in 2018 to recognise authors of manuscripts for excellence in scientific and technical written communications. The award is for papers presented and submitted for publication from the annual Additive Manufacturing with Powder Metallurgy conference organised by the Metal Powder Industries Federation (MPIF) and APMI International.

The award aims to enhance the quality of technology transfer in the PM literature by increasing the professional level of papers submitted for the conference and to enhance and promote the science and technology which is fundamental to additively manufactured Powder Metallurgy products, processes and materials.

Paper excellence is measured using a system of four quality standards: the paper is scientifically or technically new, innovative, or is a constructive review; has clear presentation in writing, organisation, graphics, format, and has professional integrity; has clear industrial application; and has long-term value.

The authors will be officially recognised during AMPM2022, scheduled to take place in Portland, Oregon, USA, from June 12–15.

The paper is now available to read from the MPIF website.

www.mpif.org

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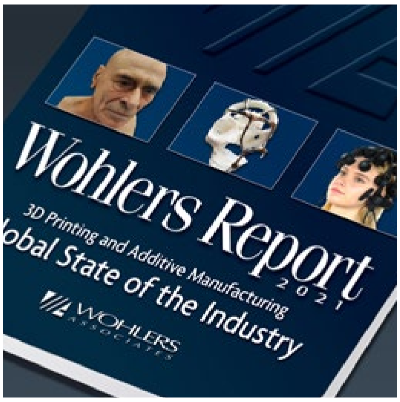
ASTM International acquires Wohlers Associates

Global standards organisation ASTM International has announced the acquisition of Wohlers Associates, Inc., Fort Collins, Colorado, USA, a leading Additive Manufacturing consultancy and market intelligence specialist. As part of the acquisition, ASTM International will acquire the *Wohlers Report,* an industry-leading market analysis for the AM industry.

"We are thrilled to welcome Wohlers Associates to the ASTM family," stated Katharine Morgan, ASTM International president.



Wohlers Associates, Inc published its Wohlers Report 2021 earlier this year (Courtesy Wohlers Associates, Inc)

"Wohlers has been a trusted source of intelligence and analysis for the AM community for more than thirty years, and I am excited to see what our two trusted and credible brands can accomplish together for this industry."

Morgan looks forward to combining the *Wohlers Report*, and the full portfolio of products and services from Wohlers Associates, with the work of ASTM's members and the AM Center of Excellence (CoE). This alignment will result in new possibilities for business intelligence, advice, and resources in the global AM community.

Moving forward, Wohlers Associates will do business as 'Wohlers Associates, powered by ASTM International'. Terry Wohlers, the organisation's principal consultant and president, will join ASTM International and serve as head of AM market intelligence. Noah Mostow of Wohlers Associates will become ASTM's new manager of AM market intelligence and analytics. Both will serve under ASTM's AM CoE.

"I could not be more excited about joining the world-class team at ASTM International," added Wohlers. "Through ASTM, we can now accept more projects than in the past and our advisory services team is now larger than ever. We are glad ASTM has made a commitment to publishing the report for years to come."

Future editions of the *Wohlers Report* are expected to be integrated into ASTM's flagship product Compass, an online subscription platform. Wohlers has expressed his confidence in ASTM International's ability to maintain the quality, neutrality, and value customers expect from the *Wohlers Report*.

The acquisition of the Wohlers brand is said to support ASTM's growth vision and investment to expand its footprint in the AM industry with robust AM programmes, services, and product offerings. These newly acquired services complement the organisation's existing programmes and services to support the industrialisation of AM technologies.

ASTM intends to leverage the existing Wohlers brand and build on its market influence and access to AM industry decision-makers worldwide. The acquisition is expected to bring new value to many industries, thus enabling wider adoption of AM products and services.

www.wohlersassociates.com
www.amcoe.org

Formnext USA to launch in 2025

Formnext organiser Mesago Messe Frankfurt and Messe Frankfurt North America have announced that, in partnership with Gardner Business Media Inc (GBM) and the Association for Manufacturing Technology (AMT), they will launch Formnext USA in 2025. The event is scheduled to take place in Chicago, Illinois, at McCormick Place, from March 14–16.

AMT will bring with it its experience in producing IMTS – The International Manufacturing Technology Show, reported to be the largest manufacturing technology event in the Americas, as well as members who represent a growing and prominent Additive Manufacturing community. GBM will focus on the marketing and promotion of the event.

Prompted by the continued and accelerated adoption of AM in the USA, the partners will debut a series of events with the Formnext brand to build its presence in the country. Formnext is scheduled to make its US market debut at IMTS – The International Manufacturing Technology Show, which runs in Chicago from September 12–17, 2022. Formnext will present the AM4U Area in the show's AM pavilion.

In 2023, the AM4U Area presented by Formnext will be co-located with the Additive Manufacturing Conference in Austin, Texas.

Launching in 2024, Formnext Forum Austin starts as a new event of Formnext in Germany. It will feature a range of topical seminars and exhibition areas covering a variety of AM and next-generation smart industrial production solutions.

"Formnext has been a resounding success as the global meeting point in Europe, and we are confident that the combination of Additive Manufacturing, materials and innovative process technologies will also perfectly address the current and future needs of the North American manufacturing industry," stated Sascha Wenzler, VP for Formnext at Mesago Messe Frankfurt.

www.formnext.com

GE and US Air Force reach milestone in Pacer Edge programme

Building on the earlier success and momentum of the Pacer Edge programme, GE Additive and the US Air Force (USAF) entered Phase III of its metal Additive Manufacturing pathfinder. This phase aims to tackle the USAF's sustainment 'cold starts' (aircraft engine components that take over 300 days to procure) head-on. Currently, the organisation faces approximately 800 cold starts each year.

"The first priority for the USAF and GE team has been to create digital 3D technical data packages (TDPs) for hard-to-procure, obsolete cold start parts and deliver four airworthy, near-net castings. These TDPs will eventually mean that part obsolescence will be a thing of the past," stated Alexa Polites, USAF Pacer Edge programme manager, GE Additive.

Over the coming years, the joint team intends to create at least five TDPs, increasing in technical complexity, across the USAF's sustainment platforms.

"The teaming of GE and the USAF legitimises utilisation of Additive Manufacturing to address critical needs of the ageing aircraft that are currently unsupported within the existing supply chain," stated Zack Miller, Chief, Advanced Manufacturing Program Office, Air Force Rapid Sustainment Office.

Bellcrank and cross shaft arm, additively manufactured in colbalt-chrome on a GE Additive M2 Series 5 machine (Courtesy GE Additive)

Beth Dittmer, Chief, Propulsion Integration Division, Tinker Air Force Base (AFB), Oklahoma, added, "Pacer Edge is accelerating the USAF's widespread adoption of 3D metal printing to organically solve supply chain shortages and realising its promise to improve warfighter support by drastically reducing lead times and creating additional sourcing options."

Phase III is reported to have already resulted in two successfully additively manufactured components: a bellcrank and a cross shaft arm (pictured). These were manufactured in cobalt-chrome on a Concept Laser M2 Series 5 at GE Additive's Cincinnati, Ohio, facility. Progress has also been made on additional components using Alloy 718.

The cornerstone goal of the Pacer Edge programme is the creation of organic capabilities at Tinker AFB. One way to achieve that is by ensuring that intellectual property generated within the programme is owned by the US Government, enabling the USAF and Department of Defense to additively manufacture these parts themselves in the future. The programme remains on schedule with the goal of having airworthy production castings delivered to the USAF in spring 2022.

www.ge.com/additive

www.afrso.com

Registration opens for AMUG Conference 2022

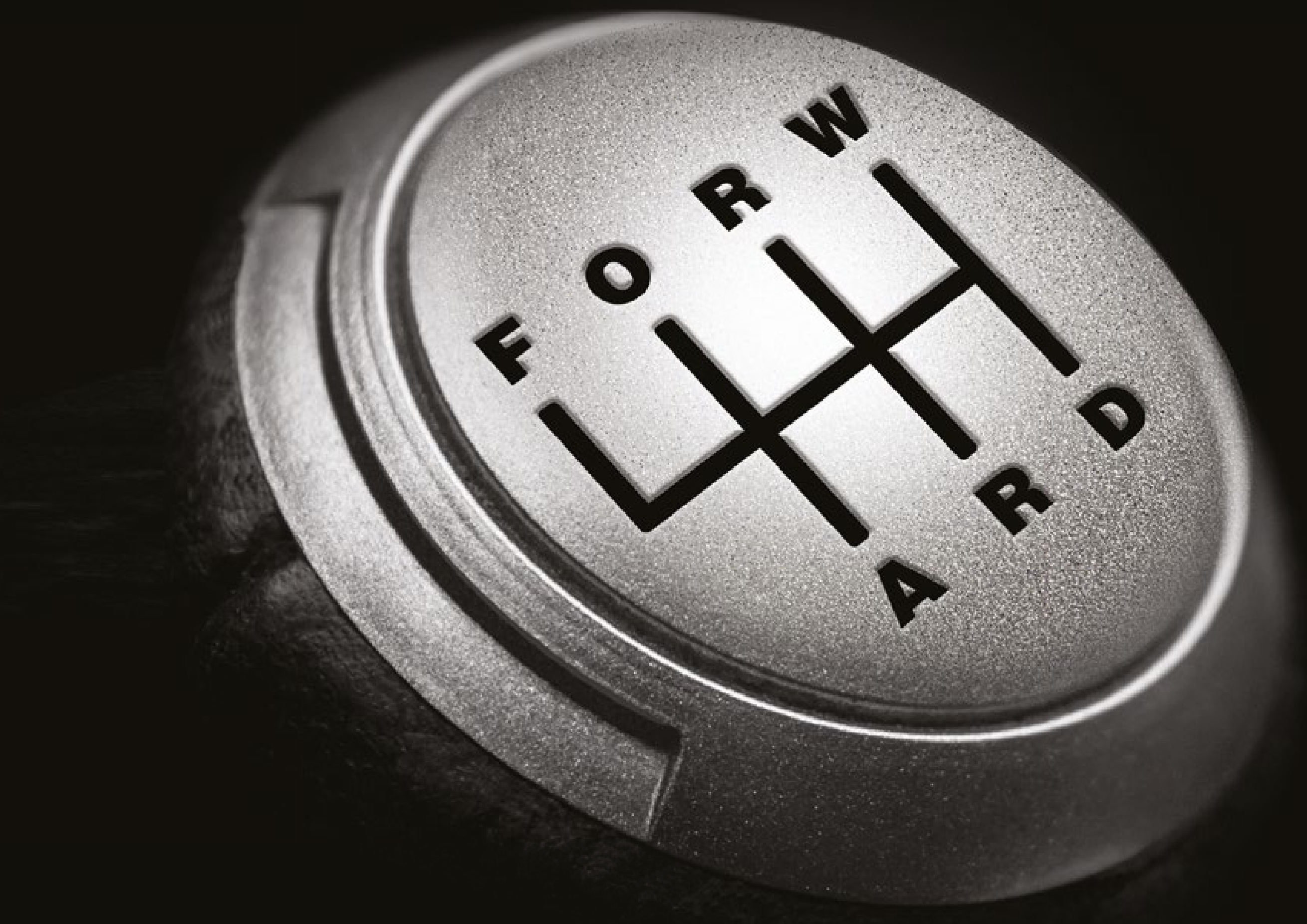
The Additive Manufacturing Users Group (AMUG) has opened online registration for its 2022 AMUG Conference, scheduled for April 3–7, in Chicago, Illinois, USA. The AMUG Conference is a unique gathering of AM users, of all experience levels, that assemble to provide and share valuable insights and experiences. Through dialogue from the stage and conversations during breaks, meals and networking activities, AM users share expertise, best practices, real-world results, challenges and application developments. With a programme that encourages participation from early in the morning to late at night, attendees can interact with their peers for over fifty hours over the five-day event.

The AMUG Conference will include keynotes, panel discussions, technical sessions and hands-on workshops designed to help users get more from, and do more with, their AM solutions. Building from past agendas, AMUG is adjusting its 2022 conference programme to deliver more training and hands-on experiences – for example, workshops and Training Labs will offer engaging environments where the AM tools are the focal point of the information exchange.

The conference agenda is expected to offer nearly 150 presentations and hands-on workshops. One highlight will be the seventh annual Innovators Showcase. The showcase is an on-stage interview, which has the feel of a fireside chat, where attendees get to know an innovator in the industry and discover insights from that individual's experiences. The conference programme also includes the AMUGexpo, which is expected to have over 140 participating companies from April 3–4.

Early registration, available until January 7, offers registrants a 33% reduction in attendance cost. Sign up is available through the organisation's website.

www.amug.com


FORWARD

Additively manufactured Ford Mustang exhaust system boosts performance

Eplus3D, Hangzhou, China, reports that it has recently worked on the development of an exhaust system for a Ford Mustang, customising and optimising its performance though the use of metal Additive Manufacturing.

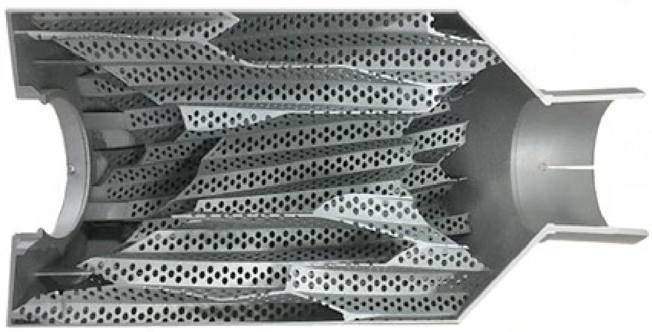
Having been contacted by a car modification company, Eplus3D looked at how AM could be used to customise exhaust components – not only to improve performance, but to adjust the sound that the exhaust system makes. The objective was to be able to make these adjustments lawfully while offering the car enthusiast an alternative to the stock exhaust option. The exhaust components were evaluated by Eplus3D, and, in the early stage of the project, Eplus3D's designers produced a customised 3D model using the Rhino design software. The internal structure of the exhaust pipe was optimised and designed for the AM process, increasing the operation efficiency and reducing its size.

After completing the design, Eplus3D produced a polymer AM model of the exhaust pipe used to test the gas flow and visually communicate the design to the customer, enabling further product improvement where needed.

The final design was said to offer a more pleasing, supercar-like sound (as requested by the customer), and reduced the weight of the system by around 67%. The optimised gas flow helped alleviate issues with power loss, often found when exhaust systems are unable to output the exhaust gas effectively at higher speeds.

Once the design was confirmed, Eplus3D used a number of its nationwide AM service centres to simultaneously build multiple components on its EP-M260 AM machines, thus shortening the time of delivery. The part is reported to be currently under trial on the Ford Mustang.

www.eplus3d.com



The final design reduced the weight of the system by around 67% (Courtesy Eplus3D)

The optimised exhaust part is under trials on the customer's Ford Mustang (Courtesy Eplus3D)

America Makes and ANSI release Gaps report on 'Standardization Roadmap for Additive Manufacturing'

America Makes, Youngstown, Ohio, USA, and the American National Standards Institute (ANSI) have announced the availability of a Gaps Progress Report, which tracks efforts by standards developing organisations and others to address gaps identified in the 'Standarization Roadmap for Additive Manufacturing' (version 2.0), published by the America Makes and ANSI Additive Manufacturing Standardization Collaborative (AMSC).

The AMSC is a cross-sector coordinating body established in 2016 whose objective is to accelerate the development of industry-wide AM standards and specifications consistent with stakeholder needs. Developed with contributions from more than 300 individuals from 175 public- and private-sector organisations, 'Standardization Roadmap for Additive Manufacturing' lists published standards, those being developed, and others that are needed to help develop the AM industry. It identifies ninety-three gaps where no published standard or specification currently exists to respond to a particular industry need. The roadmap also flags sixty-five of these gaps as requiring pre-standardisation research and development.

The Gaps Progress Report was compiled by ANSI staff based on inputs from standards developing organisations, subject matter experts, alert mechanisms, and independent research. It lists newly published standards and new standards projects, alongside suggestions for future roadmap modifications. The report is not a consensus document, but is intended to serve as a 'living document' that will be maintained and periodically re-published as standards development work continues or until such time as the AMSC undertakes to develop a next version of its standardisation roadmap.

www.americamakes.us
www.ansi.org

Additive Appliances looks to AM for coffee machine heat exchangers

Additive Appliances, an Italian-based startup developing optimised household appliances, has announced that, together with Kilometro Rosso Innovation District, it has secured an EU grant via the Digital Innovation Hub for its project to develop additively manufactured heat exchangers for domestic coffee machines. The funding is expected to accelerate Additive Appliances' development of an efficient, more sustainable coffee machine.

In a coffee machine, controlling the water temperature and pressure is key to extracting the best out of the coffee, explained Additive Appliances. The machines can use electro-thermic devices to control the process variables, but this involves embedding several components which can be hard to recycle; thermo-mechanic devices, on the other hand, are easier to recycle, but don't always perform as accurately, and have issues with repeatability and quality. Currently, consumers have to trade off between quality and sustainability, the company stated.

Additive Appliances aims at changing this by leveraging AM at different stages of product development, including final parts production. The blend of AM and conventional manufacturing makes it possible to control temperature and pressure through embedded, conformal, high-efficiency – yet ultra-compact – heat exchangers.

"If we look at the history of consumer products, major state-of-the-art advancements usually belong to new or improved technology. Coffee machines are no exception: steam power, electricity, and electronics are good examples of how technology impacted coffee brewing," stated Tommaso Beccuti, Chief Executive Officer, Additive Appliances. "We are now adding digital manufacturing technologies to that list, pioneering the exploration of a new design and manufacturing space for coffee machines. Indeed, we believe many other appliances can be enhanced by AM, and our vision goes beyond coffee. Working with Kilometro Rosso will be a further step to fulfil it."

Additive Appliances is developing additively manufactured heat exchangers for domestic coffee machines (Courtesy Pexels)

The use of AM can also enable functional personalisation, where small batches can be engineered to exalt specialty coffee varieties, or to individual consumer preferences. AM can also reduce the overall number of components needed, significantly reducing the carbon footprint of the equipment's lifecycle from production to recycling.

The grant follows the closing of a successful pre-seed financing round and being announced as a winner in the AM Ventures-sponsored Additive Startup Italia competition. The DIH-World recognition is an important milestone, allowing the company to work closely with innovation districts like Kilometro Rosso and take advantage of the Digital Innovation Hub network.

Kilometro Rosso promotes Additive Manufacturing through Lisa Tech – the Living Space for Additive Technologies, a laboratory for companies and professionals who need AM production competencies and services. The laboratory is equipped with Laser Beam Powder Bed Fusion (PBF-LB) AM machines and works with aluminium and titanium powders. The infrastructure also includes an optical tomography IR system that allows real-time control of the process and component quality.

Giuseppe De Marco, Additive Manufacturing Engineer at Kilometro Rosso, concluded, "Italy is one of the propulsion centres of the European manufacturing industry, and Kilometro Rosso is a point of reference for the territory. We are always open and receptive to innovation, serving partners and supporting all innovative initiatives which are projected towards the future. We are glad to support Additive Appliances through Lisa Tech, the Living Space for Additive Technologies. We are sure the collaboration will lead to new solutions development enabled by Additive Manufacturing technologies."

www.additiveappliances.com

MX3D manufactures critical industrial pipeline clamp using hybrid process

MX3D, based in Amsterdam, the Netherlands, has successfully completed the production of an industrial pipeline clamp using its Wire Arc Additive Manufacturing (WAAM) technology, a wire-based Directed Energy Deposition (DED) process. The pipeline clamps are used in the chemical and oil & gas industries to prevent safety incidents, while extending the life of an installation before maintenance is required.

As part of the TRINITY Demonstration Programme, designed to leverage advanced manufacturing technologies for the future of European manufacturing, the pipeline clamp was made and tested in collaboration with Team Industries and TiaT, two companies with extensive experience in the maintenance, testing and (emergency) repair of complex industrial pipe systems. The BWI (Belgium Welding Institute) handled the material testing and Lloyd's Register supported MX3D with the certification process.

Short lead times are vital in the oil and gas industry, but the current lead time of pipeline repair can be as long as two to three weeks; this can translate into a potential lost value of several €100,000s to €1 million per day. Current repair processes by clamps typically rely on CNC milling, specialised manual labour, or a combination of both. Each of these processes have their downsides, however: CNC milling has high material waste (on average, >80% of the original material) and specialised labourers are becoming more scarce.

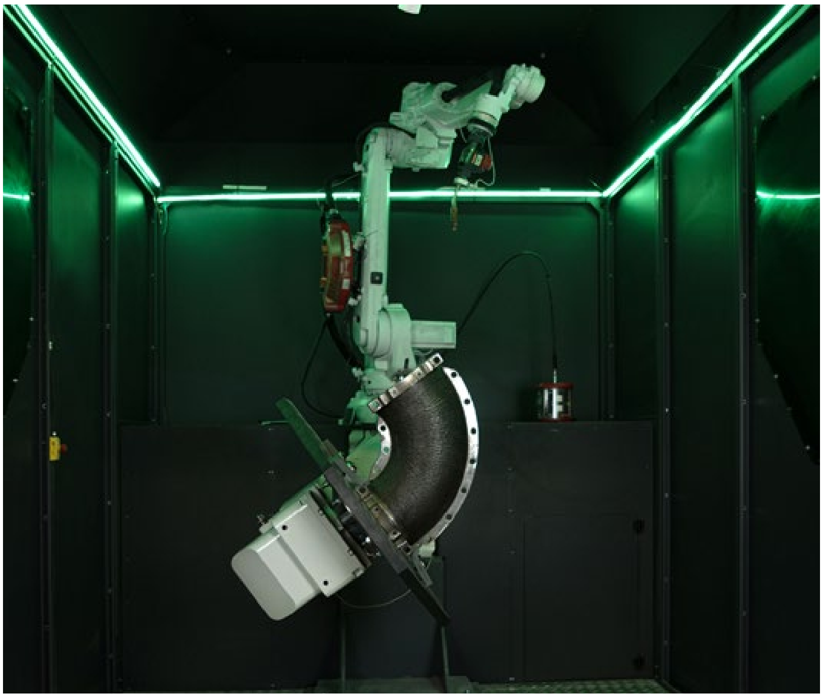
During the scope of the clamp project, a typical repair part for pipelines was researched and manufactured with a hybrid WAAM process. This technique combines the advantages of traditional manufacturing (e.g., precision machining) with the advantages of WAAM (e.g., form freedom, high deposition rates and minimal material waste).

The consortium managed to reach a high level of assurance for the clamp. The BWI tested the materials and confirmed the additively manufactured material complied with key Team Industries requirements for this material. TiaT performed non-destructive testing, such as Ultrasonic Testing (UT), Penetrant Testing (PT), Radiographic Testing (RT), showing no relevant defects. TEAM Industries also performed a pressure test, which ran until the maximum pressure of the test installation (> 60 Bar) without any failure.

"WAAM-produced components can offer a real advantage for the production of bespoke elements, as regularly used in, for example, piping, or for petrochemical industries," stated Fleur Maas, Managing Director, BWI. "The alternative production methods of these (sizeable) components tend to be relatively costly, and not always able to deliver parts quickly (for example, in the case of small series, and/or where the casting mould is no longer available)."

The base and material used was ASME IIA SA-516-70, a type of steel often used in the chemical and oil

MX3D's industrial pipeline clamp, manufactured with ASME IIA SA-516-70 using a hybrid WAAM process (Courtesy Merlin Moritz, MX3D)



The clamp being additively manufactured within the build chamber of the M1 machine (Courtesy Merlin Moritz, MX3D)

& gas industries. The requirements for the mechanical properties of this material were dictated by its most common use case: pressure vessels working at medium to low temperature. The destructive tests were performed following ASTM A370. The results of these tests proved that the additively manufactured material, even in its least favourable direction, has mechanical properties similar to or better than the base material, and, thus, fits the ASME requirements.

The project introduces Hybrid WAAM, a new approach intended to counter two known disadvantages of AM: the need for post-processing and precision. While large-scale AM can produce parts very fast, traditional manufacturing techniques can sometimes still be faster for the production of simple shapes. Conventional techniques can also achieve a higher level of precision than large-scale AM. By introducing a hybrid approach, the project consortium used WAAM only for the most complex geometrical parts of the clamp, while using traditional manufacturing for the simpler parts, resulting in time saved. Hybrid WAAM is said to have several advantages over conventional technologies such as forging, CNC-milling and manual welding (requiring speciality welders) for the oil & gas industry:

The clamp undergoing radiographic testing (Courtesy Merlin Moritz, MX3D)

- Forging: WAAM has a shorter fabrication lead time as it can produce locally, on-demand and at remote locations
- CNC-milling: WAAM has a much lower material waste due to using an additive rather than a subtractive process
- Manual welding: the manufacturer is less dependent upon the availability of speciality welders, as robots can fabricate around the clock

By incorporating pre-manufactured standard components into the WAAM process (i.e., hybrid WAAM), each of the above-described benefits are increased by reducing lead time and manufacturing time compared to regular WAAM.

"A different way of production also means a different way of inspection," added Andre Elling, TiaT. "This is what TiaT focused on during the interesting project. This new fabrication technology using robotic WAAM has promising results, even for high-demanding industries such as the oil & gas industry, where qualification is at the heart of the sector."

www.mx3d.com

MELD technology to be used in 'world's largest' metal AM machine by US Army

MELD Manufacturing Corporation's MELD technology has been selected for the US Army's Jointless Hull Program, as announced at the US Army annual meeting in Washington, DC, USA, October 11, 2021. Under the programme, MELD technology will be used to leverage AM at a very large scale.

The technology will be used on two machines, the larger being able to additively manufacture components measuring 6 x 9 x 3.5 m (20 x 30 x 12 ft), which will be installed at the Rock Island Arsenal – Joint Manufacturing and Technology Center in 2022.

A second machine will be delivered with a build volume of 1.5 x 1.2 x 0.9 m (5 x 4 x 3 ft). The effort will be carried out by a team coordinated by LIFT and led by ASTRO America, with subcontractors Ingersoll Machine Tool, Siemens, and MELD Manufacturing.

"The need for large-scale metal components with a short lead time is clear. This metal printer, capable of printing vehicle hulls, is a fantastic demonstration of what is possible with MELD," stated Dr Chase Cox, MELD's Director of Technology .

The programme, along with other US Army programs, was set to be reviewed during the Army MELD User's Group meeting, held at the Association of the United States Army (AUSA).

MELD is a patented, award-winning Additive Manufacturing technology based on a process similar to friction welding, and can be used for the building and repair of metal components using off-the-shelf solid-state materials or powder. MELD machines do not utilise conventional AM technology, and, in fact, come under their own category of process type; the process does not involve melting, and is capable of additively manufacturing fully dense parts.

www.meldmanufacturing.com

Metal AM in automotive: How the Czinger 21C is redefining next-generation car manufacturing

The Czinger 21C hypercar is a 'tour de force' of metal Additive Manufacturing. With over 350 AM components used in the vehicle's structure, suspension, brake systems, drivetrain and beyond, this is the realisation of the bold vision of Kevin Czinger, CEO of Divergent 3D. Behind the headlines about the car's record-breaking performance, however, is a far more important story: the development of the Divergent Adaptive Production System (DAPS), a complete software/hardware solution designed to replace traditional vehicle manufacturing. Jeff Kerns reports for *Metal AM* magazine.

The automotive industry is undergoing many changes, with regulations and demands for greater sustainability and electrification driving innovation. Current tooling and production volumes in the automotive industry often lead to incumbent inertia. As a result of these factors, OEMs are looking for new solutions to increase production, adhere to regulations, and increase flexibility.

Metal Additive Manufacturing is a proven solution. Other industries, such as aerospace, now widely use metal AM to increase efficiency, reduce part count, eliminate tooling, reduce time to market, and more. However, this technology is still nascent when it comes to bridging the gap between prototyping and production in the automotive space.

Divergent 3D, based in Torrance, California, USA, was founded in 2014 with the aim of revolutionising the automotive industry through advanced technologies such as metal AM. In 2019, the automotive manufacturer Czinger Vehicles was founded; this company is majority owned and controlled by Divergent 3D, but separately financed. This article introduces the company and man behind Divergent 3D, Kevin Czinger, and the Czinger 21C hypercar (Fig. 1), to explore how the solutions developed by these two companies are changing the way OEMs are thinking of automotive production.

Metal AM in the automotive industry

Prototyping with metal AM is nothing new in the automotive industry. R&D can often justify higher prices to test a part and make design iterations faster and more productive.

Fig. 1 A Czinger 21C hypercar on Hollywood Boulevard (Courtesy Czinger Vehicles)

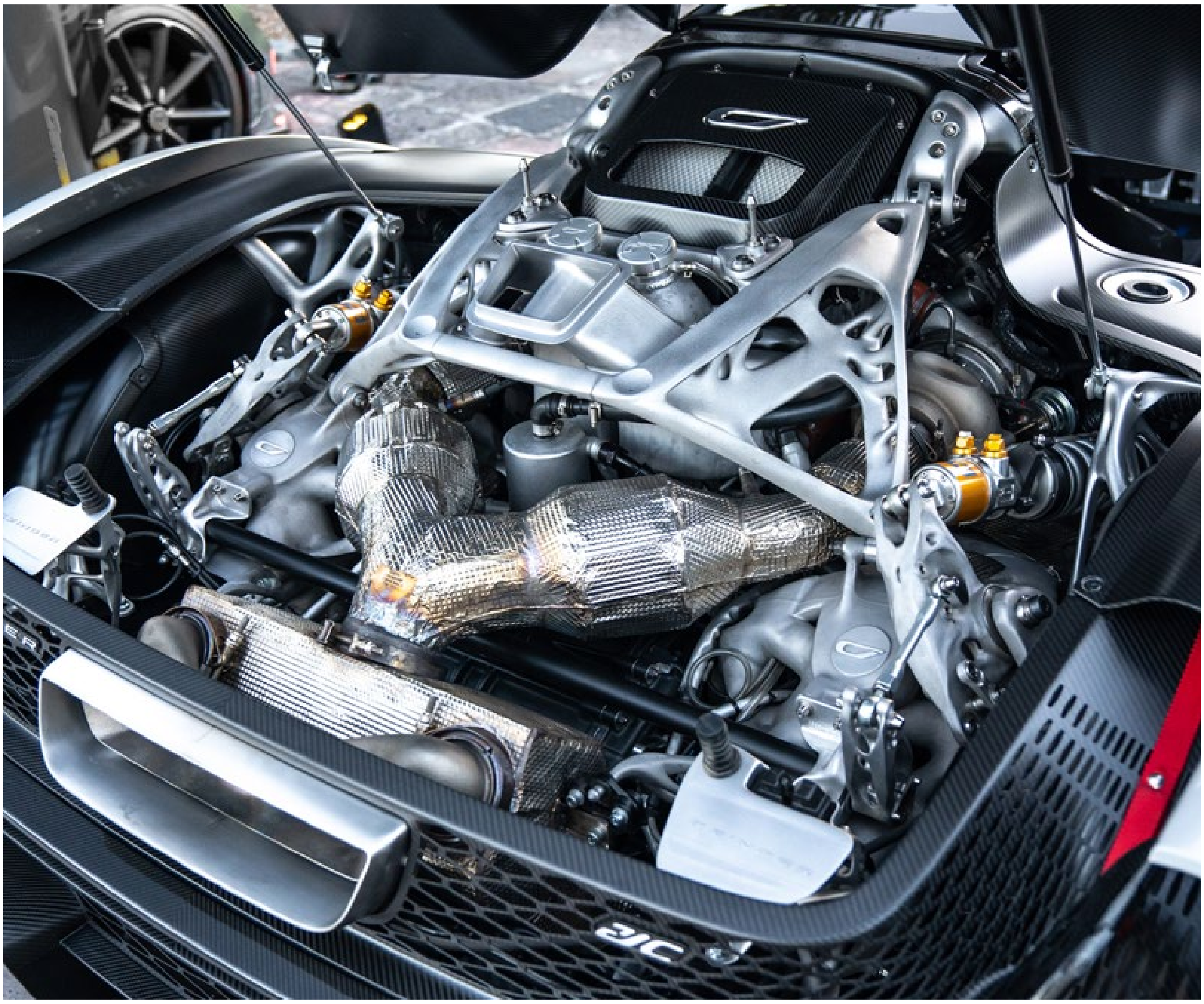


Fig. 2 View inside the engine bay of the Czinger 21C, clearly showing how the potential of metal Additive Manufacturing has been heavily leveraged throughout the car, from the vehicle's chassis to brake, suspension and exhaust components (Courtesy Czinger Vehicles)

As metal AM advances, the question looms of if, or how, this technology will move from prototyping to production.

The cost benefit of additively manufacturing conventional automotive parts is not enough to justify the investment cost for current metal AM production. For metal AM to bridge the gap between prototyping and production, engineers need to change the way they think of design. The traditional design constraints that have become standard in automotive design are not the same constraints that exist in AM. Additionally, engineers must consider how new AM solutions will scale. Industry 4.0 and more holistic solutions are producing many innovations that make great case studies, but do not easily scale to production quantities.

In 2015, Divergent 3D unveiled its proof-of-concept car, the Blade. The design for this vehicle features metal AM components and nodes that form complex integrated structures. Founder and CEO Kevin Czinger wanted to demonstrate a new way of thinking about automotive design and manufacturing. However, Divergent 3D was not planning on stopping at a concept vehicle; its goal was to mass produce vehicles with limited or no direct tooling in a fully digital end-to-end integrated system. Czinger has been challenging the automotive industry for years with a passion to build, and he believes that much of the United States' manufacturing needs a serious upgrade. Divergent 3D would later evolve this proof-of-concept into the 21C produced by the Czinger vehicle company.

"The analogue manufacturing of vehicles, and, in particular vehicle structures, is over 100 years old," stated Czinger. "It is based around single gauge sheet steel or aluminium alloy, stamping, fixturing, and welding in a very analogue, capital intensive process." The steel unibody is a foundation of automotive design, but is still manufactured similarly to the way it was at the start of the assembly line.

Static processes force the automotive company to become volume driven. When the focus of production

Fig. 3 This render of the Czinger 21C's rear structure shows how a lack of traditional processing and tooling constraints results in an integrated, more organic geometry (Courtesy Czinger Vehicles)

is on volume it hinders flexibility. One of the drivers for developing high-strength steels rather than adopting aluminium alloys is so car companies do not have to retool production lines. Aluminium is lightweight, but not as strong as steel. Designing components in aluminium would require more material and could not use the same moulds already in place for steel.

The idea of swapping one material for another is the same mentality that needs to change for metal AM to work in automotive. Simply switching from steel to aluminium, or milling to Additive Manufacturing, is not enough. The Blade offered a glimpse of how automotive design and manufacturing may have to shift to meet regulations, have more flexibility, and stay competitive in the automotive industry. The view of the engine bay (Fig. 2) and the render of the 21C's rear structure (Fig. 3) show how a lack of traditional processing and tooling constraints can result in an integrated, more organic geometry.

Challenges in moving into metal AM

"We have to get away from these 100-year-old analogue systems and mindsets," said Czinger. "With a fully digital end-to-end system, it is possible to build the functionality of braking systems, motors, battery cells, and more directly into the structure of a vehicle." Digital architecture could eliminate resources, parts, and fasteners associated with housings, brackets, and other components. This digital mindset and architecture have allowed Czinger to become the first advanced car company without any major direct tooling. But, before revolutionising automotive manufacturing, there were challenges to overcome.

Right now, AM is not known for mass production. For smaller components, metal Binder Jetting (BJT) promises increased overall build

"We have to get away from these 100-year-old analogue systems and mindsets. With a fully digital end-to-end system, it is possible to build the functionality of braking systems, motors, battery cells, and more directly into the structure of a vehicle."

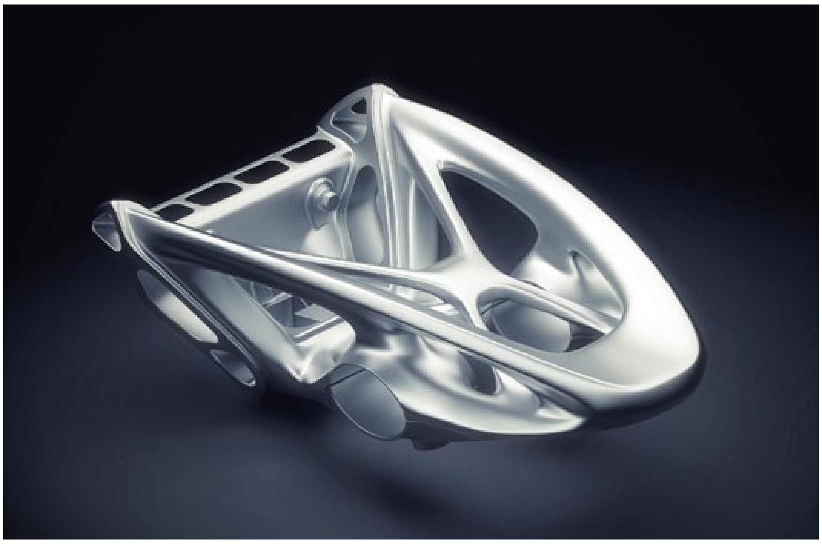


Fig. 4 The 21C's steering column (Courtesy Czinger Vehicles)

Fig. 5 The 21C's BrakeNode™, and integrated upright and brake component (Courtesy Czinger Vehicles)

Fig. 6 A rear lower control arm (Courtesy Czinger Vehicles)

rates, but as a process, it is unsuitable for the large, load-bearing parts required for the automotive structural elements designed by Divergent. That is not to say that it will not play a role in the production of smaller, lower-load bearing, AM automotive components – particularly for applications where related processes such as Metal Injection Moulding (MIM) have found success.

Electron Beam Powder Bed Fusion (PBF-EB) is used widely for aerospace component production, but current commercially available models lack the build chamber volume Divergent required, as well as suffering from a general lack of industrial penetration outside of the aerospace and medical device sectors. Also, PBF-EB is a more complex process and challenging for materials with a low melting point such as aluminium, magnesium, and zinc.

It is Laser Beam Powder Bed Fusion (PBF-LB) that can now deliver the geometric dimensioning and tolerancing (GD&T) and strength specifications needed in a wide range of automotive parts. However, when Divergent 3D was started, the technology did not offer the build rates necessary to compete at an automotive production rate.

Many companies have since worked on increasing both laser power and the number of lasers to improve build rates. Metal AM has continued to gain interest in the automotive sector, as its adoption and innovation progress in aerospace and other industries, which have benefited from its ability to produce lightweight complex parts, high capacity for customisation, and minimal to no tooling.

Reducing the tooling and upfront costs of automotive manufacturing could represent a disruptive shift in design, manufacturing, and business strategies. But, in order to demonstrate this, it was imperative for Divergent 3D to get metal AM to produce parts at a real industrial production rate. "We had to generate a manufacturing system that was fully optimised across multiple

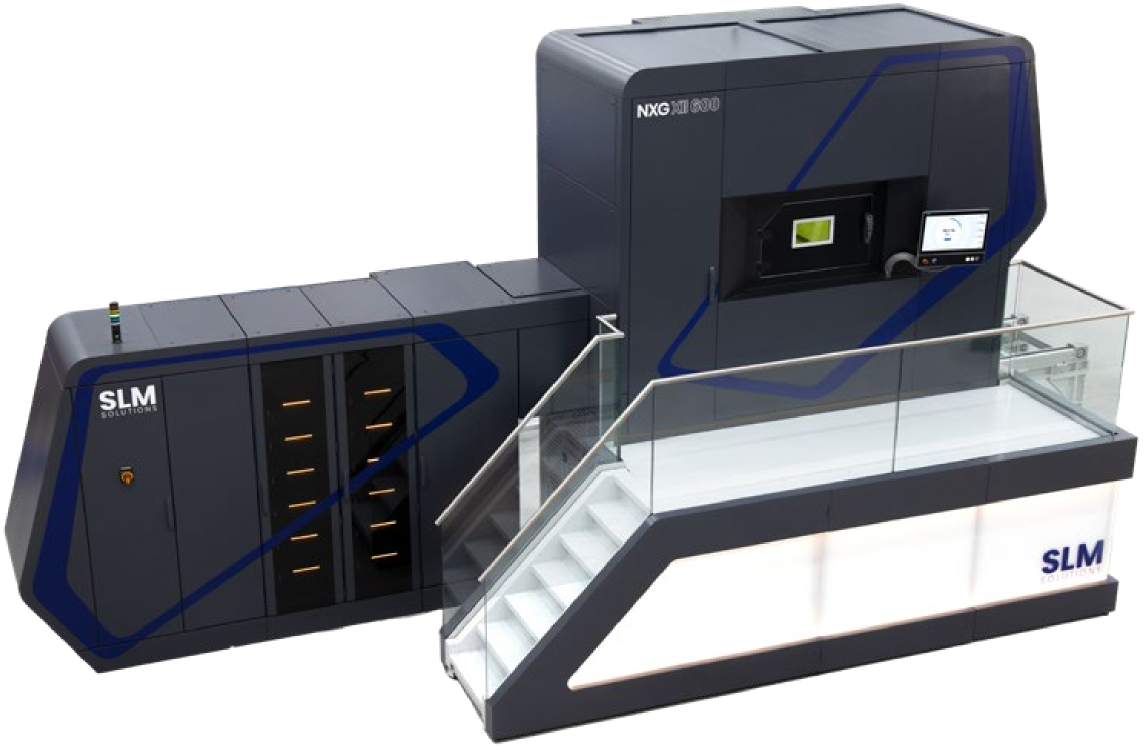


Fig. 7 The NXG XII 600 Laser Beam Powder Bed Fusion (PBF-LB) machine from SLM Solutions is, states Czinger, able to achieve the necessary automotive production rates for vehicle manufacture. Divergent 3D currently operates two NXG XII 600 metal AM machines, with the third pre-production machine being delivered in February 2022. In October 2021, it announced the purchase of three more, with deliveries starting in June 2022 (Courtesy SLM Solutions)

objectives," Czinger explained. "Everything from stiffness, cost of production, assembly, and creating that structure at a real industrial rate. Not aerospace or prototyping rates, but an automotive production rate! Our initial goal was to target cars in the DEF segments [full-size, exclusive, and luxury cars] with a production rate of around 5,000 vehicles."

> *"We had to generate a manufacturing system that was fully optimised across multiple objectives. Everything from stiffness, cost of production, assembly, and creating that structure at a real industrial rate. Not aerospace or prototyping rates, but an automotive production rate!"*

That goal was set over four years ago and, despite metal AM technologies advancing quickly, there wasn't a machine in the market that could reach the production rate needed. "We knew forming a partnership with an AM machine manufacturer was the best strategy to achieve the necessary production rates," said Czinger. In 2017, Divergent 3D and SLM Solutions formed a development partnership, which resulted in the SLM Solutions NXG XII 600 (Fig. 7), released in November 2020. This machine is equipped with twelve 1 kW lasers and is capable of building at speeds 5–20 times faster than that of the current state-of-the-art, enabling it to achieve the necessary automotive production rates.

Following the success of this development, the partnership between Divergent 3D and SLM Solutions was extended, with SLM Solutions appointing Kevin Czinger to its supervisory board. Along with seven SLM 500 machines, three SLM 280 machines and one SLM 125 machine, Divergent 3D currently operates two SLM NXG XII 600 metal AM machines, with the third pre-production machine being delivered in February 2022. In October 2021, it announced the purchase of three more, with deliveries starting in June 2022.

	AlSi10Mg	AlMgSc	Divergent Crash Alloy
Condition	Annealed	As-built	As-built
YS (MPa)	145	290	265
UTS (MPa)	240	360	330
EL (%)	16	18	21
Suitable for energy absorbing applications	No	No	Yes
Powder cost [$/kg]	-	250-350	<< 20% of AlMgSc

Table 1 Typical mechanical properties for high elongation additively manufactured aluminium alloys (Source: Divergent generated test data; built on an SLM280 system, optimised parameters, vertical ASTM E8 specimens)

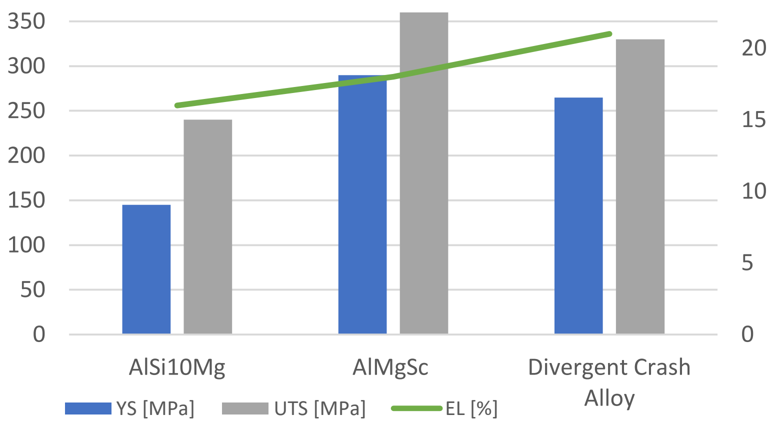


Fig. 8 Comparison of the mechanical properties of high-elongation additively manufactured aluminium alloys (Courtesy Divergent 3D)

Fig. 9 Trapezoidal crush rails used for performance testing of the custom Divergent Crash Alloy (Courtesy Divergent 3D)

The materials challenge

The challenges facing metal AM's adoption go beyond the AM machine itself. "When we started this goal, metal powders were really limited," stated Michael Kenworthy, CTO and VP of Additive Manufacturing and Materials at Divergent 3D. "We found some good commercially available aluminium alloys that work well as a heat exchanger or other components, but none of the alloys had the desired performance characteristics we needed for energy absorption in a crash test."

"Even a material such as Scalmalloy, used in F1 racing, is printable with high elongation and has great mechanical properties, but was not good enough to survive our crash design," he explained. "It was apparent that we would have to engineer our own material."

While some companies are currently involved in interesting work with nanoparticles and other research, it is important to think fundamentally about an alloying strategy. To develop a new material, it is imperative to achieve the cost structure the company needs to scale and compete with the mass production and established economics of the automotive industry. Today, Divergent 3D has multiple proprietary alloys and adhesives to maintain the necessary build rates, cost structure, and performance (Table 1, Figs. 8-9).

When considering conventional automotive design, selecting aluminium alloys or Scalmalloy over steel seems cost prohibitive. Steel still costs less per pound than aluminium, and can provide greater fatigue strength and a higher endurance limit. While the cost of some higher-end vehicles justifies the additional cost of aluminium, Czinger is not just swapping traditional steel parts. While the current model 21C is a hypercar with a price tag that could justify using aluminium alloys, Czinger believes it will scale for more cost effective vehicles.

Generative design, topology optimisation, and other AI software solutions are now widely available

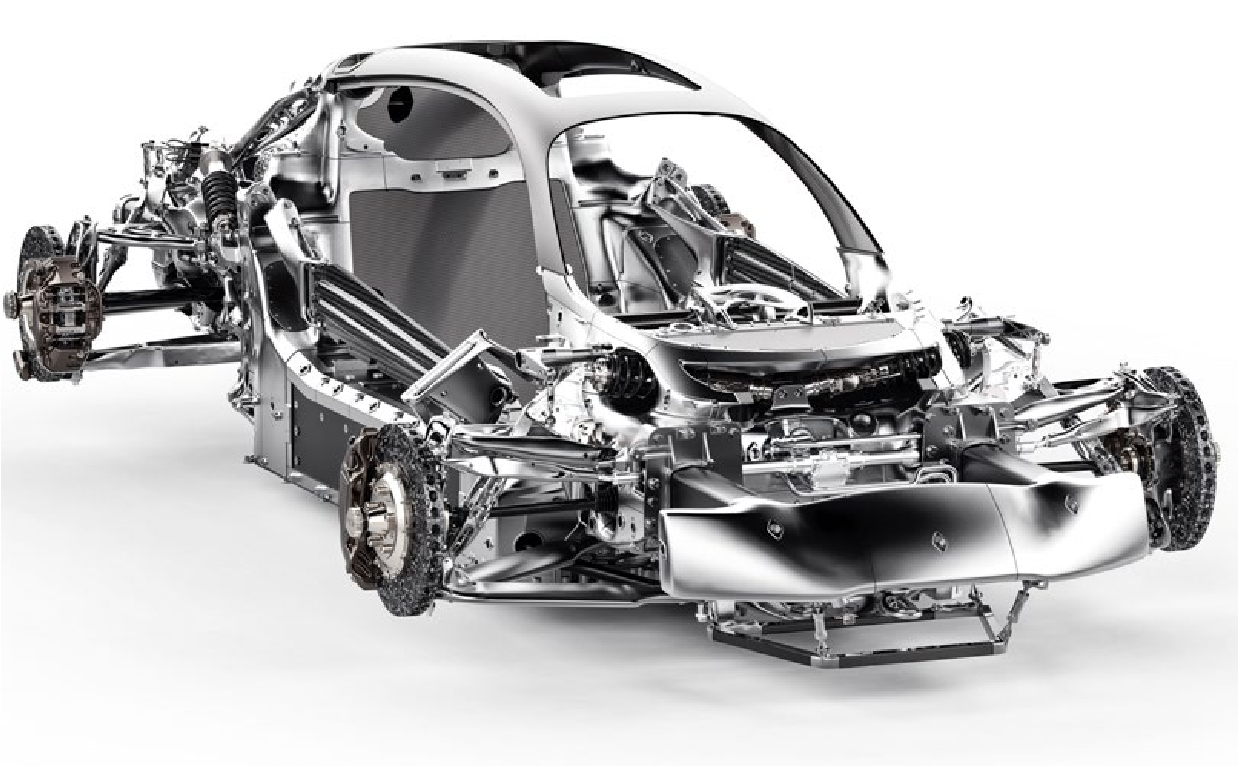


Fig. 10 Render showing the front safety structures, suspension and braking systems, all of which leverage AI to optimise component designs for performance whilst taking advantage of the opportunities presented by AM (Courtesy Czinger Vehicles)

on the market. These programmes give engineers the ability to define constraints and requirements for parts, and let AI generate different designs, optimising and testing designs through iterations which would be beyond the capabilities of the human designer. Generative design tools often create organic geometries that are difficult or impossible to manufacture with traditional processes, but pair well with Additive Manufacturing. The use of these designs makes aluminium more cost-effective to use, thanks to the reduction in weight, the ability to create complex geometries, surface finish, build speed and the potential for the added design features that they offer.

"We are seeing a reduction in mass of 15 to 25% or higher on parts that are already designed for higher end, lightweight vehicles," Kenworthy explained. "Clearly, there's a huge dematerialisation opportunity, but there are more benefits. Using software to digitally design and test parts, we drive structures to failure. This fast iterative loop has let us generate stronger, lighter structures that have surpassed the traditional service life by three or four times without failing." Through its understanding of the process and material, Divergent 3D achieves an accuracy of 95% or better correlation between its simulations and real-world performance.

The manufacturing challenge

To bring together these new technologies and materials, Divergent 3D still faced the well-known AM workflow challenges of post-processing, support removal, powder management, and assembly, which needed to be optimised to maintain the high production rates and low costs set by the company. "We have a propri-

"Using software to digitally design and test parts, we drive structures to failure. This fast iterative loop has let us generate stronger, lighter structures that have surpassed the traditional service life by three or four times without failing."

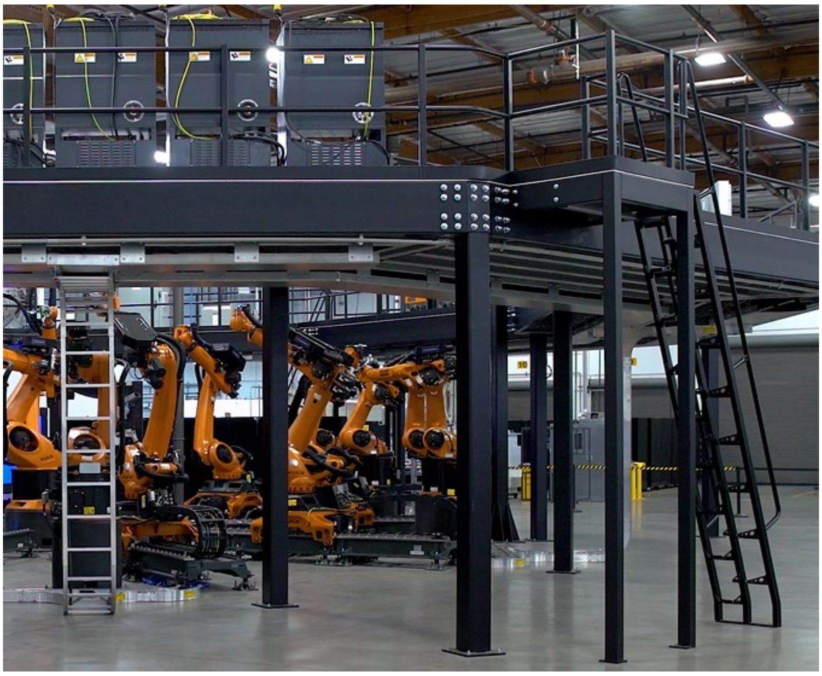


Fig. 11 The Divergent Adaptive Production System (DAPS) is a complete software/hardware solution designed to replace traditional vehicle manufacturing (Courtesy Divergent 3D)

"Given a set of digital requirements as the input, the system automatically computationally engineers, additively manufactures, and assembles complex structures. DAPS can manufacture and assemble structures without fixtures to move seamlessly between different subframes or vehicle models..."

etary process for support removal, if needed, and a process for recycling materials," Czinger stated. "From a cost perspective, we look at the total system cost. All amortised fixed and variable costs across an end-to-end production system that takes a set of requirement inputs for a product structure. With this total cost and input requirements, our system automatically designs, additively manufactures, and assembles, without the use of fixtures, that structure as an output. That total output cost for the entire system is what counts."

Divergent has invented a manufacturing solution to address system level challenges. The Divergent Adaptive Production System (DAPS) is a complete software/hardware solution designed to replace traditional vehicle manufacturing: a complete modular digital factory for complex structures (Fig. 11). Given a set of digital requirements as the input, the system automatically computationally engineers, additively manufactures, and assembles complex structures. DAPS can manufacture and assemble structures without fixtures to move seamlessly between different subframes or vehicle models, with zero switchover time.

Its modular design helps solve another challenge: adoption. Presenting disruptive technology to industry is bound to see resistance. Companies often adopt new technologies from the starting point of prototypes or case studies, with the idea of starting small, then scaling. With some projects, a new technology pilot may succeed, but fail when scaled.

Divergent 3D was focused on a full, end-to-end digital, modular, and scalable manufacturing system from inception. Using this system, a company could feasibly start with a single unit which could assemble part of a subframe and, as confidence and a ROI is gained, these cells can take over more assemblies on the company's schedule. As the company grows, more cells can be integrated.

For example, Czinger explained, "If you had an EV with front and rear frames with a production rate of 50,000 to 150,000 subframes annually we could do that with one cell. Then, to scale to 300,000 frames per year, you just add a cell." The assembly cell has a footprint that is approximately 20 metres in diameter and stands about 6 metres high. Currently, a single assembly cell is capable of producing 50,000 to 150,000 subframes or 10,000 complete vehicle chassis per year, with dramatic cost savings over existing methods.

Additionally, all the tooling and fixturing is replaced, so everything is dynamic for new designs and business strategies. A company can be more dynamic in meeting market demand and responding to technology development, and not locked into a design with a traditional volume strategy that greatly hinders production flexibility.

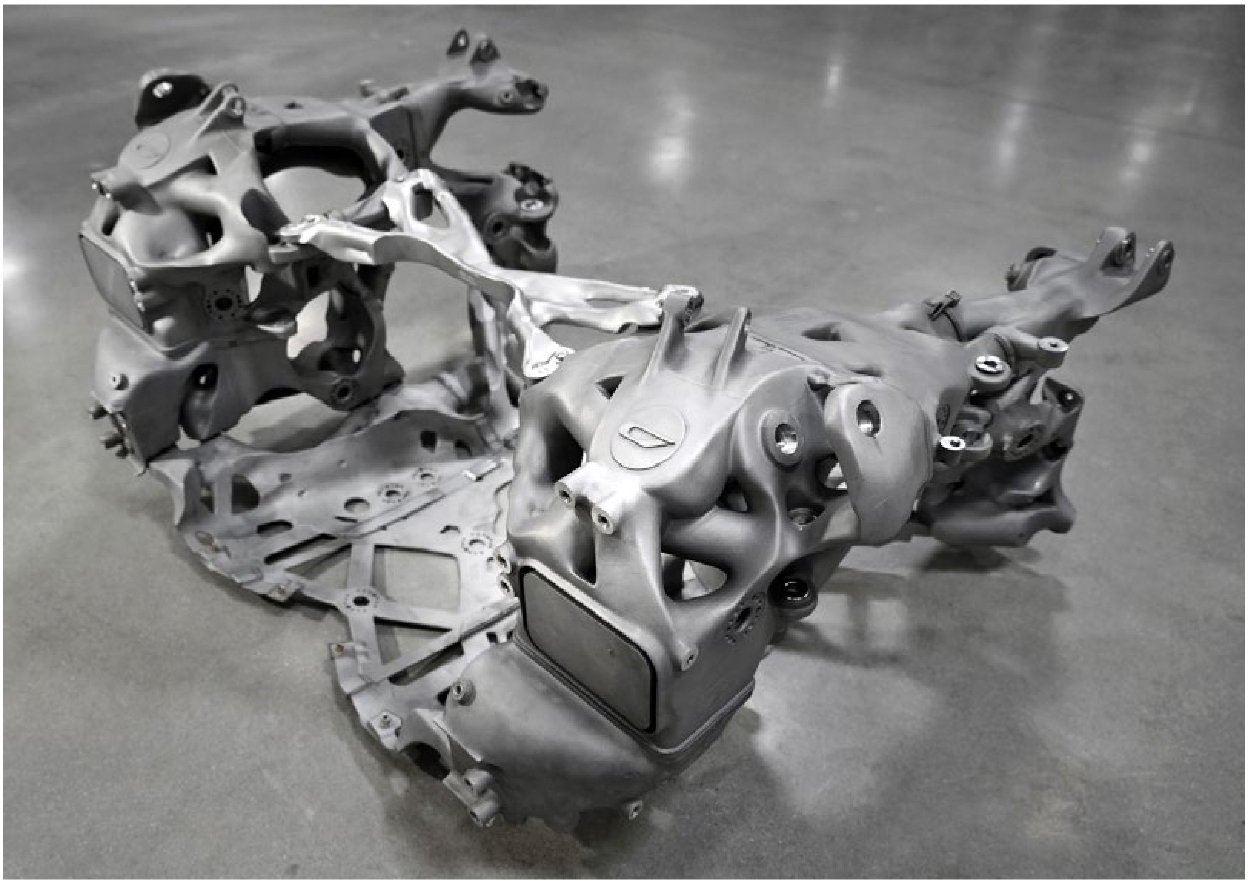


Fig. 12 The assembled rear structure, showing the extent to which metal Additive Manufacturing has been used on the 21C (Courtesy Czinger Vehicles)

The results and future developments

"We have architected, invented, and built our system in house," stated Czinger. "We use automated design with AI elements, proprietary materials, purpose-built AM machines, and a fixtureless assembly cell using proprietary adhesives and metrology to design, build, and assemble. There are over 470 patents filed around that production platform and three subsystems." The results of this technology and work are perhaps summed up best in Czinger's hypercar: the 21C.

While the number of additively manufactured parts is still increasing, the current version of the 21C has over 350 AM parts, with major applications including the front and rear impact structures, the rear subframe, and entire front structural assembly. The list of metal AM parts continues under the hood with powertrain components, including the intake plenums, all of the exhaust components and heat shielding. Additionally, the gearbox casing is fully optimised for AM and will be additively manufactured for the production 21C vehicle. "We are continually iterating the 21C and seeing further improvements on the horizon including optimised, printed cell carriers for the battery," said Kenworthy. "About 20% of the car's total mass is made with metal AM. As we further lightweight some components, we redesign others for AM, so it has remained at roughly the same overall percentage as the structure evolved over the last few years."

This hypercar, developed with Divergent 3D's technology, is already breaking lap records for production

"While the number of additively manufactured parts is still increasing, the current version of the 21C has over 350 AM parts, with major applications including the front and rear impact structures, the rear subframe, and entire front structural assembly."

Fig. 13 Elevated view of the 21C (Courtesy Czinger Vehicles)

"The 21C shows that Divergent 3D's architecture delivers extremely high performance right out of the box, and that it is possible to have a fabless car design business model. The hypercar is almost sold out of its initial eighty production units and has grabbed the attention of at least four of the top ten automotive OEMs."

cars. At the Laguna Seca Raceway on July 21, 2021, the 21C beat the previous McLaren Senna's record of 1:27:62 by more than 2 seconds, clocking in at 1:25:44. Later, on September 23, 2021, the 21C broke the Circuit of the Americas (COTA) track record, previously set by the McLaren P1, by more than 6 seconds. The new COTA record is 2:11:33.

The 21C shows that Divergent 3D's architecture delivers extremely high performance right out of the box, and that it is possible to have a fabless car design business model. The hypercar is almost sold out of its initial eighty production units and has grabbed the attention of at least four of the top ten automotive OEMs. Czinger could not disclose the names of these companies, but stated, "The first of those vehicle production programmes will be on the road, at volume production, in the first quarter of 2022."

What Divergent 3D and Czinger have accomplished proves that metal Additive Manufacturing can move into automotive production, with the right approach. Currently, high-end vehicles in the DEF segment are targeted, but Czinger believes the industry might be only eight to ten years from disrupting compact passenger segment A type vehicles. This technology could change business strategies to offer shorter lifecycles, greater customisation, and more sustainable practices.

Automotive OEMs will have the freedom to vary their capacity between models and adapt faster to market designs and technologies. As more efficient structures are generated, the digital end-to-end architecture will make it easy to track data and generate cost productivity curves to compare against calculated total system costs. It will be possible to streamline production metrics and compare a minimally viable product against a target market segment, so that management understands how to drive cost productivity metrics and scale accordingly.

Fig. 14 The 21C's AM architecture has delivered extreme performance 'straight out of the box', breaking production car records at both Laguna Seca and the Circuit of the Americas (Courtesy Czinger Vehicles)

These are just some of the reasons why Divergent 3D and Czinger's 21C is disrupting more than just track records. Divergent 3D's technology serves as an example of what many companies are striving towards in the new industrial revolution: as the automotive industry continues to see higher regulation and increased electrification, metal Additive Manufacturing will play a pivotal role in modernising older mindsets and production.

"The idea is to ultimately democratise this technology," said Czinger. "Imagine every major city creating an adaptive digital footprint for itself. Designing and circulating materials locally while sharing information globally. Each system can adjust and adapt to local needs and resources, which will aid in more efficient, flexible, and sustainable production."

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Buying time with digital spare parts: Opportunities for metal Additive Manufacturing

Spare parts keep the world turning, and their complex supply chain is an industry in itself, specifically designed to get trains moving, ships sailing, and industry producing. But this is an expensive business, and one driven by calculated risk. Do you reduce your profits by stocking every expensive, highly engineered part that you might need, even though the chances are that most will never be used? Here, Joseph Kowen considers if digital part inventories, in conjunction with metal Additive Manufacturing, can transform how the spare parts industry operates. What are the opportunities, and how are early adopters already taking advantage of them?

The AM industry is always on the lookout for the next big application and observers of the industry are obsessed with the search for applications where AM makes sense. There are relatively few verticals where AM makes a broad, segment-wide business case for its use. The industry which has arguably adopted AM most broadly is dental, although only a small part of that is metal AM. The key characteristic of the dental industry that drives its adoption is the high value of small, custom dental parts. Medical implants have also proven to be a fertile area for metal AM due to the ability to build complicated, lightweight parts that mimic the geometry of the natural structures that they replace. Aerospace also offers some potential, but this is for specialised applications – more space, less aero.

We have all heard of cases where AM has saved the day when reverse-engineered or urgent parts are needed. Often, these stories have been based on opportunity, rather than part of a wider business strategy. Could it be that 'spare parts by AM' offer as much potential as any of the most successful AM applications on the market today? What are the parameters for this opportunity? What are the hurdles? And who is doing what? In this article, we'll attempt to answer some of these questions with an overview of a topic that crosses typical segment lines.

The dream of digital parts warehouse

In March 2021, the world watched the unfolding drama of the giant container ship Ever Given, which became stuck in the middle of the Suez Canal on its way to Europe. Its

Fig. 1 The Ever Given became stuck in the Suez Canal on its way to Europe, blocking the lifeline that delivers an estimated 12% of global trade by volume (excluding oil) annually

"The potential for easy, on-demand procurement of spare parts from a digital warehouse is one key aspect of the digital parts paradigm, offering its own challenges on the one hand, and exciting opportunities on the other."

decks were packed with more than 18,000 containers carrying goods from Asia to markets in Europe and the Americas. To put the blockage in context, nearly 19,000 vessels, carrying an estimated 12% of global trade by volume (excluding oil) traversed the 193 km long canal in 2020. The blockage of the canal had the immediate effect of delaying more than 350 ships on their passage westwards. Lloyd's List estimated that each day of the blockage was holding up $9.6 billion in trade – $400 million per hour. No logistics and supply chain specialist failed to take note. The effects of supply chain disruptions cause serious economic woes in developed countries, ranging from delays in deliveries of new cars, fourfold increases in shipping costs, and higher fuel costs, to the disappointment of being unable to get holiday gifts delivered on time. Supply chain disruption is an important factor in rising inflation in several key economies.

For years, analysts have pondered the shift of huge swathes of manufacturing capacity to Asia, where high-capacity manufacturers have made significant strides in the production of a seemingly endless range of products at low manufacturing costs with which western countries cannot compete. The strategic implications of that shift were clear, but companies were apparently unable to resist the short-term profit, even though the result was that they would be making their products, or parts of their products, half a world away from the point of need. The strategic risks and environmental costs – to the extent that they were not fully internalised – were brought sharply into focus by the image of a single, giant ship blocking a canal.

The term 'digital parts warehouse' is a captivating idea that never fails to excite. The concept of not having to store any physical parts, and producing them only when necessary, is extremely attractive. New parts that have been designed with AM in mind are candidates for a new paradigm in supply chain management. But what about parts that were made years ago, in a pre-AM era, using the conventional manufacturing methods suited to the designs of the day? The potential for easy, on-demand procurement of spare parts from a digital warehouse is one key aspect of the digital parts paradigm, offering its own challenges on the one hand, and exciting opportunities on the other.

The numbers are large

The spare parts manufacturing business is a multi-billion-dollar opportunity worldwide. Various estimates of the size of the market have been calculated; since the spare parts business extends across several vertical segments, an estimate of the size of the market is an amalgam of estimates in each of its segments. As shall be seen, some segments are more relevant for AM than others, and we will focus on them.

French consultancy Theano Advisors (part of Eight Advisory since late 2020) broke down the market for spare parts and came up with a figure, for the AM spares market, of $173 billion, including both metal and polymer parts. The most relevant of the markets surveyed, using figures for 2018, were the petrochemical ($26.9 billion), mining ($10.7 billion), rail ($7 billion) and shipping ($5.9 billion) industries. Together, this totals $50.5 billion. This already large number does not include significant consumer segments that use spare parts, such as the automotive business.

Other market studies have estimated the total metal spare parts market at more than $500 billion, a figure which covers all industries, including automotive, but does not make a distinction between those parts which are suitable and not suitable for AM. Airbus estimates that the maintenance, repair and overhaul (MRO) market for aircraft parts of all kinds stood at $60 billion in 2020, though presumably the market has suffered some contraction as the aerospace industry deals with declining travel needs.

While estimates of this kind that show the 'total addressable market' for a particular category of products tend to be large, and are designed to impress consumers of the data, especially investors, they do offer some perspective. If we assume that only 5% of the AM-suitable parts market of the target segments from the Theano study represent immediately addressable and economically sensible AM potential, that figure is still large in the world of AM, which Wohlers Associates estimated to be worth $12.7 billion last year. Put another way, if only 5% of the immediate AM potential of spare parts were to be realised, a market of $2.5 billion, that would represent close to 20% of the entire current AM market. If only $500 million of the total spares market (20%) was accessible to metal AM, it would represent a significant part of the metal AM business. Metal AM industry analysts Ampower estimated that the total metal AM market for machines, materials and services in 2020 was about $2.3 billion.

Spares specialists

Before we get too excited by the vast potential that is seemingly a click away, most agree that the path towards unlocking this potential is long and arduous. The battle to additively manufacture spare parts is fought part by part. Notwithstanding the challenges, a few companies are focusing on this segment. They offer expertise in the identification of appropriate parts and in shepherding the process to successful execution. Here is a partial list of some of the companies and organisations addressing this challenge, either as service providers or as an internal corporate function.

Ivaldi

Ivaldi is a young company headquartered in California, USA. Its roots are in Norway, and it also operates an engineering office in Mexico. The company is closely connected to the maritime industry; one of its lead investors is Wilh. Wilhelmsen, a Norwegian shipping company with a presence in ports around the world that services more than 25,000 vessels per year. Ivaldi has more than twenty-five employees.

Under the slogan 'Send files, not parts', the company assists customers through three stages of the spare parts manufacturing process: screening, analysis and evaluation of parts to qualify suitable inventory; building and certifying products for digital distribution; and implementation or spare parts manufacture through a global network of pre-certified parts-on-demand manufacturers.

The company is a participant in a Joint Industry Program (JIP) co-funded by the Marine and Port Authority of Singapore, and supported by the National Additive Manufacturing Innovation Cluster (NAMIC), which was established to advance the use of AM to build parts for the maritime industry in Singapore. The JIP consists of fourteen partners, including shipping companies, parts suppliers, and – most significantly – a maritime classification society. Without approval from a classification society, parts cannot be insured for use at sea. The programme plans to advance the possibility of part-family certification, thereby speeding the certification of similar parts in the future. Espen Sivertsen, CEO of Ivaldi, describes the objective of the project as such: "Up until now, certification of critical parts has been very costly and time-consuming because each part has to cover new ground. By working together on key part categories, we aim to remove some of the remaining barriers for mass adoption."

Impeller for mining equipment

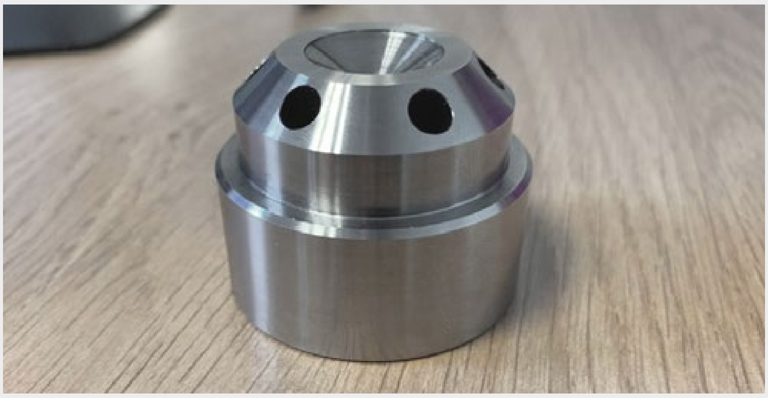
An additively manufactured 316L stainless steel impeller for a pump used in mining equipment, produced using Laser Beam Powder Bed Fusion (PBF-LB) (Courtesy Ivaldi)

This 316L impeller for a pump used in mining equipment was produced using PBF-LB for Ivaldi for a customer in South Africa. The part weighs 1.4 kg, measures 165 x 165 x 19 mm, and has internal features which would have been difficult and expensive to machine.

According to Ivaldi, the use of Additive Manufacturing to produce this semi-critical spare part resulted in an average per unit saving of $1,500, and reduced the lead time from ninety days to just six. By producing a single spare part as needed, the company was able to reduce its minimum order quantity from nineteen parts to just one, and estimated a yearly savings potential in the production of its spare parts by AM of $1.2 million.

Further, the shipping distance from the point of manufacturing to the point of need was reduced by 10,000 km; the total carbon dioxide equivalent (CO_2e) saving in producing this spare by AM was calculated at 80 kg.

Selecting appropriate spare parts



An oil burner nozzle selected for AM by SpareParts 3D for Braskem. The part distributes the flow of steam and fuel in a burner in a petrochemical plant. Produced by PBF-LB using MS1 maraging steel, the part has a 44 mm base diameter. The part is nickel electroplated. Production lead time was twenty-five days (Courtesy SpareParts 3D/Braskem)

In 2020, Brazilian chemical company Braskem selected SpareParts 3D to assist it in implementing AM for its spare parts programme. Headquartered in São Paulo, the company is Latin America's largest petrochemical company. The company contracted SpareParts 3D to identify which parts in a large inventory could be suitable candidates for AM. The company had identified a number of problems, risks and costs in its spare parts management: long lead times for critical parts, obsolescence of parts, and high inventory costs due to minimum order quantities.

SpareParts 3D's approach was to process a large dataset obtained from Braskem's ERP system to identify and analyse a subset of 15,000 parts that could be manufactured by AM. The analysis considered parameters such as part value, minimum order quantities and historical lead times for producing replacement parts.

SpareParts 3D says that selecting the correct parts is the key to a successful AM spare parts strategy, explaining that many companies make the mistake of selecting the most complicated parts from an engineering point of view. In most cases, such a part will not provide a business case for AM, and companies can become frustrated with the process. The most suitable parts are generally those that answer commercial needs and not technological needs, such as the needed production frequency and lead times. For this reason, parts should be reviewed through the prism of the purchasing history of the part, and not only through the eyes of the engineering team.

In addition to the maritime industry, the company is targeting the mining industry due to the overlap in the type of parts used in these industries, such as pumps and valves. The company is collaborating with the Anglo-American mining group in South Africa on applications in the mining segment.

SpareParts 3D

'Having the right part, in the right place, at the right time, at the right price' is how SpareParts 3D describes its business. The Paris-based start-up has roots in Singapore, and members of the management team are located in both places. The company's activities in Singapore connect it to the maritime spare parts business, which, as already noted, has been targeted by the Singapore government through NAMIC, the maritime authority and the Singapore Shipping Association as an important opportunity for the country. The company was a member of the initial Joint Industry Program in the country, which was led by DNV-GL (now known as DNV) and which mapped out opportunities for AM in the maritime industry.

SpareParts 3D offers a number of services relating to the production of spare parts and digital inventory. The Digipart Convert service identifies parts where it makes sense to consider AM as a solution. The company also offers a scanning and engineering service that develops parts from 2D drawings, or reverse engineers a physical part for which no drawings exist. And, finally, the company will produce the part through a network of providers selected and qualified to offer a technically sufficient part at the lowest cost.

Paul Guillamot is co-founder and CEO of SpareParts 3D. He said that many potential customers initially don't fully understand the potential of using AM to make spare parts. "In the metals area, most of the use cases involve the shortening of lead times to produce parts that are not available from stock. Even parts that are not too complicated from a design point of view, at first glance, might still take a long time to produce due to multiple processes that might be required, such as part joining or casting."

In certain industries where equipment needs to last twenty-to-thirty years, such as the oil and gas industry, it has found that in the range of 60% to 70% of the stock of spare parts held by the company is dead stock. This means that these parts have no future commercial potential and cost the company money for each day that they are on the books, taking up space in warehouses without serving any useful purpose. "The lowest figure you will find for the cost of holding inventory is 15% of the value of the stock, although it could be as high as 25%," explained Guillamot.

SpareParts 3D has developed methods and software tools for assisting companies in identifying which parts make sense for production by AM based on an analysis of a company's procurement history of those parts.

Replique

Replique is a young start-up company focusing on the spare parts market. Based in Mannheim, Germany, the company currently operates out of BASF's Chemovator incubator. Not unlike its peers in the AM spare parts space, it is focused on the markets with greatest potential: machinery, mining, oil and gas, agriculture, construction and transportation. By its calculation, the addressable spare parts market in these segments is between $30 and $40 billion, of which it believes at least 6%, or possibly up to 10%, could be additively manufactured.

Replique's model is to accompany its customers through a process that includes optimising the digital design, which includes converting 2D drawings into 3D designs, or reverse engineering parts for which no digital design is available. This can be a painstaking task. The next stage is a part qualification service, where required. Once the digital files are available, the company will assist in the establishment of a digital inventory which will store the parts, as well as monitor activities at the next stage of the process: production. The company will arrange for manufacturing of the parts through a network of service providers that it has selected and approved. Actual orders are managed by Replique. End customers receive the parts from Replique, which bears ultimate responsibility for assuring technical quality.

Replique already has customers in Germany and France. Many of them use the service for polymer parts, but they are beginning to address the metal AM market, as well. Currently, one of its key metal customers operates in the transportation segment, but cannot be named for reasons of confidentially.

Company founder and CEO Max Siebert noted that in many cases the potential of AM spare parts supply becomes increasingly apparent with each part, as customers come down the learning curve. "Once the ice is broken, customers begin to see the benefits and potential of solving spare parts pain through our service." A successful part that meets a critical need is an important driver for discovering new potential. Interestingly, they find that smaller organisations are often more open than larger organisations in understanding how AM spare parts can shorten the journey to getting equipment up and running.

Fig. 2 A turbine paddle wheel for the dynamo machine of a steam locomotive, produced by DED AM (Courtesy Deutsche Bahn)

Deutsche Bahn

The German railway company commenced its journey in the Additive Manufacturing of spare parts about six years ago. It began modestly, with the manufacturing of a polymer coat hanger for a compartment in a train, but has made significant strides since then and now addresses many different applications in rail transportation. Today, one third of all AM parts produced for the company are metal.

The pain faced by the maintenance organisation of a railway operator is easy to understand. A train costing millions of Euros that first entered service twenty-five years ago is taken out of service because a critical part is not available. Many ICE trains that entered service in the 1990s are still in operation. Considering only the

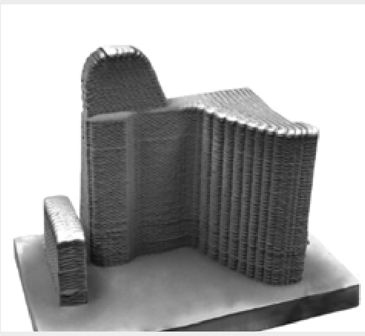
Secondary roll stop component for trains

A secondary roll stop component produced by wire arc DED (above and below). The lowest image shows the part as-built and prior to machining (Courtesy Deutsche Bahn and Mobility Goes Additive)

This secondary roll stop component, a heavy steel part attached to the underside of each passenger car on model 1 and 2 Deutsche Bahn ICE trains to limit their lateral play, was produced using wire arc DED Additive Manufacturing. It is a safety-relevant part that originally went into operation in 1989. Due to its design and function, the part does not usually require replacement, and, as a result, spares for the part are not held in stock.

In the case in question, the secondary roll stop incurred damage which resulted in the ICE train being withdrawn from service, incurring an immediate need to replace the part. Due to high manufacturing costs, long lead times and a minimum order quantity on a part that is rarely needed, it was decided to manufacture the part using AM, in this case by wire arc DED Additive Manufacturing. The part measures 22 x 31 x 33 cm, was produced in 100NiMoCr, and weighs 27 kg. It was tested and qualified for use by TÜV-SÜD.

The outcome was a reduction in lead time of six months, and a total cost reduction on the manufacture of the spare part.



company's high-speed trains, of 106 ICE model 1 and 2 trains produced between 1989 and 1997, 103 are still in service. When these trains break down and a replacement part is not available, it could take some time to get them back on the tracks.

Stefanie Brickwede is head of AM at Deutsche Bahn (DB). She explained that DB does not, in general, manufacture AM parts internally, but relies on authorised external providers to produce parts. Not all providers are specified for railway use, and the AM team at DB is responsible for ensuring that standards are met. The bulk of the work of the AM team, which numbers ten internal staff and forty external experts, involves making sure that maintenance facilities all over Germany are supported in their efforts to decide when AM makes sense. The company uses a framework for assessment developed by software company 3YOURMIND, to which it has added its own knowledge and insights. Its efforts are designed to develop a bottom-up approach whereby AM parts offering the greatest savings are located and pursued by the maintenance teams. "Using AM has definitely paid off," Brickwede stated. "We have produced 25,000 AM parts relating to 250 use cases over the course of the AM programme."

Going back to the example of the out-of-service train can help us understand the calculus of when it makes sense to use AM. The maintenance team predicted that the stranded train would take nine months to get back into service. Some of the parts were cast, and neither drawings nor patterns for casting were available for equipment that was first produced twenty-five years ago. With the help of AM, however, the company was able to get the train back into service within four months.

Safety-relevant parts are not outside the ambit of the work of the AM team, although engineering and certification can take time. One such part, produced by a wire-arc Directed Energy Deposition (DED) process, is part of the train positioning hardware that prevents the train from leaning too far into curves at speed (see box).

DB's leadership has inspired a number of other railway operators to add AM as a tool for maintenance operations. In addition to her responsibilities as AM leader at DB, Brickwede also leads an industry group call Mobility Goes Additive, in which no fewer than eight railway operators in Europe are members.

Military applications

No overview of the AM spare parts area would be complete without touching on what military organisations are doing in this area. Since the military values factors such as uptime and battle readiness with a non-commercial perspective, the cost factor that would play an important role in a commercial enterprise's outlook is severely blunted, if not eliminated completely. Military equipment – whether aircraft, motorised vehicles or naval vessels – that cannot operate because of a delay in obtaining a critical part have to be replaced with working equipment to maintain defence readiness. Added to this, military bodies generally operate equipment that is decades old. The legendary B-52 bomber, for example, first took to the skies in 1952, and is expected to remain in service for some years to come. Currently, seventy-eight of the aircraft are still in service. Finally, while safety is always a concern, regulation of commercial products is often more stringent than for military equipment, meaning that there may be fewer hurdles in the adoption of AM parts for military use.

Funding has started to flow to support the development of AM for the military, as leaders have begun to realise the importance of AM in general, and in spare-parts manufacture in particular. Most recently, in November 2021, Florida International University received $22.9 million from the US Army over five years to advance AM for military applications.

Fig. 3 An additively manufactured wheel-set bearing cover for a Class 294 locomotive, produced on a Gefertec arc605 DED system (Courtesy Deutsche Bahn)

"The maintenance team predicted that the stranded train would take nine months to get back into service... with the help of AM, however, the company was able to get the train back into service within four months."

Fig. 4 Costs for carrying inventory are a silent but critical factor that can weigh heavily on a company's overall business

The French armed services have also been active in developing a decentralised model for spare parts manufacture using AM. Centrally maintained files are sent securely to remote locations to be additively manufactured locally, even in areas of deployment. The French Land Forces contracted French block-chain company Vistory to safeguard the digital transfer of parts for local production.

The cost of inventory

Costs for carrying inventory are a silent, but potentially critical, factor weighing heavily on a company's overall business. Out of a desire to offer an optimal service level for customers, services managers and salesmen often push for a safety inventory of spare parts that exacts a cost that they may not be fully aware of. Their incentive is to keep customers happy almost at all costs. The financial management of the company has a different incentive, saving costs and increasing profitability, that is at odds with customer-facing functions in the company.

"...services managers and salesmen often push for a safety inventory of spare parts that exacts a cost that they may not be fully aware of. Their incentive is to keep customers happy almost at all costs. The financial management of the company has a different incentive..."

There are four main cost components to carrying inventory. The largest component is capital cost, which means the cost of money, and interest on that cost, invested in the parts held in inventory. 'Inventory service costs' include factors such as administrative costs and insurance for maintaining the inventory. The larger the desire, or the regulatory requirements, for maintaining spare parts, the higher the service cost. Carrying inventory comes with risk, called the 'stock risk cost.' This cost includes factors such as reduction of inventory for reasons other than sale, misplacement, theft and physical damage that could befall the items in inventory. And, finally, there are storage space costs, including rent, transportation and other costs related to the physical maintenance of the inventoried parts. In the best of all possible cases, the annual costs together amount to 15% of the value of the stock. In the case of large metal parts of the kind that serve the industries representing the highest potential for AM, spare part costs are in most cases going to be higher, and could reach as much as 25% of the value of the stock. As has already been noted, rail, shipping and oil & gas are industries in which the expected life cycle of equipment is at least twenty years.

The stock level and cost is exacerbated for another reason, as well; the expected demand for a particular part could be a low number every year, and so the burden of carrying parts in stock is even more acutely felt. If we add to this a common practice of minimum order quantities, dead stock and carrying costs could be even higher. By way of example, imagine that the minimum order quantity of a part is ten pieces, and the expected demand is only two parts per year, which takes into account a 'customer satisfaction' cushion. The real demand could be one part per year. The minimum order represents optimistically five years of stock, and there is a possibility that part of it is going to end up dead. Add to that the carrying cost of the stock over the entire period. There could be some situations where it might make business sense to scrap part of the minimum order on the day that it is supplied, although few organisations would have the courage to do that. The result is warehouses laden with parts that might never be used.

Taking the example a step further, another thought to consider is that if circumstances dictate that you have to buy ten times more stock than you actually need, due to the reality of minimum orders, then it implies that the manufacturing cost of the AM part could be ten times more than a conventionally produced but unneeded part, and you will still come out ahead. This simple example might not be entirely accurate in all cases, but one can easily understand how the cost of AM part production, which for series production might be too high for to be economically viable, is a reduced factor in the context of spare parts. Put another way: High costs of metal AM are less likely to be the disqualifying factor for spare parts than for new parts.

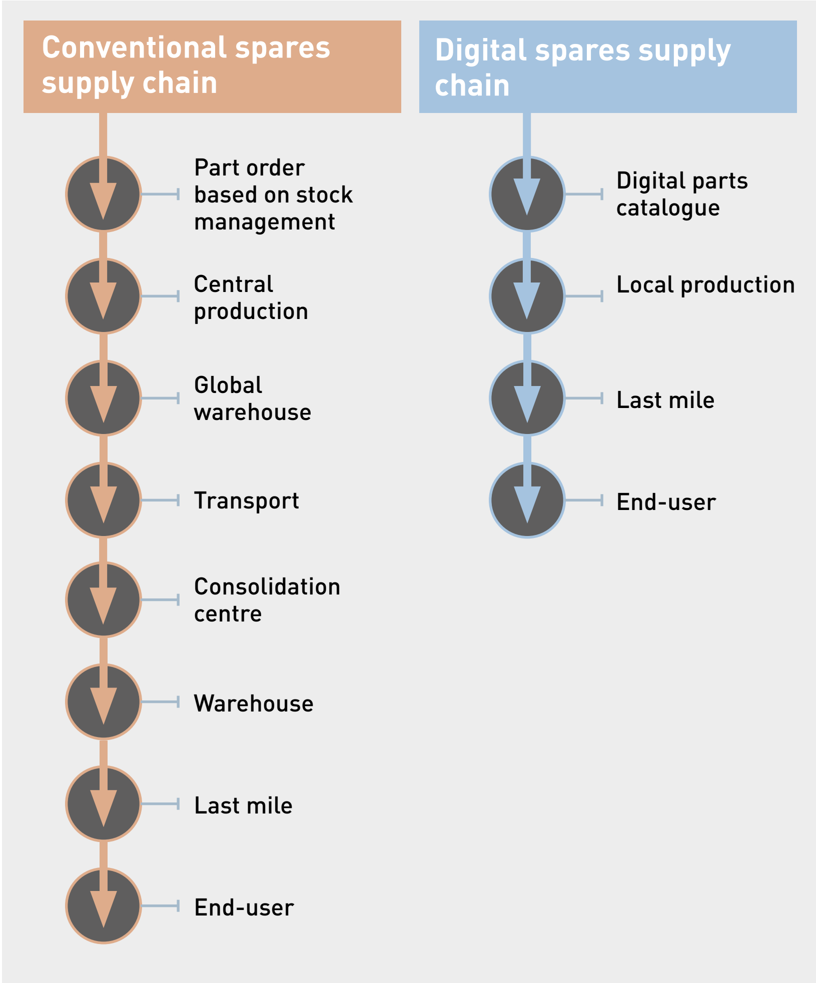


Fig. 5 Stages in a conventional spare parts supply chain vs the digital spares supply chain

Given this reality, the promise of on-demand spare parts might be an even more interesting option than it appears at first glance. The companies serving the AM spares market report that companies get more excited over time as the benefits of a digital spare parts inventory become clearer.

To fully appreciate the simplicity of an on-demand digital supply chain, it is instructive to break down the stages a conventional supply chain and compare it to the digital alternative. Fig. 5 illustrates this. The benefits of a digital supply chain for appropriate parts in suitable industries: lower total cost, shorter time to supply, lower environmental impact, which all leads to higher customer satisfaction.

Insights and what we have learned

The metal spare parts market represents a significant opportunity for metal AM. Since metal products are generally designed to last many years, they often form key elements of equipment or systems that have been around for many years, for which no spare parts – or, in many cases, even digital designs – exist. The process of identifying suitable parts, and reverse engineering a legacy part to create a digital design, is long and painstaking.

Fig. 6 In November 2021, ABS, ConocoPhillips Polar Tankers, Sembcorp Marine Ltd and 3D Metalforge reported that parts fabricated by AM had been installed six months earlier on the oil tanker The Polar Endeavour by Sembcorp Marine. They were recently inspected and found to be in good working condition (Courtesy Sembcorp Marine)

"The AM of spare parts, like all AM applications, does not make sense in all cases. Success with additive spare parts manufacture begins with a bottom-up identification of a part with a good business case."

Certifying the design and meeting regulatory standards in a particular industry add yet another layer of time-consuming complexity to the task of translating potential to parts.

The Additive Manufacturing of spare parts, like all AM applications, does not make sense in all cases. Success with additive spare parts manufacture begins with a bottom-up identification of a part with a good business case. Technically complex parts might not be the best candidates for a successful spare part business case. Identification of suitable cases is as much about the logistics, supply chain and purchasing functions in an organisation as it is about the engineering function.

The cost of time is an important element in the assessment of the economic viability of building a spare part using AM, and economic loss should also be factored into the calculation. Some parts can be justified for production by AM based purely on cost, and this is especially true if minimum order quantities are a factor, or if tooling must be made for producing castings. Equipment downtime can cause economic loss that dwarfs the cost of making the spare part, as in the case of mining, rail, shipping or oil and gas operations, but these non-budgetary items need to be appreciated and considered by functions in an organisation with a holistic view of the business, and not a purely cash-driven analysis of the parts replacement alone.

Companies specialising in spare parts identification and production are starting to emerge. Not all organisations, particular medium-size enterprises, will have the resources or the knowledge to develop an AM spare parts strategy internally, and would do well to consult with experts who have accumulated know-how in spare parts production by AM. Even accounting for the cost and profit of the external expertise, in suitable cases there will be clear economic viability for engaging experts who are already making their way down the learning curve.

For the spare parts specialists, focusing on the verticals with the richest potential will offer the best chance of success. While each part is a project unto itself, learning-curve efficiencies will begin to kick in as the spares segment develops. In addition, we can expect a certain degree of software automation to emerge in areas like business case analysis of historical spare parts usage, and even in the conversion of 2D designs to 3D. We can expect the costs of 3D scanning to continue to decrease.

The spare parts segment is not without its challenges, but an analysis of the numbers and the potential suggests that it will grow at a lively pace, driven by improvements and reduced costs in metal AM processes, and encouraged by increased understanding of the risks of complicated supply chains, greater environmental awareness and the willingness to internalise externalities in economic analyses of business cases. Watch this space.

Author

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Burloak and the AM scalability challenge: A contract manufacturer's perspective on the shift to volume production

We all love to talk about how Additive Manufacturing can transform product design, improve an application's performance, reduce part count and material waste, enable faster design cycles and far more besides. But what is less often discussed is the challenge of scaling up production once an application has been developed. It is this aspect of AM that has been the focus of activity at Burloak Technologies. In this article, the company's Jason Ball, VP & General Manager, and Keyvan Hosseinkhani, Technical Director, consider the challenges of scaling AM, and how they can be overcome.

In recent years, Additive Manufacturing has swiftly gained prominence in the manufacturing space – and with good reason. Because this evolving manufacturing technology essentially allows teams to manufacture parts 'from the ground up', countless organisations are using it to break free from the design constraints of traditional manufacturing methods and experience a whole new world of product and process possibilities.

The benefits of AM are well documented. This form of manufacturing helps companies overcome costly product performance issues, resulting in stronger materials, fewer parts and reduced weights. It decreases broader organisational costs by allowing for designs that slash greenhouse gas (GHG) emissions, create localised sourcing options or accelerate design cycles. In many cases, it also leads to significantly less material waste.

What the media coverage and AM service provider web pages seem to omit, however, are stories about companies that have successfully scaled this technology or fully integrated it into their manufacturing processes. That's because, despite AM's host of benefits, it simply hasn't evolved to that level. Yet.

That's not to say scaling AM isn't possible – it very much is. While current business cases remain few and far between, some companies (particularly those in the aerospace, space and power generation sectors) are already realising success. In this article, we'll unpack why AM scaling isn't more widespread, what it will take to launch AM to the next stage of adoption, and which practical solutions are needed to get us there.

Fig. 1 An EOS M 290 Laser Beam Powder Bed Fusion AM machine post-build (Courtesy Burloak Technologies)

Fig. 2 The materials lab is an essential part of any metal Additive Manufacturing facility (Courtesy Burloak Technologies)

The complex challenges of scaling AM

Given the extensive applications for AM, pinpointing a single cause for its limited scalability is virtually impossible. Rather, there are numerous reasons why a company might invest in an AM prototype, but fail to mass-produce that prototype at scale.

Given how nascent AM is, misconceptions and an unfamiliarity with the AM design process are likely the primary culprits. Most engineers currently in the workforce do not have design for Additive Manufacturing (DfAM) skills. Their mindsets are rooted in traditional methods of design – methods that involve carving away existing materials and which work within these constraints. This lack of AM expertise can make it difficult to reframe design thinking, or change or modify a design, to leverage the full potential of AM.

To make widespread adoption even more challenging, AM isn't the silver bullet that many companies make it out to be. While some applications are well suited to AM, many are not. To differentiate the two, you need a clear understanding of AM design rules and the technology's restrictions, and that knowledge comes with a steep learning curve. Similarly, because in-depth DfAM knowledge is still scarce in most industries, few companies have engineers in-house who can identify opportunities well-suited to AM, hampering efforts to make strong business cases for its adoption.

This lack of familiarity with AM design concepts becomes a problem when a company pushes an engineering team towards AM without a clear understanding of why a shift in manufacturing processes is needed. To get the most out of an AM part – and get it to a point of scalability – it's important to define why this method of manufacturing is advantageous, and how it stands to improve upon existing functional and business requirements. This exercise can help ensure an organisation is considering the full AM picture, while building steps such as part design, manufacturing, post-processing and quality assurance into the business case. Without completing this preliminary exercise, it may be possible to prototype a part with AM only to find scaling it simply might not make financial sense.

To understand some of the existing barriers to scaling AM, consider some of these common challenges:

Technological and process challenges

Even if you create a prototype that makes financial sense to build at scale, technology issues are not uncommon. Many organisations encounter a range of technological and process challenges that make scaling a prototype incredibly arduous, forcing them to revert to traditional forms of manufacturing. These challenges span the gamut, including things like:

<u>Materials development</u>

In subtractive manufacturing, qualified materials are delivered directly from mills to distribution centres. AM, on the other hand, begins with a metal powder – and this powder requires a lot of additional material testing to ensure properties and components are acceptable. This step can add considerable time to the manufacturing process.

This difference in materials can also lead to potentially unforeseen investments when switching from traditional manufacturing to AM. For example, if you're a tooling company switching from machining/casting to AM, you will likely need new simulation efforts to accommodate design changes or the use of different materials.

<u>Manual post-processing</u>

Right now, Powder Bed Fusion AM requires manufacturers to build support structures with each part. These support structures have to

Fig. 3 Whilst larger format PBF-LB machines such as these EOS M 400 4 quad laser machines bring enhanced build speeds, post-processing remains a challenge when looking to scale production (Courtesy Burloak Technologies)

be manufactured alongside the wanted part, then removed from the final components. This step in the AM process can't yet be fully automated – meaning it requires manual labour, support and tools, which can slow down efforts to scale production.

Technology reliability

As with many developing industries in their early stages, today's AM technologies lack standardisation, which further complicates efforts to scale. If you want to manufacture two parts on two different platforms – or on two different machines from different manufacturers – the parts are unlikely to come out identical. To maintain a homogeneity and quality, therefore, you're better off sticking to one machine line. Beyond making it difficult to produce large runs in a preferred timeframe, this tactic also relegates manufacturers to ongoing reliance on older-generation technology.

Skilled labour

As we mentioned before, AM is a relatively new industry – so new, in fact, that it's not yet a curriculum fixture in engineering and trade schools. This, combined with the fact that each AM technology requires a different set of skills, makes it difficult to find people with the training to run the latest equipment or support AM scaling at large. AM teams also need the ability to understand and respond to varying lead times and capacities, which will inevitably be unique to every project, and organisations must be able to develop and financially support a long-term plan when technology is changing at a rapid pace.

Quality assurance challenges

Quality assurance is critical in all forms of manufacturing, both subtractive and AM. But, when you're producing products at scale, AM is

"If you want to manufacture two parts on two different platforms – or on two different machines from different manufacturers – the parts are unlikely to come out identical. To maintain a homogeneity and quality, therefore, you're better off sticking to one machine line."

AM scalability in action

A customer in the aerospace industry came to us with a part they needed to redesign and, ultimately, wanted to produce at a large volume. They were hoping AM could help them reduce the number of pieces required to make the part, while simultaneously improving its performance.

Burloak's team of DfAM experts worked closely with the company to pinpoint the part's existing shortcomings, determine the organisation's goals and zero in on an optimal part design. Within six weeks, we moved from design concept to prototype with amazing results. Rather than the previously-required thirty-five components, the new AM part was made of just one – and it was significantly stronger and lighter.

Pleased with the prototype, the company gave us the green light to help them scale its production. Because one of our pieces of equipment already met the customer's qualification standards, we only had to bring the rest of our equipment through a delta qualification process, which is essentially a less-time-consuming version. Today, we have many of these machines producing the customer's parts at scale, and are working on qualifying additional AM systems to support even greater production.

"...because the morphology of the powder can change over time, both the powder and the finished parts must be tested across the production lifecycle to make sure they continue to conform to the necessary performance standards."

another ballgame. To understand why, it's helpful to understand the difference between a traditional manufacturing machine shop and an AM shop.

Quality assurance process

In a traditional shop, you likely purchase your material from a trusted supplier and receive a certification to ensure the grade of material you want is what you indeed purchased. Once you start running that material through your machines, you take your parts to an inspection room to measure their geometries and confirm manufacturing consistency.

In an AM facility, on the other hand, you don't use solid materials – you use powder. To build your parts properly, that powder must possess highly specific metallurgical qualities that must be tested in a metallurgical lab, which can be costly to run. Additionally, because the morphology of the powder can change over time, both the powder and the finished parts must be tested across the production lifecycle to make sure they continue to conform to the necessary performance standards.

Quality performance standards

All AM materials have different performance and thermal properties, and knowing which quality standards are needed for specific applications requires a lot of legwork. Because industry-wide performance standards don't yet exist in AM, every company must develop their own, which adds to existing quality assurance challenges. Developing these standards can take months – if not years – to complete, as every machine, process and material must be qualified by each supplier.

Customised testing

Conducting that amount of testing simply isn't feasible at a larger scale, which is why it's important to have a quality plan in place to streamline the process. To understand how this works, imagine you want to create

Fig. 4 Tensile testing of built samples. Conducting high volumes of testing simply isn't feasible at a larger scale, so quality plans need to be put in place to streamline the process (Courtesy Burloak Technologies)

parts out of titanium: Right now, there are two different powder bed AM methods for this metal, but each one produces different geometries and product profiles. Even when produced on the same machine, these variations can still exist.

Understanding this, you can't have a standard profile for all titanium parts. Rather, as you scale up, you must be prepared to develop different quality plans. If you're producing only ten parts, for instance, it may be reasonable to conduct significant testing on each part. As you move up to 1,000 parts or more, however, you'll have to adopt a sampling plan. Determining the right plan is particularly challenging at present because, unlike with traditional manufacturing, there aren't yet industry-level quality standards in AM. It's up to each company to create its own standards and associated specifications to adhere to its desired quality safeguards, creating a further barrier to AM scalability.

"In many ways, making the decision to scale your AM efforts creates a 'chicken and egg' challenge... you'll never truly know its scalability potential until you invest in the necessary capital equipment and try it out."

Financial inhibitors

In many ways, making the decision to scale your AM efforts creates a 'chicken and egg' challenge. While a prototype might seem feasible in theory, you'll never truly know its scalability potential until you invest in the necessary capital equipment and try it out – a leap that can cost upwards of $1,000,000.

The trouble is that potential challenges or barriers only make themselves visible after you make that investment. It's quite possible that quality control issues, unforeseen technology investments or your choice of materials could cause problems only at a higher scale, making the experiment financially unfeasible. And you may not reach that point until many years down the road, after you've poured money and resources into the project.

Fig. 5 A bay of CNC machines for the post-processing of AM parts (Courtesy Burloak Technologies)

Overcoming the obstacles

As you can see, the barriers facing widespread AM scalability are far-reaching and complex. Overcoming them will require collaboration on the part of government, the manufacturing industry, academia and AM technology manufacturers and operators – and the path forward will be anything but easy. Here are some of the ways in which the key stakeholders can help move the needle forward.

Government

As governments across the world strive to tackle climate change and mitigate its negative impacts, many are looking to support new ways of reducing greenhouse gas emissions, particularly through clean energy initiatives. In the automotive sector, for instance, car manufacturers have long been required to adhere to strict fuel economy regulations – and these mandates are quickly extending to other sectors, as well. Additionally, a growing trend to reduce reliance on the global supply chain and bring more manufacturing dollars back home has motivated governments to create programmes designed to encourage domestic production.

AM offers a pragmatic solution to both mandates and stands to bolster national competitiveness in the process. Because of this, governments would be well served in providing funding programmes to help alleviate the vast financial cost of AM adoption and make scalability more feasible. As demand for AM increases, governments could also help meet the growing need for skilled labour by working with educators and industry to build AM programmes and facilitate a competitive talent pipeline.

Educational institutions

As AM gains momentum, educational institutions will increasingly need to train engineers in core DfAM principles. By supporting part consolidation and topology optimisation, DfAM can help manufacturers reduce both material weights and usage, resulting in less costly, lighter weight parts. It is also incumbent on industry to work with educators to help structure training programmes that allow engineers and designers to upskill. Given the significant savings potential inherent in industrial-scale AM, demand for enhanced skillsets (e.g., AM design expertise, qualified machine technicians, new types of quality control and next-generation software development) is only set to accelerate.

Industry

Part of AM's maturation process will inevitably involve the adoption of consistent, industry-wide quality standards – and widespread scalability will not occur until those standards exist. The trouble is, creating standardised process specifications to prove out each additive mixture is easier said than done.

Today, the few companies that have managed to produce parts via AM at scale have poured a lot of time and money into creating their own specifications. While some of these specifications may be consistent across industries, the truth is that most vary tremendously.

To overcome this challenge, many working groups – comprised of members of industry associations – are trying to find a common thread that will allow a basic framework to govern AM quality. ASTM International formed such a committee back in 2009 and ISO followed suit in 2011. Since then, several other standard development organisations have taken a crack at proposing globally consistent standards, ranging from AM process and equipment standards to those for finished AM parts.

The hope is that, with these parameters in place, individuals at the design level – who have ideally gone through an AM-focused education programme – will be able to integrate quality standards at the outset of the process, allowing the information to seamlessly flow downstream.

Fig. 6 Each AM technology requires a different set of skills, making it challenging to find people with the training to run the latest equipment or support AM scaling at large (Courtesy Burloak Technologies)

AM technology manufacturers

Regardless of which AM company you end up scaling with, they're going to have one thing in common: immature technology. That's because AM, itself, is a relatively new industry – and, in many ways, the technology still needs to evolve before we reach a point of seamless scalability.

Equipment reliability can vary from company to company, but your rate of success can also vary from batch to batch. As such, the equipment still has a lot of room to evolve and grow (depending on the technology) by adding more lasers, more power per laser, better control of the laser spot size, more consistent performance and other features. The challenging thing is that these advancements can only be achieved with time – and, perhaps, experience.

On the plus side, the digital infrastructure required to support AM is accelerating apace. Platforms now exist to streamline workflow management, analyse machine performance and schedule both production and post-processing, laying the foundation for improved scalability across the board.

Individual businesses

AM adopters can increase their rate of scalability success by doing the appropriate legwork up-front and making sure there's a sound business case for AM adoption. During this process, it's critical to consider the big picture and understand all facets of the investment, including the total cost of ownership, benefits of faster time-to-market and the long-term impact of improved part performance. From there, if a business case exists to scale your AM production, you'll need to develop a clear roadmap to keep your efforts on track.

Thankfully, this process is increasingly being supported by chemical and material manufacturers that continue to introduce innovative raw materials for AM.

"...it's critical to consider the big picture and understand all facets of the investment, including the total cost of ownership, benefits of faster time-to-market and the long-term impact of improved part performance."

Fig. 7 Hot Isostatic Pressing technology is used as a final processing step for some metal AM applications to eliminate residual porosity or optimise microstructures (Courtesy Burloak Technologies)

Solutions at our fingertips

As this assessment shows, a lot of things have to happen before scaling AM becomes an accessible and reliable endeavour. That said, partners such as Burloak are taking steps to accelerate the process and eradicate many of these barriers through enhanced AM solutions.

For instance, one of the greatest challenges in this space is variations in maturity – whether you're talking about expertise, technology, processes or industry standards. To overcome this issue, Burloak has made significant investments across the board. Not only do we employ some of the most knowledgeable and experienced AM advisors in the business, but we also offer all the high-performing tools you need, in-house.

This includes technologies such as Electron Beam Powder Bed Fusion (PBF-EB), Laser Powder Bed Fusion (PBF-LB); the Material Extrusion (MEX)-based processes High Speed Extrusion (HSE) and Fused Deposition Modelling (FDM); Directed Energy Deposition (DED); Binder Jetting (BJT); CNC machining; Hot Isostatic Pressing (HIP); vacuum heat treatment; and surface finishing equipment. Additional metrology and testing tools – such as a coordinate measuring machine, profilometer, micro-computed tomography (CT) and laser scanning (among others) – allow us to achieve extremely tight tolerances, precisely verify parts and assemblies and conduct a vast range of non-destructive testing to meet the most stringent quality parameters. This means everything from Additive Manufacturing to post-processing is conducted on the most reliable technology in the business – and tested in our state-of-the-art metallurgical lab.

Our team has spent years carefully studying all AM technology brands on the market and has taken steps to invest in equipment that offers the least variability from machine to machine. Additionally, every process we perform on a given machine comes with detailed operational instructions. This standardisation makes it easier to scale AM production. Specifically, we only have to go through the time-consuming qualification process for a product once – so if a customer comes back to us, even years later, requesting a larger run, we can do so with shorter lead times and guaranteed quality.

Solving for scalability

Perhaps one of Burloak's greatest advantages is that it's part of Samuel, Son & Co. – a 165-year-old company that specialises in metal processing, distribution and part manufacturing. With experience serving customers in virtually every industry, Samuel has a strong track record of operationalising and scaling manufacturing processes – and implementing virtually every type of metal processing and manufacturing technology currently available on the market.

This affiliation offers Burloak access to an unparalleled depth of

"As more organisations face mounting pressure to reduce GHG emissions, localise production and slash manufacturing costs across the board, AM could be the answer they're looking for. Which means scalability could be closer than we think."

knowledge and expertise related to part design and manufacturing, while allowing us to be technologically agnostic – and ensure every customer receives the best manufacturing recommendations for their required parts. Below are just a few ways we apply this knowledge to AM:

Consistent standards

One common practice when scaling a design at Burloak Technologies is to develop standardised processes and procedures. When a new project comes to Burloak, we work with the customer to understand their requirements, specifications and qualification needs – and then develop standardised processes to meet those requirements as well as the requirements of future projects.

For example, our Powder Metallurgy lab has been conducting mechanical testing in-house and collecting invaluable data for years. This data has helped us collaborate effectively with our customers to build out robust quality standards designed to meet their needs. Our strong Quality Management System, meanwhile, enables us to implement standardised work procedures to better define things like production needs, powder management requirements and quality specifications.

Essentially, in the absence of industry-wide standards, we work with our customers to establish our own set – and then apply those standards to relevant customers in relevant industries as we move forward. This standardisation in processes allows us to reach unparalleled levels of quality and repeatability – levels that are high enough to meet the stringent requirements of the aerospace industry, as well as power generation, automotive, space, energy and industrial manufacturing. This approach also saves a lot of time because we don't have to start from scratch with every new customer; many can skip over the standards development process and move right into production.

Local production

Another area Burloak is focusing on to help facilitate AM scalability is localisation. Because AM facilities aren't nearly as commonplace as traditional manufacturing facilities, it can be difficult to find a partner situated near your desired market, resulting in complex supply chain issues. Finding a partner with the capacity to produce parts at scale can also be a challenge.

To help alleviate this issue, Burloak offers an end-to-end AM facility in Oakville, Ontario, Canada as well as another facility in Camarillo, California, to support customers in the United States.

The way forward

While we are likely still a few years off from widespread AM scalability, the option exists for companies with a strong business case for the technology. As more organisations face mounting pressure to reduce GHG emissions, localise production and slash manufacturing costs across the board, AM could be the answer they're looking for. Which means scalability could be closer than we think.

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3D GALLERY
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3D PRINT

3D PRINT

Binder Jetting and beyond: Insights from Fraunhofer IFAM's second workshop on sinter-based Additive Manufacturing

After a one-year break, seventy industry and R&D participants from twelve countries found their way to the 2nd Workshop on Sinter Based Additive Manufacturing, Bremen, Germany, held from September 15–16, 2021. Industry suppliers, part producers, end users and researchers, as well as experts from the event organiser, Fraunhofer IFAM, considered the status of existing and new technologies in the field. Whilst metal Binder Jetting (BJT) received most attention, Material Extrusion (MEX) technologies were also covered in depth. Prof Dr-Ing. Frank Petzoldt and Dr Sebastian Hein report.

Binder Jetting: Pushing equipment, binders and powders to the next level

As the sinter-based AM technology which allows for the highest production rates for metal parts, the first day of the workshop focused fully on metal Binder Jetting (BJT). While most participants agreed that this is a maturing technology for limited series production, some, such as Desktop Metal's CEO Ric Fulop, went so far as to say that the technology is ready for mass production.

BJT is a flexible production method that is especially well known for manufacturing prototypes and metal parts in small-scale series. However, speakers at the workshop showed its potential for mass production. Fulop joined the workshop via livestream from the USA and gave insights into his company's Single Pass Jetting (SPJ) machines, built for high-speed production of metal parts. He also discussed new equipment from his company that will integrate the sintering process, thus making sinter-based Additive Manufacturing more accessible and easier to use for customers. These integrated technologies would indeed bring the industry a lot closer to a closed mass-production process.

Throwing a light on current developments in new binders, Andrew Klein from The ExOne Company showed promising results for nanoparticle-based binders for working with reactive metals such as copper. By incorporating nanoparticles as sintering aids, ExOne reached an average of 2% higher green density. Currently, the company is optimising the binder and BJT system to apply them to aluminium and titanium.

Fig. 1 Ric Fulop, Desktop Metal's CEO, presented at the workshop and stated that BJT technology is now ready for mass production

Fig. 2 ExOne's Eric Bader discusses BJT technology with a workshop participant

Fig. 3 Seventy industry and R&D participants from twelve countries attended the 2nd Workshop on Sinter Based Additive Manufacturing

Alexander Rütjes, Volkswagen AG, looked at sinter-joining possibilities for BJT parts, which is especially interesting for such companies which must consider the challenges of both depowdering of intricate parts and manufacturing large parts at scale. As one route to face these challenges, Alexander Rütjes gave insights into initial results of joining green parts by using powder interlayers in the sintering process, thereby allowing Volkswagen to exploit sintering as a joining process on a microscopic level.

When it needs to be tough and hard: Sinter-based AM also possible for cutting tools

Two speakers presented BJT case studies for the production of cutting tools and argued that sinter-based AM is especially suitable. Iñigo Agote, Tecnalia, Spain, explained that conventional manufacturing methods considerably limit the possible shapes of cutting tools and are only profitable above a certain number of produced tools in order to amortise the cost of the dies. Moreover, lead times for new developments are very long. In areas like design flexibility and prototyping, AM offers considerable advantages – and, since AM usually also entails less steps than conventional methods, it is worthwhile to explore AM. But which AM method to choose?

As Powder Bed Fusion (PBF) AM processes, in particular Laser Beam Powder Bed Fusion (PBF-LB), work with high-energy sources that melt the materials and creates very high cooling and heating rates, typical materials for cutting tools (e.g., WC-Co, M2, H13, ceramics and cermets) do not withstand such thermal shocks, which lead to cracks in the material. Moreover, the obtained density of the parts is often too low for tooling applications. In contrast, sinter-based AM processes do not use heat sources to consolidate the material. According to Agote, it is basically a die-less manufacturing process, which uses conventional post-processing to finish the part. Binder Jetting, then, compared to other AM methods, brings the known advantages of good surface quality, high resolution, a high production rate and a considerable cost reduction.

While Agote showed that Tecnalia achieved good mechanical properties with WC-Co by using BJT, Mikael Schuisky from Sandvik Additive Manufacturing, Sweden, discussed in depth the available metal powders and their properties for manufacturing cemented carbide tools. Both speakers showed the capabilities of BJT for the production of metal parts that need to be both extremely tough and hard. Though the costs for BJT of a cemented carbide component is, according to Schuisky, still 2-5 times that of conventional manufacturing today, he is confident that sinter-based AM has the potential of getting into the same range in the near future.

Know your powder: Powder properties and part quality

Three speakers shed light on metal powders, their properties and how they can contribute to part quality. Ralf Carlström introduced a new fine metal powder from his company, Höganäs AB, Sweden, for use in Binder Jetting, that is more cost-effective while offering high-quality properties. Metal powders for AM are typically produced by gas atomisation technology. Since 2015, however, Höganäs has been working intensively on the development and refinement of water atomised fine powders. In April 2021, the company opened a new fine powder plant in Johnstown, Pennsylvania, USA, where this technology is implemented on a larger scale.

Water atomisation has the benefit of having a higher scalability for the powder producer, thus reducing costs, from which the powder buyer, in turn, also profits. Water atomised powders have slightly different morphological and chemical characteristics than gas atomised powders, though. Carlström shared experiences from using water atomised fine 316L powder for Binder Jetting. Among other things, the results showed a sintered density of over 98% and a higher density area close to the part surface. The latter has positive effects for the surface finish, corrosion protection and mechanical properties.

Alexander Elsen from Heraeus Group. Germany, provided a deep dive into the capabilities of powder production focused for AM processes. Several powder properties were demonstrated, as well as their relation to the powder's flowability. He stressed the importance of a robust process in order to keep the specifications simple, which is usually not the case in AM today.

Bastian Barthel is a researcher at Fraunhofer IFAM, whose work looks at the relation of powder particle properties to parameters in the manufacturing, curing and sintering processes. At the workshop, he presented some of his findings. For instance, using metal powders like 316L, A11 and Nikro 128, with various layer thicknesses, Barthel ran separate build processes at two different roller traverse speeds (5 mm/s and 20 mm/s). Subsequently, he looked at the density of the green part. He discovered that a lower layer thickness significantly improves green part density. The traverse speed, though, is dependent on the powder's flowability – here, particle shapes come into play. For instance, spherical powders show superior flowability and packing behaviour and, thus, can be processed faster. Irregularly shaped powders, on the other hand, achieve better results from lower roller traverse speeds. In short, he showed that particle shape and particle size distribution have a major impact on processing behaviour. For manufacturers, this means that powder quality management is crucial for building mass production processes with BJT.

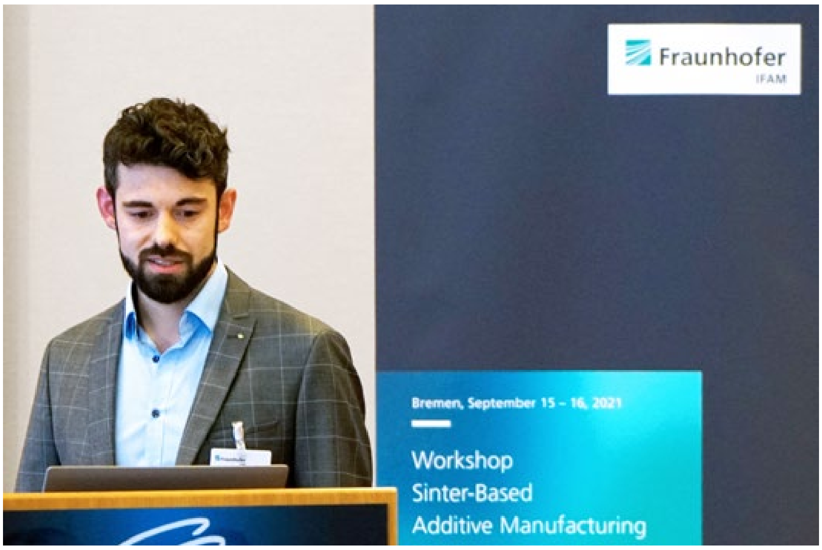

Fig. 4 Fraunhofer IFAM's Bastian Barthel presented research on the relation of powder particle properties to parameters in the BJT manufacturing, curing and sintering processes

"Carlström shared experiences from using water atomised fine 316L powder for Binder Jetting. Among other things, the results showed a sintered density of over 98% and a higher density area close to the part surface."

Automation and simulation: New approaches for better results

On the way to becoming a method for mass production, Additive Manufacturing technologies like BJT still have several hurdles to overcome. In his presentation, Andreas Hartmann from Solukon considered the depowdering step, often done manually. Manual depowdering, however, can cause considerable time

Fig. 5 A workshop panel discussion featuring Matthias Schmidt-Lehr (AMPower), Mariel Diaz (Triditive), Ralf Carlström (Höganäs AB), Iñigo Agote (Tecnalia), Mikael Schuisky (Sandvik Additive Manufacturing) and Andrew Klein (The ExOne Company)

loss, danger and quality defects, as Hartmann pointed out; his company has developed an automated solution. The automation of this process step supports time savings, safe and complete powder recovery as well as reproducible cleaning results, thus enabling a better quality management. This can be a key factor for Additive Manufacturing technologies to meet the requirements for mass production. Automating this step allows for integration into a fully digitally controlled process. Hartmann showed how an automated depowdering process can be optimised for each part geometry using intelligently controlled endless axis rotation. Current developments for the handling of plastic parts achieve unpacking and cleaning within sixty minutes – something which metal AM should hope to achieve as soon as possible.

Another aspect in need of better understanding and control is shrinkage during sintering. Dr Kiranmayi Abburi Venkata, Simufact Engineering, Germany, pointed out that sintering usually densifies the part from 60% to 95%, 35% of which is nonlinear shrinkage. In order to achieve a better grip on the sintering results, a simulation of the process is practically mandatory. All manufacturers know that large shrinkage requires compensation, as creep effects during sintering can be catastrophic. Yet, as Abburi Venkata highlighted, material data available in the literature are insufficient for use in existing simulation models. Simufact Engineering has developed a simulation software that implements several important functionalities, such as the prediction of densification and distortion under friction and gravity. Further enhancements are planned to be incorporated, but promising results were shown with the already existing tools.

"...sintering usually densifies the part from 60% to 95%, 35% of which is nonlinear shrinkage. In order to achieve a better grip on the sintering results, a simulation of the process is practically mandatory."

Of great importance to understanding the sintering process is the thermal balance in the furnace. Götz Hartmann, Magma GmbH, addressed the challenge that furnace temperatures are non-uniform and transient. Moreover, there is practically no reliable – and certainly no real-time – thermic and thermomechanical data of powders during sintering. At the same time, parts undergo three-dimensional stress and strain due to creeping that we want to control. One approach to understanding and optimising this process is by using process simulations. Hartmann showed Magma's fast way to generate furnace CAD models as a basis for thermal and gas flow simulation. The potential to combine this approach with further simulation tools may represent a way to a practical sinter simulation for specific machinery.

New technologies and materials for other sinter-based AM

Material Extrusion (MEX)

Though BJT was the most discussed AM technology at the workshop, other technologies and processes were also presented. A very promising new technology comes from Spain's Triditive, called Additive Multimaterial Deposition (AMD). This MEX-based technology can process filaments based on metals, composites and polymers simultaneously. Mariel Diaz, CEO and founder Triditive, focused on the production of metal parts in her presentation and showed how Triditive can optimise process parameters in order to achieve the best results for high-density parts.

Another MEX-based AM technology that can also process up to three materials, was presented by Vincent Morrison from Germany's AIM3D. This young company started as a spin-off from the University of Rostock, Germany, and has developed the what it calls Composite Extrusion Modelling (CEM). This uses well-known thermoplastic injection moulding materials, but in standard feedstock pellets rather than filament. Compared to MIM, CEM requires fewer steps in the production chain, resulting in faster lead times. Morrison presented an impressive use case in which the company significantly reduced the usual MIM lead times of eight-to-twelve weeks to one-to-three days using CEM.

Firat Hizal, Head of Metal Systems at BASF, Germany, reported on new filaments from his company that will make complex designs manufacturable via Fused Filament Fabrication (FFF). Support filaments for the commercially available Ultrafuse 316L and 17-4 PH stainless steels will soon be on the market. Further filaments based on titanium and nickel alloys are currently under development.

The Danish company AddiFab tested several MIM feedstocks, such as BASF's Catamold 8620, to see if they could shorten lead time using its Freeform Injection Moulding (FIM) technology. CEO Lasse Guldborg Staal was a presenter at the workshop and reported that first green bodies were ready for debinding and sintering forty-eight hours after receiving the first batch of granulate feedstock. First analyses of the parts show important similarities to MIM parts. AddiFab is currently looking for project partners to explore the possibilities of this technology and new material combinations.

Fig. 6 Mariel Diaz, CEO, Triditive, explained how Triditive is optimising process parameters for high-density parts

"Support filaments for the commercially available Ultrafuse 316L and 17-4 PH stainless steels will soon be on the market. Further filaments based on titanium and nickel alloys are currently under development."

Vat Photopolymerisation (VPP)

Thomas Studnitzky and Robert Teuber from Fraunhofer IFAM introduced two novel sinter-based approaches in AM that process paste-based feedstock. Recently, the institute has expanded its equipment to explore new AM technologies and material systems. Studnitzky started with Lithography-based Metal Manufacturing (LMM) also known as Vat Photopolymerisation. Feedstock is a paste containing metal powder combined with a photosensitive organic binder system. It stays in the solid state at room temperature, but liquidises at approximately 50°C. At the beginning of the process, a heat blade liquefies the paste in a reservoir and then distributes it onto the build platform. Subsequently, selective curing by near UV-light (405 nm) takes place to cure the desired geometry, layer by layer. When the process is complete, a solid block containing cured and non-cured feedstock is moved from the build chamber. Non-cured feedstock is then removed by melting, and the resulting part can be debound and sintered. Studnitzky sees many advantages

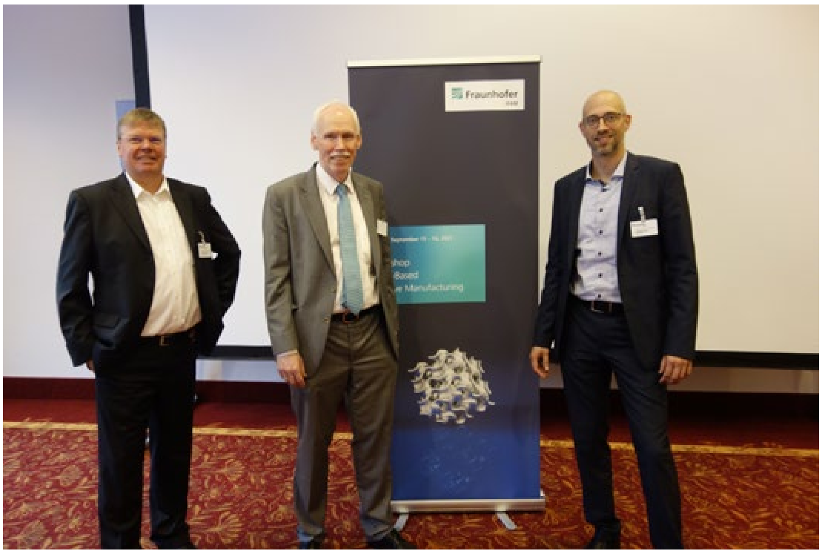

Fig. 7 From left to right, Fraunhofer IFAM's Dipl Ing Claus Aumund-Kopp, Prof. Dr-Ing Frank Petzoldt and Dr Sebastian Hein

for this process – for instance, there are nearly no design restrictions and no cost-intensive operator time is required for demoulding or the removal of support structures.

MoldJet

Robert Teuber presented the MoldJet process from Tritone, Israel. This is a paste processing AM technology that opens up new possibilities in the design freedom of metal components and offers enormous productivity. It combines two manufacturing processes for the flexible production of customer-specific parts. These work alternately with layered component production. First, the mould is produced in one layer as a negative of the component geometry from a wax-like polymer via inkjetting heads. This layer of mould material is then filled with metal powder paste via a slotted nozzle and a 'squeegee.' Due to the layer-by-layer design, the production of complex components with undercuts or even internal channels is possible without the use of support structures. By arranging several components next to each other, a whole batch of parts can be produced in one build. In addition, several batches can be placed on top of each other.

Conclusion

The second Fraunhofer IFAM workshop on sinter-based AM offered participants a thorough overview of current developments in the field, highlighting a technology which is, in some cases approaching technological maturity, and which is making encouraging progress toward readiness for mass production. It is clear from the presentations given during the seminar that the sinter-based AM processes currently available on the market offer considerable benefits for a range of applications, with further opportunities coming into reach with process optimisation.

After a long period without live events, all participants were eager to discuss these promising topics in the flesh once more, and are sure to have returned home with inspiration for their own projects. We look forward to seeing the further developments on offer at the next workshop.

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The inestimable value of AI: How Machine Learning can help AM project teams achieve their goals and beyond

They each have similar two-letter acronyms, and, for both technologies, it can be hard to separate hype from reality. But Artificial Intelligence (AI) and Additive Manufacturing also overlap in interesting and beneficial ways. In this article, Stephen Warde of Intellegens considers how AI methods such as Machine Learning (ML) could help AM to deliver against expectations – and at the very least, to meet more realistic and commercially essential objectives, such as consistently delivering lighter, stronger components and supporting on-demand manufacturing.

It's possible to think of many applications in which Machine Learning can be applied to Additive Manufacturing, from generative design of part geometries to defect detection in manufactured components. In this article, we'll focus on how the metal AM development process moves from the design or selection of powders towards the successful, repeatable manufacture of parts. Anything that makes this workflow faster and more reliable will be of enormous value, particularly in sectors such as aerospace, where new materials and parts must go through numerous certification cycles, often taking years and costing millions of dollars.

The project teams engaged in this area have what appears to be an ideal application for Machine Learning: they want to optimise a series of processes. Material composition, operating conditions, and process settings all interact with one another and impact the outcomes of these processes in complex and subtle ways. Even though we can describe and understand individual effects through the laws of physics, establishing all of the factors at play and grasping how they interact in multi-dimensional space is beyond straightforward human comprehension. But Machine Learning doesn't care about understanding those physical laws; it should be able to take data on the inputs and outputs of any process and 'train' models to capture how the inputs give rise to the outputs. Such a model could then, for example, predict which inputs will deliver optimal outputs. Can't we simply apply this to AM?

Fig. 1 Machine Learning has proved to be invaluable in the development of new AM alloys for aerospace applications

"In AM – which is further complicated by the inherent variability of many processes and machines – DOE approaches can struggle to reduce the experimental workload to a manageable amount."

It turns out that, yes, we can use Machine Learning for data-driven AM. But it's not so simple! As a result, this potential is only now beginning to be realised.

The challenge

To understand what's difficult about applying Machine Learning, let's look at how material and process optimisation typically proceeds and, thus, where the data that could feed a Machine Learning approach comes from. In both the development of new AM materials and the subsequent optimisation of AM processes, experimental design techniques are typically used. The most common are Design of Experiments (DOE), which systematically investigate the effects of varying parameters in the system. Testing every property of interest for every possible combination of material and build parameters is, of course, impossible.

The DOE process sets out to identify a set of experiments that will tell us the most about the system for the least effort, applying various statistical methods to propose which factors to vary. The knowledge and intuition of scientists also helps to narrow the options. This approach can significantly reduce the amount of experimentation required to obtain reliable coverage of the search space. But DOE usually still requires large numbers of tests and a lengthy, expensive process. In AM – which is further complicated by the inherent variability of many processes and machines – DOE approaches can struggle to reduce the experimental workload to a manageable amount.

This is in part because DOE statistical methods, although they improve on 'Change One Separate variable at a Time (COST)' approaches, are still limited in their ability to efficiently explore the universe of potential solutions. Machine Learning could potentially learn complex interactions between all of the factors involved, and so find better ways to cut the amount of experiment required. But there is a 'catch-22': to train a Machine Learning model typically requires a critical mass of quality data that is complete (i.e., has no 'holes') for all of the factors that you wish to model. But real-world experimental datasets are rarely complete, and building them is expensive.

Even constructing a relatively small training dataset that is complete for every factor of interest is difficult. Firstly, this presupposes that you know what the most interesting factors are, which may not be the case in an emerging tech area. Even if you can limit the properties to consider, it is usually not possible to measure every one of these properties for a single test coupon – think of the many mechanical properties that are measured through destructive testing. Building datasets by testing different samples that replicate the same input conditions is also difficult in AM, where performance is notoriously sensitive to tiny variations in factors such as geometry or processing conditions.

Ideally, AM teams would start with the project data that they already have and use Machine Learning to mine that. Because this involves aggregating data from many different tests, and possibly many different projects, the result will be a dataset that, while rich, is inherently sparse. That is, if imagined as a spreadsheet where the rows are materials or parts, and the columns inputs and outputs, then the spreadsheet would be riddled with blank cells. The data, brought together from multiple sources and subject to the vagaries of AM processes, will also be noisy. Faced with real-world experimental data, Machine Learning usually fails. These challenges can be mitigated, to some extent, with a large data processing effort and the application of smart data science, but each additional step reduces the likelihood of Machine Learning being applied in practice by AM teams.

Solving the 'sparse, noisy data' problem for alloy design

Meeting the 'sparse, noisy data' challenge for Machine Learning, specifically in the context of materials design, has been a focus of research by Dr Gareth Conduit and his collaborators at the University of Cambridge. The team developed a novel Machine Learning tool that has specialist capabilities to handle sparse experimental data. Working with Rolls-Royce, the tool was validated for the design of alloys. These include two nickel-base alloys for jet engines, two molybdenum alloys for forging hammers, and an alloy for additively manufacturing combustors. Each alloy had around a dozen individual physical properties that were predicted to match or exceed commercially available alternatives, and predictions have been experimentally verified.

This Machine Learning method has been commercialised by university spin-out company Intellegens as the Alchemite™ software. The aim, as Gareth Conduit explains, is to "change the contemporary approach to materials design, which comprises many cycles of trial and improvement. We use Machine Learning to short-circuit this approach, designing a material that fulfils all of the target criteria."

Since Intellegens was founded in 2017, the technology has been put to work on a wide variety of applications, within and beyond the materials and process field. In AM, these included a further example of material design – this time, working with GKN Aerospace and the ATI Boeing Accelerator to identify a new titanium alloy that could maximise thermal conductivity without diminishing mechanical properties for heat exchanger applications. Marko Bosman, Chief Technologist at GKN Aerospace highlighted the benefits of "a powerful tool for virtual experimentation, unleashing unexplored territory in the search for better metal alloys tailored to future applications."

The virtual experimentation referenced by Bosman does not replace all physical experiments, but it helps researchers to choose which of those experiments to do. Gareth Conduit points to the importance in this process of accurate uncertainty quantification in the Machine Learning model: "We do not just predict a set of properties. We have invested a lot of effort in ensuring that our Machine Learning algorithm gives the scientist detailed information about the uncertainty of every value – that is, how much trust they should place in it. This is essential to help scientists identify which candidate materials are most likely to succeed."

Machine Learning can also be used to enable adaptive design of experiments. Here, predictive power is focused not on proposing a new material, but on the continuous improvement of the Machine Learning model itself. The tool identifies what missing data would most effectively reduce the uncertainty in the model's predictions, and can even factor in the cost of particular experiments to propose which tests should be done next in order to have the most positive impact on improving the model for the least cost.

This combination of capabilities – designing new materials, virtual experimentation, and adaptive design of experiments – can lead to dramatic results for materials development once they become feasible from a starting point of sparse, noisy experimental data. The Rolls-Royce project, for example, saw new materials identified with a 90% reduction in the amount of experiment required.

Fig. 2 Ian Brooks of AMRC with one of the machines used in Project MEDAL

Project MEDAL – optimising process parameters

If Machine Learning has demonstrated its viability for improving the design of new AM materials, what about the next step in the AM process: optimising process parameters to enable consistent builds of parts from these new feedstock materials? Process parameter optimisation is the focus of Project MEDAL, a collaboration based at the University of Sheffield's Additive Manufacturing Research Centre (AMRC) North West, involving Boeing, and supported by the UK's National Aerospace Technology Exploitation Program (NATEP).

Project MEDAL concentrates on Laser Beam Powder Bed Fusion (PBF-LB) methods, as it is the most widely used metal AM technology in industry. The project aims to dramatically reduce the amount of experimentation required to identify the right process parameters to manufacture high density, high strength PBF-LB parts from a new feedstock material. Ian Brooks, Technical Fellow and the project lead at AMRC (Fig. 2), describes the tradi-

"The project aims to dramatically reduce the amount of experimentation required to identify the right process parameters to manufacture high density, high strength PBF-LB parts from a new feedstock material."

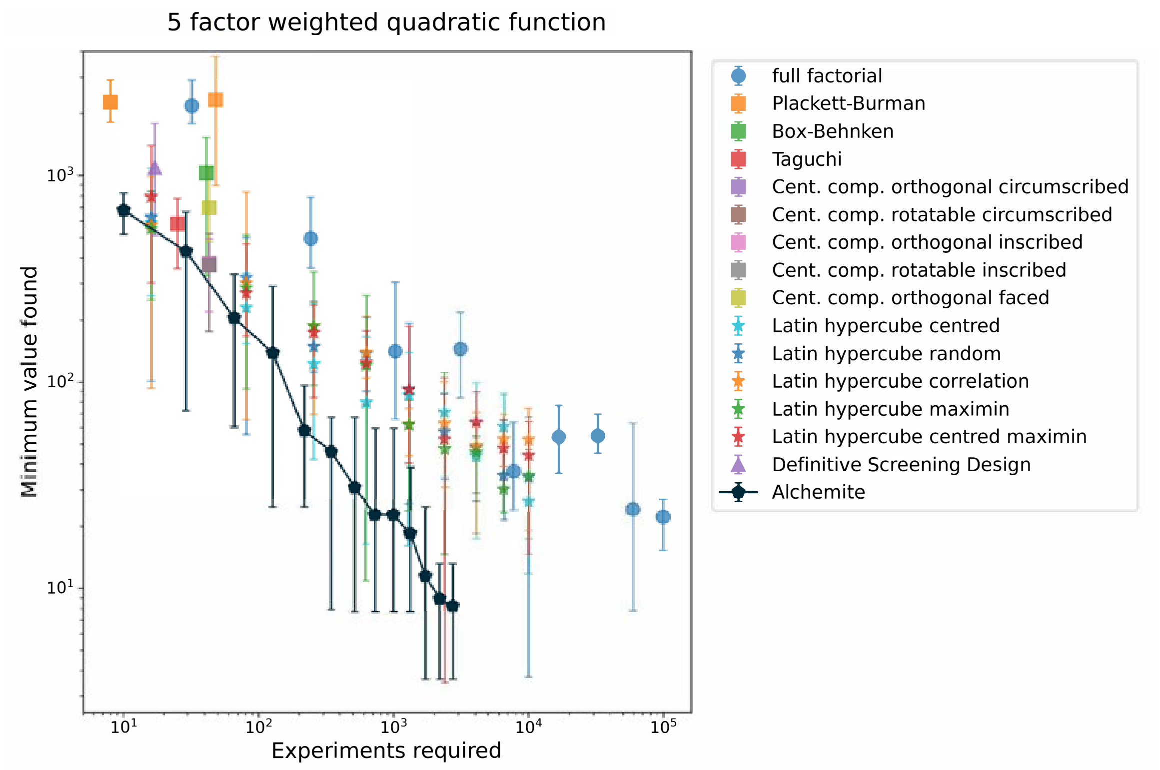

Fig. 3 The number of experiments required to converge on a solution using Alchemite™ Machine Learning (lower, dark blue line) when compared with standard DOE methods. The graph is a log scale, so shows order-of-magnitude improvements

> *"Just as we saw with materials design, the key challenge is to reduce the amount of experiment required in a situation with a large number of variables that interact in a complex manner. The idiosyncrasies of AM machines add to the difficulty."*

tional process development cycle as: building and treating test samples, testing them, and then repeating the process with modifications until it converges on an acceptable solution – usually a balance between performance and cost. Just as we saw with materials design, the key challenge is to reduce the amount of experiment required in a situation with a large number of variables that interact in a complex manner. The idiosyncrasies of AM machines add to the difficulty. Brooks illustrates how costly this can be: "A standard test methodology here would be taking a sample, mounting it, polishing it, etching it, and then analysing it and generating a response variable from a microscope or similar – so time-consuming and cost-intensive."

Presenting progress so far in the project at a recent webinar, Ian Brooks showed a comparison between using the Machine Learning and a range of standard DOE methods in identifying the experiments required to find the process parameters that would minimise a key process outcome. Machine Learning "was able to converge on the optimum solution with far fewer experiments." Again, order-of-magnitude reductions were found for some of the response variables studied. Work to build on these findings is on-going (Fig. 3).

"The opportunity for this project is to provide end-users with a validated, economically viable method of developing their own powder and parameter combinations," Brooks explained. "[The findings] will have applications for other sectors including automotive, space, construction, oil and gas, offshore renewables, and agriculture."

Lukas Jiranek, AM Engineer at Boeing Research & Technology, explained the company's involvement in the project: "Across the company, Boeing employees are scaling up AM to produce metal and polymer components for a number of Boeing products and applications. There are currently over 70,000 AM components flying on various Boeing platforms. With these multiple efforts and the data-rich AM process chain, Machine

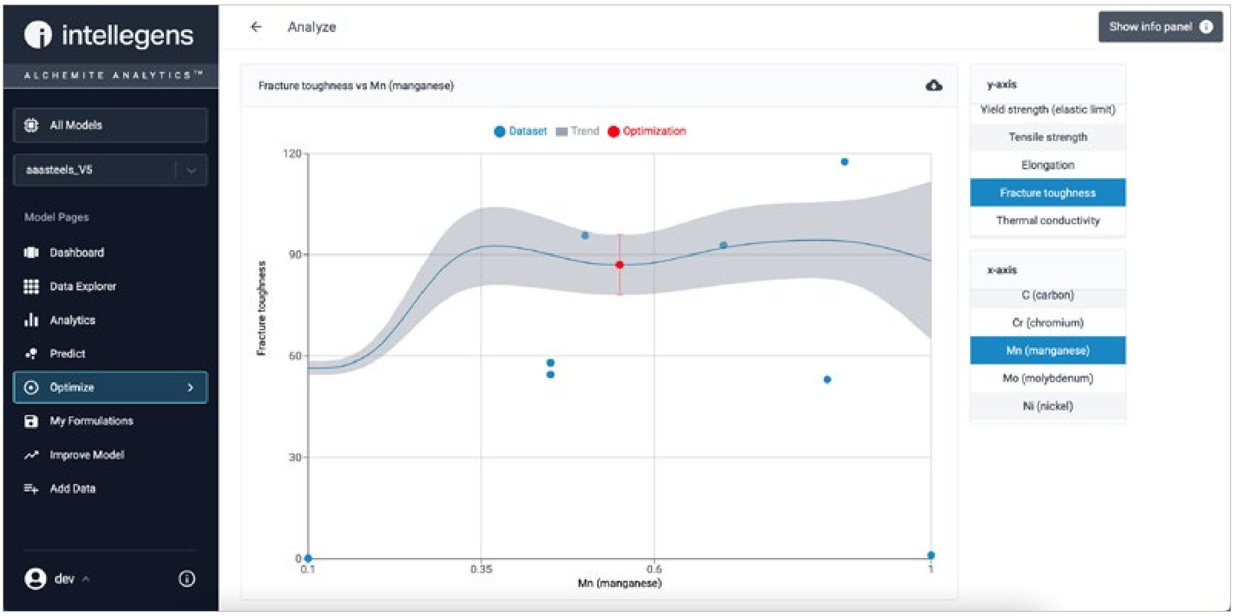

Fig. 4 For Machine Learning to have the desired impact, it needs to be deployed via accessible software. Here the Alchemite™ Analytics user interface is being used to visualise predictions of material properties from a Machine Learning model

Learning has the potential to be a key technology in accelerating the further development and adoption of AM. Project MEDAL is a valuable step forward in creating and proving-out standardised approaches to Machine Learning for data-driven AM process parameter development."

Machine Learning in practice

This focus on practical implementation raises an important question. Can novel Machine Learning branch out beyond research projects and become a mainstream tool for AM project teams? "That's already happening," states Ben Pellegrini, CEO at Intellegens. "But it does require us to think hard not just about whether the technology works, but also about its deployability. We call this the 'ML Ops' challenge – Machine Learning hasn't yet had the impact it could have because it doesn't get operationalised; it's just too hard to use. Of course, in many cases, that's because people have not even been able to get past square one with sparse, noisy, experimental data. But even as we solve that problem, we need to be thinking about who will use the technology, and how."

According to Pellegrini, that means thinking about two key classes of user. "The power users who will push the boundaries are data science teams – and they, quite rightly, will not be constrained to using one Machine Learning tool. They want methods that will easily plug-and-play with their own in-house tools and other systems, using open standards and scripting languages like Python."

But to really impact AM projects, validated models need to get into the hands of domain experts – scientists and engineers – so that they can combine new insights into their data with their expert intuition. This is a key message that Intellegens has heard from customers, said Pellegrini: "Alongside smart methods, they are guiding us to place an equal focus on delivery through easy-to-use desktop software that generates useful analytics without too much need to pre-process data or specify the detailed assumptions underlying the model" (Fig. 4).

"...to really impact AM projects, validated models need to get into the hands of domain experts – scientists and engineers – so that they can combine new insights into their data with their expert intuition."

"Most companies for whom materials and process data is a vital corporate asset now have systematic programs in place to digitalise that asset, thus protecting valuable intellectual property, and making it much easier to exploit."

Businesses also need to think about how Machine Learning can integrate with their data management infrastructure – both to push the right data into the Machine Learning models, and to capture results and the models themselves so that they can be shared and reused. The leader in materials data management, engineering simulation software giant Ansys, is one company that has been thinking about this. "Most companies for whom materials and process data is a vital corporate asset now have systematic programmes in place to digitalise that asset, thus protecting valuable intellectual property, and making it much easier to exploit," explained Sakthivel Arumugam, Senior Product Manager at Ansys. "We provide a solution to enable that specialist data management with Granta MI™, and we've recognised that our customers now want Machine Learning embedded into that infrastructure for their Additive Manufacturing material and process data."

Conclusion

So, Machine Learning does have the demonstrated potential to help AM project teams, both in the design of new AM materials and in the processing of those materials to build AM parts. Practical implementations that deploy the technology for use in AM are gaining ground. We've seen a few specific examples, and there are sure to be many more.

But we've also seen some of the challenges that need to be overcome, and thus the criteria against which any solutions in this area need to be measured. Can they overcome the difficulties of training Machine Learning models with real-world, sparse, noisy, high-dimensional data? Do they provide the right combination of tools both to design new materials and processes and to support adaptive design of experiments? Do they provide an accurate understanding of the uncertainty in their predictions, enabling rational decision-making? Can they be deployed effectively both to data science teams, who want to combine and customise best-in-class Machine Learning, and to AM scientists and engineers, who just need a pragmatic tool to get useful insights from their data? Machine Learning solutions that tick these boxes can help to deliver more reliable, repeatable AM projects, sooner, and at lower cost – something real behind the hype for both AM and AI.

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The need for global standardisation: Takeaways from the Standards Forum at Formnext 2021

As metal Additive Manufacturing progresses toward more widespread industry penetration, the need for globally recognised and agreed upon standards increases. The day before Formnext 2021, key standards organisations and a cross-section of the Additive Manufacturing community attended the annual Standards Forum at Formnext. The forum's programme illustrated the industry's awareness of the need for standardisation and highlighted some of the challenges faced. Noah Mostow reports on the discussion on behalf of *Metal AM* magazine.

In a fast-paced industry like Additive Manufacturing, standards can sometimes be overlooked – but this is quite possibly the most important development for AM to reach widespread adoption. Standards establish a threshold for minimum requirements and provide guidelines for the effective and successful implementation of technologies. Perhaps most importantly, they create opportunities for economic growth by helping to open trade in regions of the world that choose to embrace them.

On November 15, 2021, industry experts gathered for the Standards Forum at Formnext 2021 in Frankfurt, Germany. Organised by the US Commercial Service, part of the US Department of Commerce's International Trade Administration, ASTM International, and ISO. The forum was held one day before the official launch of Formnext, and focused on the adoption of AM through standardisation. Key takeaways from the event are that standards:

- Facilitate industry adoption by building trust and confidence
- Provide AM guidelines to organisations in compliance with regulatory agencies
- Develop a baseline for product performance

It may be surprising to some that only about 5% of forum attendees were from standards development organisations (SDOs). In fact, as many as 120 attendees came from eighty-eight organisations in aerospace, electronics, energy, and medical, and many other sectors partici-

Fig. 1 Members of eighty-eight organisations gathered to discuss the adoption of AM through standardisation at the Standards Forum at Formnext 2021

Fig. 2 An additively manufactured titanium acetabular hip cup can rely on as many as sixty standards to support its design, certification, and manufacturing (Courtesy LimaCorporate)

"Many SDOs are expanding their AM efforts, which supports further adoption – however, this could lead to duplicate or conflicting standards, causing challenges for the industry."

pated, including research institutes, software producers, and machine manufacturers.

Speaking at the event, Martin White, Head of AM Programmes at ASTM International's Additive Manufacturing Center of Excellence (AM CoE), stated, "Standards can be the backbone of every AM organisation, if they are understood and applied correctly." A key challenge today is creating standards that meet the needs of the industry.

Developing standards

The first technical standard was created by Joseph Whitworth in 1841 at the end of the first industrial revolution. It described measurements for screw threads. Before this, screws were made by hand, with no set standard. The adoption of standardised system helped everyone operating a lathe to manufacture the exact same screw based on Whitworth's guidelines. Today, this standard is nearly obsolete because most screws are based on the Unified or Metric thread standard.

For AM, the first technical standard – ASTM F2792 – was published in October 2009 by ASTM International Committee F42 on Additive Manufacturing Technologies. The committee was established in 2009. The standard provided twenty-seven terms and definitions for AM, which later evolved into the ISO/ASTM 52900 standard on terminology for Additive Manufacturing. This initial version helped to ensure future standards would use the same language to describe AM processes and related terms. An important part of the standard is the development and publication of the seven standard process categories in use today.

In 2011, ASTM International and the International Organization for Standardization (ISO) signed a partner standards developing organisation (PSDO) cooperative agreement. The purpose of the PSDO was to eliminate duplicative work between ASTM International Committee F42 and ISO Technical Committee 261 on Additive Manufacturing. The organisations have published thirty-nine AM standards, and have more than seventy in development, as of December 2021.

Many SDOs are expanding their AM efforts, which supports further adoption – however, this could lead to duplicate or conflicting standards, causing challenges for the industry. SDOs in the US that create AM standards include the American Society of Mechanical Engineers (ASME), American Welding Society (AWS), and Underwriter Laboratories (UL). Globally, that extends to the Association of German Engineers (VDI), British Standards Institution (BSI), German Institute for Standardization (DIN), The

Norwegian Truth (DNV), and SAE International.

With a goal of helping to coordinate and accelerate AM standardisation efforts, America Makes and the American National Standards Institute (ANSI) launched the Additive Manufacturing Standardization Collaborative (AMSC) in 2016. The AMSC is not developing standards, but rather helping to align standards development activity.

One challenge for organisations is knowing which standard(s) to follow, or if standards for their chosen activity already exist. With more SDOs entering the AM market, duplicative work is inevitable, which can be confusing for both users and certification organisations. This was one of the main reasons for the PSDO between ASTM International and ISO and AMSC.

Further, individual organisations are creating process specifications that are often more specific than industry-wide standards. They can include build parameters, powder removal processes, and surface quality checks. Boeing's SES-15 communication satellite was built with more than fifty metal AM parts. The satellite currently orbits more than 35,000 km (21,750 miles) above Earth. The parts were made using Powder Bed Fusion (PBF) in accordance with ASTM F2924–Standard specification for AM Ti6Al4V with PBF. Other process specifications were created by Boeing, but are not available to the public.

By following standards, Boeing is able to be more confident about the parts it sends into space. After the successful launch of this satellite in 2017, the company can trust the standards and specifications used to create more satellite parts with AM by following this process.

Supporting a growing market

During the Standards Forum, William Czajkowski, of the US Embassy in Berlin, stated, "We are trying to build an industry for the 21st century and we cannot do it without standards."

Fig. 2 shows an additively manufactured titanium acetabular hip cup produced by LimaCorporate. More than sixty approved standards support the design, certification, manufacturing, and post-processing of this type of product. One example is ISO/ASTM52902-19–Geometric capability assessment of AM systems. It describes benchmark test-piece geometries and quantitative and qualitative measurements to assess. Other non-AM specific standards include ASTM F1820-13–Standard test method for determining the forces for disassembly of modular acetabular devices. These standards help build confidence among manufacturing companies and their customers. Without standards, it is unlikely doctors would use orthopaedic products made by AM. Companies can save time and money for design validation and testing by following accepted industry standards.

For years, many complained about the lack of standards in AM. Today, the challenge has shifted to not knowing which standards to use and how to go about applying them. To grow AM, it is important for the industry to collaborate to solve these problems.

"For years, many complained about the lack of standards in AM. Today, the challenge has shifted to not knowing which standards to use and how to go about applying them. To grow AM in the 21st century, it is important for the industry to collaborate to solve these problems."

Creating a baseline

As more applications of AM emerge, standards will be developed to support them. Martin White, ASTM International, stated, "At some point, you will be handed a standard that you must follow. The best time to get involved is during the development phase, so you can help shape the standard."

ASTM International creates consensus-based standards. This means that 100% of voting members must support a proposed standard. Anyone can vote if they are a member of ASTM International. The benefit to consensus standards is that the perspective and expert knowledge of those involved has been considered. As a result, the standard is almost always better.

As of December 2021, ASTM International Committee F42 on Additive Manufacturing Technologies had more than 1,000 members in over forty countries. Members include experts from a wide range of regulatory bodies and industry sectors, including aerospace, defence, medical, space, energy, and construction.

One of the best known standards for engineers is likely ASTM E8/E8M—Standard test methods for tension testing of metallic materials. This enables a person to test and compare materials or manu-

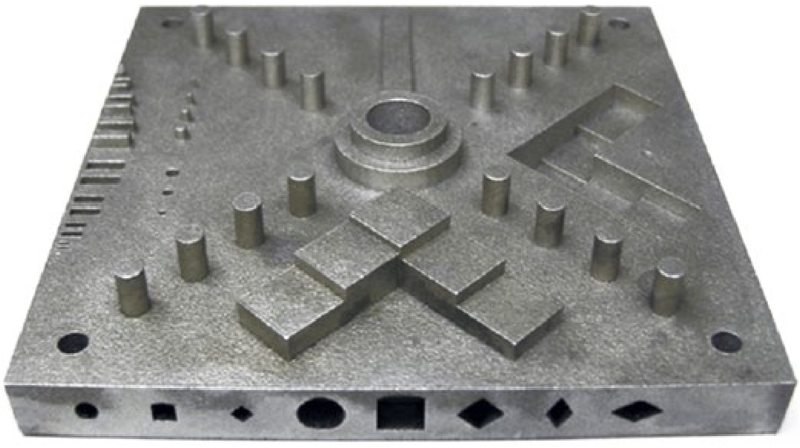

Fig. 3 Test artefact with standardised measurements to determine part accuracy (Courtesy NIST)

"As new standards are published, it is important that stakeholders are aware of them; without knowledge of available standards, individuals and organisations will seek to create their own, which would compete with accepted industry-wide standards and create redundancies."

facturing methods using the same set of parameters. A similar test for geometric tolerancing can be seen in Fig. 3. This part was designed by the National Institute of Standards and Technology (NIST). When building this part using metal PBF and recording the measurements, it is possible to validate a machine's geometric accuracy. This part led to the creation of ISO/ASTM 52902–Geometric capability assessment of AM systems.

Standards are also developed for material properties, file formats, and design parameters. ISO/ASTM52907–Methods to characterize metallic powders describes sampling, particle size distribution, morphology, and flowability, and how to characterise them. Without this guidance, it would be nearly impossible to compare two powders. For flowability, reference ISO/ASTM 52913-1–Part 1: Parameters for characterization of powder flow properties.

Conclusion

A key takeaway from the Standards Forum was that more education is needed in this area. As new standards are published, it is important that stakeholders are aware of them; without knowledge of available standards, individuals and organisations will seek to create their own, which would compete with accepted industry-wide standards and create redundancies.

The AM industry continues to expand with the support of industry standards. Standards aid industry adoption and provide guidelines for certification organisations. Standards also support AM education and training.

The next Standards Forum will again be held in conjunction with Formnext, and is scheduled for November 14, 2022, in Frankfurt, Germany.

Authors

This article was written by Noah Mostow with support from Terry Wohlers and staff at the ASTM International AM Center of Excellence

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Laser Beam Powder Bed Fusion: Process developments and numerical simulation

A technical session at the Euro PM2021 Virtual Congress, organised by the European Powder Metallurgy Association (EPMA) and held October 18–22, 2021, was devoted to the consideration of process developments and numerical simulation approaches for Powder Bed Fusion (PBF) Additive Manufacturing technologies. In this report, Dr David Whittaker reviews four of the papers presented on this topic, looking at process parameter optimisation, increasing quality for Ti6Al4V medical parts, techniques to improve the AM of hot-work tool steels, and powder spreading improvements for stainless steel.

Efficient process parameter optimisation procedure in Laser Beam Powder Bed Fusion

The first of the papers in this session came from Maria Montero-Sistiaga, Marc De Smit, Ralph Haagsma and Ian Bennett (NLR, the Netherlands), and showcased this group's development of an efficient process parameter optimisation procedure for Laser Beam Powder Bed Fusion (PBF-LB) [1].

Important PBF-LB material properties, such as porosity, microstructure and surface roughness, are largely determined by the applied layer thickness, laser power, scan velocity and distance between laser scan vectors. Past studies aimed at PBF-LB parameter optimisation have generally been based on the definition of a test matrix that covers an array of samples with different combinations of parameters. These methods require the production and analysis of a large number of samples, making them time consuming and expensive.

This presented paper described work done on the development of a new methodology for selecting PBF-LB parameters. The approach was based on the analysis of a large number of parameter combinations with a minimum number of samples. Parameters were optimised for processing AlSi10Mg alloy, which was selected because of its suitability for use in thermal control applications. In this work, the methodology for optimising the contour, hatch (also known as core or bulk) and interface parameters was investigated.

For optimisation of the contour, thin walls were built with varying laser power and scan speed. For the hatch area, blocks were built with varying hatch distance along the sample length. Finally, for selection of the optimum interface settings, the hatch area was rotated relative to the sample contour in order to induce a variable offset between the contours and the hatch. Parameter selection was carried out based on analysis of sample cross-sections. The selection methodology was described for each optimised setting.

The AlSi10Mg powder used in the study had the composition shown in Table 1. The powder particles were not fully spherical and had sizes between 20–63 μm, with an average size of 43.8 μm. The samples were processed on an SLM 280^{HL} machine. Three types of geometry were generated: thin walls, blocks with varying hatch distance and blocks with rotated hatch, as shown in Fig. 1.

Al	Si	Mg	Fe	O	Ni	Zn	Ti	Pb	Mn	Cu	Other
Bal.	10.10	0.36	0.22	0.06	<0.01	<0.1	<0.01	<0.01	<0.01	<0.05	<0.05

Table 1 Composition of AlSi10Mg powder in weight percent [1]

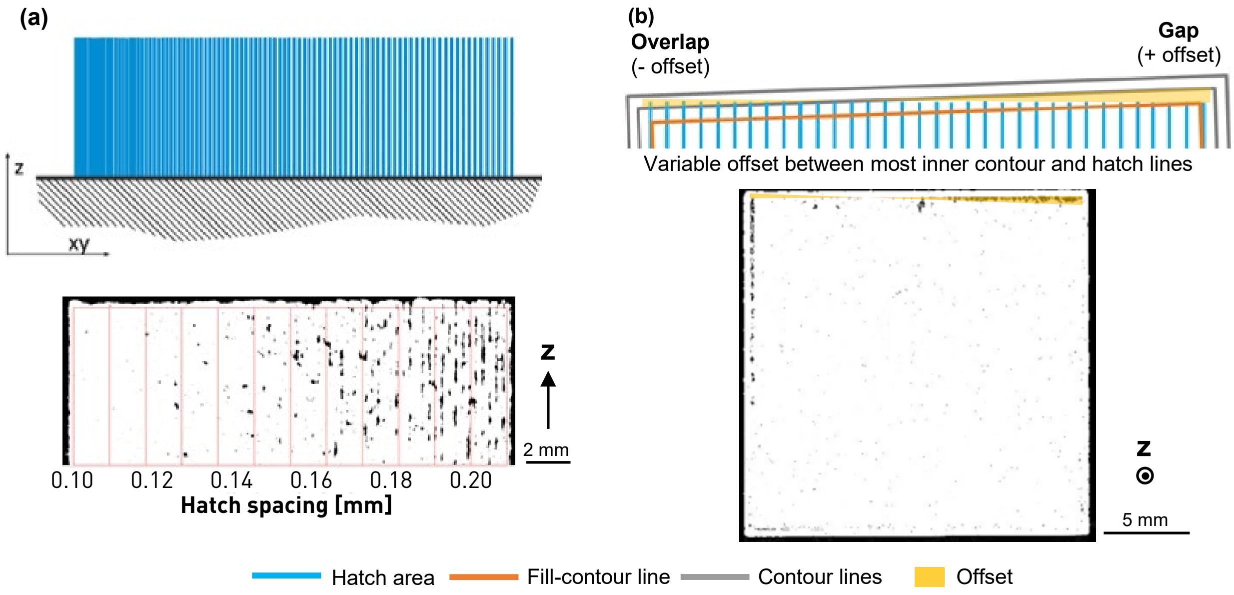

Fig. 1 (a) Example of a block with variable hatch spacing across the length, where the twelve analysed fields are depicted with red coloured rectangles, (b) schematic representation of the blocks built with a rotated hatch for creating a variable offset along the edge [1]

Thin wall samples were built by stacking single vector scans in multiple layers. Each wall was built with a specific laser power and scan speed combination. The laser power (*P*) was varied from 70 to 300 W and the scan speed (*v*) from 300 to 667 mm/s, building a total of 120 single track walls. Variable hatch block samples (10 x 20 x 7 mm) were made, in which the applied hatch line distance (track distance/space) was increased in small steps from 0.1 to 0.21 mm. Each block was built with a specific laser power and scan speed combination. Twenty-four blocks were built with a *P* of 350 W or 380 W and *v* between 875 and 1900 mm/s.

An example of the variable hatch spacing within the block is shown in Fig. 1(a). On the left side, a hatch distance of 0.1 mm was applied, then increased up to 0.21 mm on the right side. Lastly, two blocks (20 x 20 x 7 mm) with a rotation of the hatch area were built. This rotation was made in order to create a variable offset between -0.1 and 0.2 mm between the contour and the hatch area (core), as shown in Fig. 1(b). For simplicity, the linear energy density (E_L) term was sometimes used for determining a *P* and *v* combination. This was calculated as: $E_L = P \cdot v$ [J/mm].

The quality of the samples was evaluated by analysing optical microscopy images of the cross-sections using a MATLAB script. For the thin walls, the porosity, thickness and roughness were evaluated. The blocks with variable hatch and rotated hatch were analysed based only on the porosity. For this purpose, the region to be analysed was subdivided into twelve equally-shaped rectangular fields (Fig. 1(a)). With this procedure, the porosity could be analysed along the cross-section as a function of the varied parameters.

For optimisation of the contour parameters, cross-sections of the walls were analysed based on the thickness, roughness and porosity. It was observed that a low roughness was obtained at high *v* and E_v, and low porosity for low E_v. Therefore, medium E_v and high *v* should be selected for a compromise between low porosity and low roughness; 667 mm/s, 190 W and 0.28 J/mm. After selection, the thickness was considered for setting the beam compensation and the distance between neighbouring contours. The former was taken as half of the track width and, for the latter, 30% overlap was recommended. In this case, the wall thickness was 0.296 mm, hence the beam compensation was 0.15 mm and the distance between contours 0.21 mm.

After selecting contour parameters based on the thin walls, the parameters for the hatch or core were selected. Blocks with varying hatch distance were built, building each block with a specific laser power and scan speed combination. In the case of aluminium, it was observed, in previous studies by this group, that high laser power is required for building parts with low porosity. Therefore, only two laser powers were selected in this work; 350 and 380 W. Table 2 gives an overview of the analysis of the variable hatch blocks. From each block, the porosity in the 12 fields was determined. The minimum value of the porosities is shown in column 5. The field number in which this minimum porosity was measured is shown in column 6. In addition, the average porosity over a larger

[1]	[2]	[3]	[4]	5]	[6]	[7]	[8]
						Average porosity [%]	
Sample number	*P* [W]	*P/v* [J/mm]	*v* [mm/s]	Minimum porosity [%]	Min. Porosity per field	Min. in 1/3 of the block	Of rolling average 4 fields with same P
1	350	0.200	1750	0.41	1	1.09	0.57
2	350	0.218	1606	0.11	1	0.46	
3	350	0.236	1483	0.27	5	0.39	
4	350	0.254	1378	0.16	4	0.27	
5	350	0.273	1282	0.05	1	0.07	
6	350	0.291	1203	0.05	4	0.12	
7	350	0.309	1133	0.05	1	0.14	
8	350	0.327	1070	0.21	6	0.31	
9	350	0.345	1015	0.27	10	0.36	
10	350	0.363	964	0.15	5	0.72	
11	350	0.382	916	0.75	2	1.09	
12	350	0.400	875	1.36	7	1.81	
13	380	0.200	1900	0.40	1	1.58	0.48
14	380	0.218	1743	0.08	1	0.37	
15	380	0.236	1610	0.07	1	0.20	
16	380	0.254	1496	0.09	3	0.14	
17	380	0.273	1392	0.04	1	0.06	
18	380	0.291	1306	0.10	4	0.13	
19	380	0.309	1230	0.09	4	0.14	
20	380	0.327	1162	0.06	2	0.24	
21	380	0.345	1101	0.17	6	0.28	
22	380	0.363	1047	0.20	7	0.37	
23	380	0.382	995	0.50	10	0.61	
24	380	0.400	950	1.41	4	1.62	

Table 2 Overview of the analysis of the blocks with variable hatch. The column number is shown in brackets [1]

area of four fields was evaluated in column 7 in order to rule out the effect of clustered pores. This value represents how stable the parameters were over a larger area. Lastly, the average of the values in column 7 was calculated for each laser power, shown in column 8.

From Table 2, it can be observed that using a laser power of 380 W resulted in lower porosity. In addition, by looking at the rolling average (column 7), a low porosity was found in a wider scan speed range. After selecting the laser power, the scan speed was selected. For this, columns 5 and 7 were considered. It can be concluded that the sample built with 1392 mm/s showed the lowest porosity values. After selecting the *P* and *v* combination, the chosen block was analysed by looking at the porosity level for the hatch spacing. It could be observed that, below 0.14 mm hatch spacing, low porosity values were obtained, below 0.09%. A hatch distance of 0.11 mm resulted in 0.04% porosity.

After selecting the contour and the hatch parameters, the interface between the two needed to be optimised. Porosity in this region must be minimised when the parts are subjected to fatigue loading, since it is known that surface and sub-surface defects are detrimental. Therefore, in this work, the hatch area was rotated in order to create a variable offset between the hatch and the contour, as shown in Fig. 1(b). In addition, the effect of using a fill-contour, an extra contour scanned between

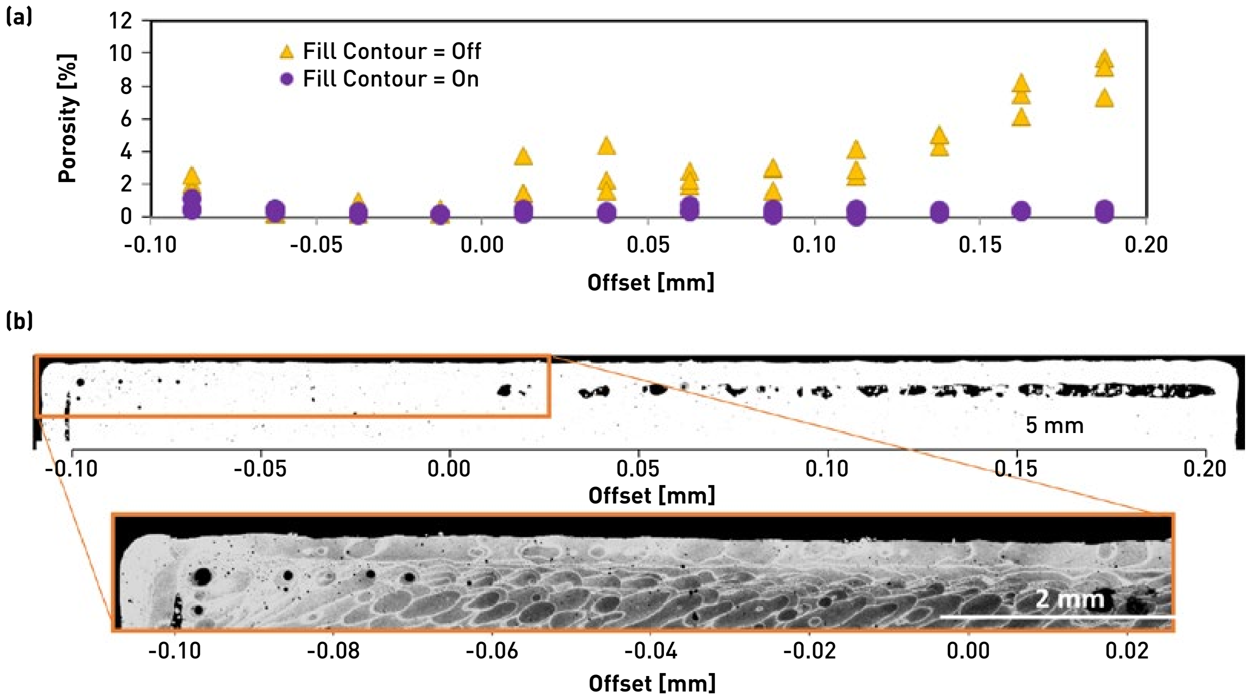

Fig. 2 Evaluation of the contour hatch interface with a variable offset along the length. (a) Porosity percentage as a function of the offset for the blocks built with no fill-contour and with fill-contour, (b) block with no fill-contour showing a good overlap for offsets < 0.00 mm [1]

"The authors made the overall claim that this proposed methodology allows an efficient optimisation method for contour, hatch and interface parameters. The contours can be optimised by building thin walls with varying laser power and scan speed."

the contour and the hatch, was evaluated.

The measured porosity in the hatch-contour region as a function of the hatch-contour offset is shown in Fig. 2. In Fig. 2(a), it is shown that the fill-contour strongly reduced the porosity between the hatch and contours. When scanning without fill-contour, the porosity increased when increasing the offset to higher positive values. This is shown in Fig. 2(b) where more irregular-shaped pores are present on the right-hand side of the cross-section. It can be observed that, above 0.00 mm, large lack-of-fusion pores were present. In order to select the appropriate offset value, a negative offset should be applied. In this case, an offset of -0.03 mm was selected. Also, it was recommended to use a fill-contour to ensure good overlap. It should be noted that these blocks were built without skywriting methods, which are known to decrease the key-hole pores at the start of the tracks. Therefore, the authors recommended that the methodology should be repeated on blocks built using 'skywriting' mode. Skywriting in Additive Manufacturing refers to the situation where the mirror used for scanning has already been accelerated to the desired speed prior to exposure.

The authors made the overall claim that this proposed methodology allows an efficient optimisation method for contour, hatch and interface parameters. The contours can be optimised by building thin walls with varying laser power and scan speed. For parameter selection, the porosity, as well as the roughness and thickness, are considered. The hatch parameters were selected based on blocks built with variable hatch spacing. This method drastically reduces the number of samples that need to be built for the selection. Lastly, a rotated hatch start allows the optimisation of the offset between the contour and the hatch in just one block. This method also allows the evaluation of the use of fill-contours and different laser dynamic modes.

Towards increased quality of Ti6Al4V medical parts by using argon-helium to reduce spatter formation

Gas	Density (kg/m³)	Specific heat capacity at constant pressure (J/(kg·K))	Thermal conductivity at 25°C (W/(m·K))
Ar	1.62	520	0.016
ADDvance Laser230	1.18	734	0.035
He	0.16	5190	0.142

Table 3 Gas properties [2]

The session's second paper, from Sophie Dubiez-Le Goff and Pierre Foret (Linde GmbH, Germany) and Marie Fischer, Gael Volpi, and Donatien Campion (3DMedLab, France), reported on a study aimed at enhancing the quality of Ti6Al4V medical parts by using argon-helium to reduce spatter formation [2].

In PBF-LB, the gas atmosphere can be used as a parameter in the process by modifying the O_2 content or by changing the gas type: argon, nitrogen, helium and argon-helium mixtures all being possibilities depending on the material. It is regularly seen that using an argon-helium mixture is beneficial. Indeed, it has been shown that with Ar-He instead of standard Ar, there is less spatter accumulation and an increased density is obtained in Ti6Al4V specimens, while using higher build rates.

In the reported study, the authors have taken an interest in the impact of the shielding gas on the manufacturing of Ti6Al4V lattice structures, as PBF-LB of fine geometries, such as lattice structures, usually generates more spatter. The aim was to highlight spatter formation using three different gases (helium, argon, and an argon-helium mixture) and to quantify the effect of using each gas on material characteristics and mechanical properties.

An EOS M290 machine, featuring an Yb laser of nominal power 400 W, was employed to build Ti6Al4V lattice structures. Gas atomised Ti6Al4V powder, supplied by EOS, was processed. Its particle size distribution was between 15 and 45 µm. Process atmospheres considered were high purity argon gas, high-purity helium gas and an argon-helium mixture from Linde, named ADDvance® Laser230. Table 3 gives the gas properties.

Parts were built using the recommended parameter set from EOS with a volumetric energy density of 55.6 J/mm³ and a 'fast' parameter set with a decreased volumetric energy density of 38.5 J/mm³.

Fig. 3 presents the nesting of the parts on a build plate: one line corresponds to three common lattice structures (gyroid, dodecahedron and trabecular) and a cube. One line was built with the recommended parameters and a second line was built behind it with respect to the gas flow from the back of the chamber to the front, with the 'fast' parameters. This pattern was duplicated and positioned in five zones of the build plate, in order to analyse a potential effect of the position on by-products' behaviour. No obvious dependence of spatter density and intensity on the position on the build plate was observed, suggesting that the gas flow was homogeneous over the entire process plate.

An optical tomography (OT) monitoring system, provided by EOS, was associated with the machine. This acquired the process radiation (i.e. emitted photons) from the building platform, supplying one greyscale image per layer. The data acquired outside the parts were analysed to characterise the by-products.

Images extracted from the OT were post-processed with image analysis software. Two approaches were used.

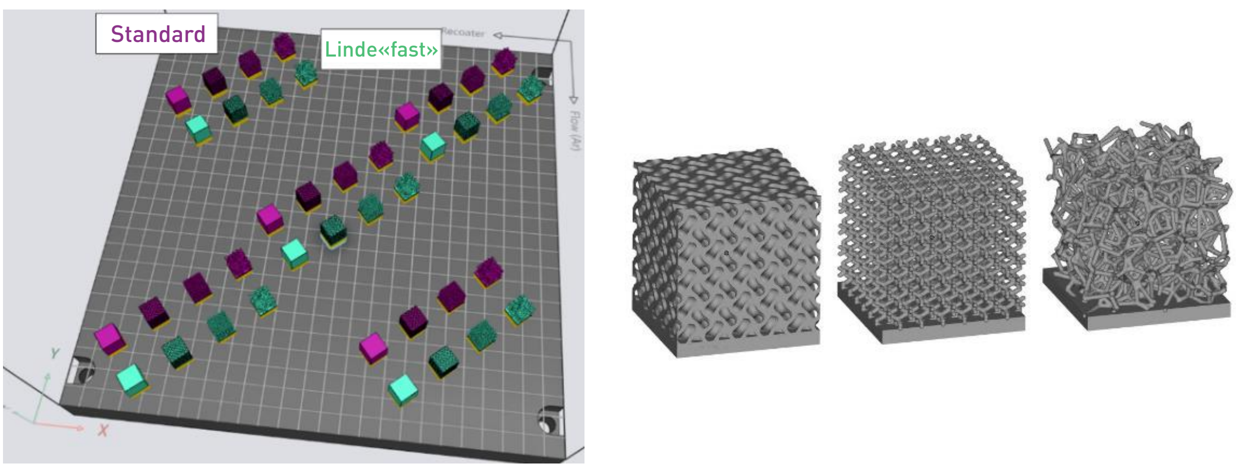

Fig. 3 Build plate setup (left) and manufactured lattice structures (right) [2]

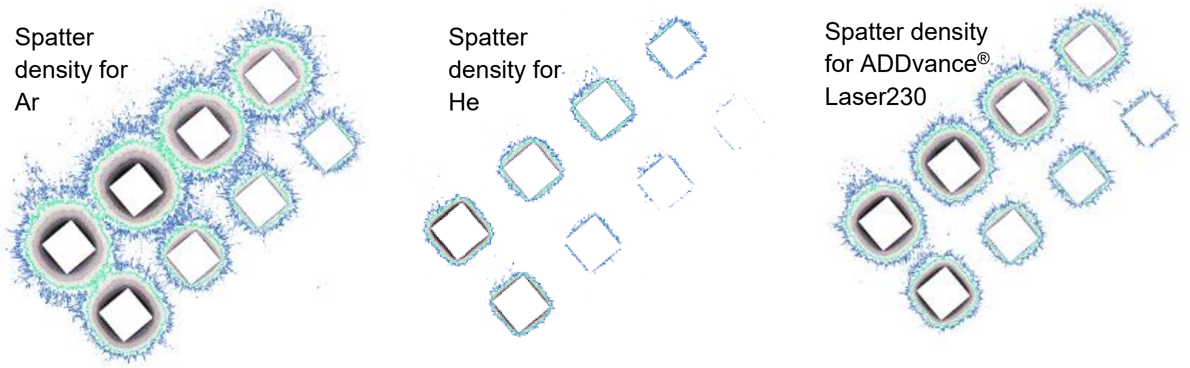

Fig. 4 Spatter density for Ar, He, and ADDvance® Laser230 mixture (from left to right) [2]

The first approach focused on the density of spatter around the parts. The result was an image, in which the grey value of each pixel was representative of the amount of spatter hitting that pixel over all the layers. The second approach focused on the intensity of spatter according to three intensity ranges. The result was an image, in which the colour of each pixel was representative of the intensity (not the quantity) of the spatter hitting that pixel over all the layers.

Fig. 4 shows the resulting image for each job (see first approach, above). The coloured lines highlight four iso-density lines: purple = high density, red = medium-high density, green = medium-low density and blue = low density. Significant differences can be seen between the same jobs built with the different gases. For the argon gas, a relatively high amount of spatter is spread well around the part, including the high density level. For the helium gas, spatter is spread less far around the parts and, for some structures, at only medium to low density levels. The ADDvance® Laser230 job seems to show an intermediate situation between the two others.

Overall, the denser parts, such as the cube, produce a larger amount of spatter, compared with the lattice parts. Indeed, as the vector trajectory length increases, the spatter ejection increases proportionally, resulting in a larger amount of spatter. This is consistent with a lesser amount of spatter observed in the trabecular structure, the most "porous" one. Also, it can be noted that the 'fast' parameter set produces a lesser amount of spatter. Hence, using lower volumetric energy density is an efficient way to reduce the amount of generated spatter.

Fig. 5 highlights all spatter emitted from the samples built at three intensities (second approach, above). This allows the extraction of the distance, at which spatter of high, low or medium intensity is projected from the part being built.

It is clear that the argon job generates the most low and medium intensity spatter. These are spread over a wider diameter around each part, while they are scarcer in the case of helium. The ADDvance® Laser230 job again shows an intermediate behaviour.

Material integrity, i.e. porosity, was analysed by means of X-ray micro-tomography. Digital radioscopies were taken while the sample rotated, resulting in 900 projections, allowing for 3D volume reconstruction. Segmentation operations were applied to the reconstructed 3D volumes, keeping the same threshold for identical structures, hence highlighting the lattice volume and the pores volume.

Fig. 5 Spatter intensity for Ar, He, and ADDvance® Laser230 mixture (from left to right) [2]

Porosity content could thus be calculated for each sample. All lattice samples from the centre of each build plate were analysed.

Overall, the porosity content was below 0.13% for all the structures. Different porosity contents were obtained, while using the respective building strategies. Overall, higher density was achieved with the 'fast' exposure parameters and this was even heightened while building under the ADDvance® Laser230 gas mixture. This strategy generates less energy and heat in the melt pool and is thus more adapted to the small melted areas in lattice structures. Also, the low porosity content obtained with the ADDvance Laser230 gas mixture can be explained by the lesser amount of spatter observed, leading to an improved stability of the process.

Mechanical characterisation of the built samples comprised compression testing with a 50 kN testing machine. The protocol was as follows: pre-load at 0.1% F_{max}, loading to 70% ε_e, unloading to 20% ε_e, loading to 50% strain; on lubricated compression plates, at room temperature. The stress-strain curves were post-processed according to the ISO 13314 standard. The elastic gradient was measured on the unloading portion of the curve and the first maximum compressive stress was extracted.

Each type of lattice followed its own failure behaviour under compression. A succession of stress peaks and breaks along with overall densification were observed for the dodecahedron structure. For the trabecular structure, small instabilities were visible in the stress-strain curve, corresponding to successive breaks of the struts. There was little densification. The gyroid structure showed one maximum stress, followed by a drop and densification of the specimen. Overall, the structures all remained in one piece.

For the first compressive stress and the elastic gradient, extracted from each curve, the average value and standard deviation were calculated, with the resulting data being presented in Fig. 6.

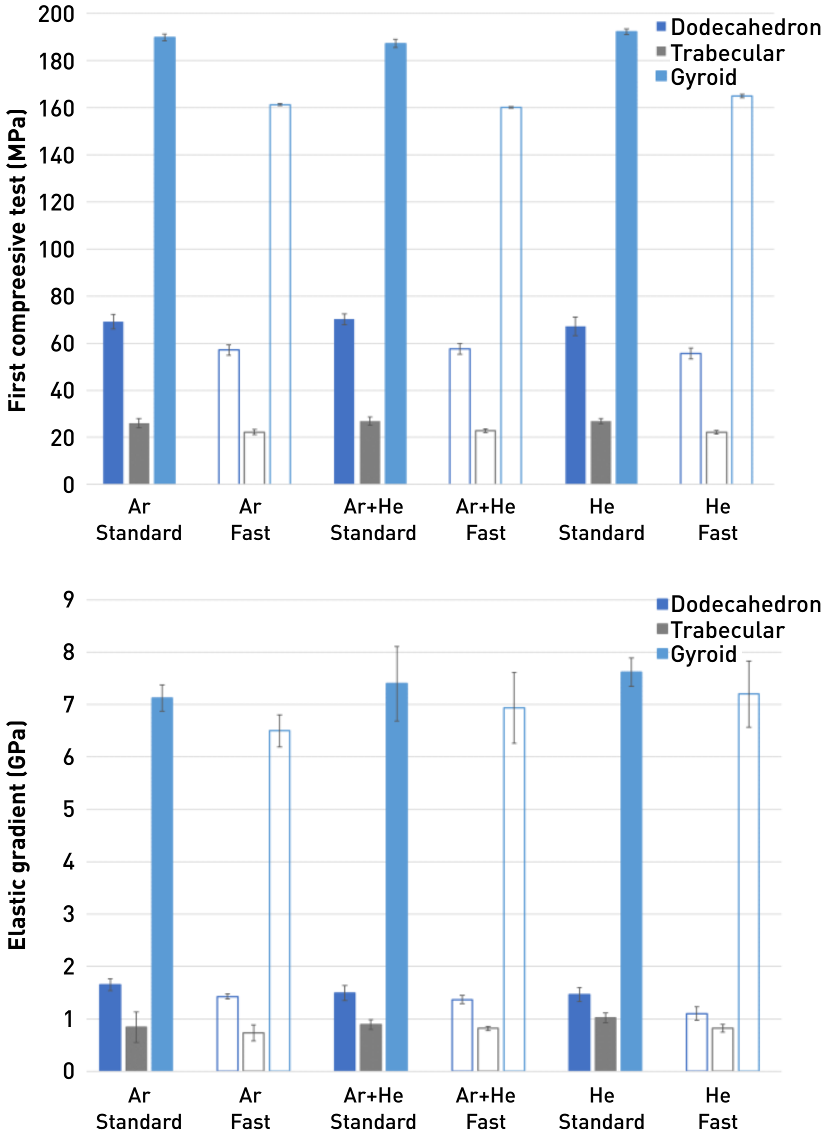

Fig. 6 First compressive strength (top) and elastic gradient (bottom) for each type of the structures in each condition [2]

The structures built with the fast exposure strategies showed slightly lower mechanical properties. The hypothesis proposed by the authors was that the struts might be slightly smaller due to the lower energy input, leading to more flexible structures. This could be resolved by adjusting the beam offset parameter in order to reach larger thicknesses. The use of the different gases does not seem to have affected the mechanical properties, suggesting that the porosity variations presented earlier do not have a significant impact. The lattice's geometric structure is the major factor.

Overall, the authors concluded that this study had demonstrated that helium or argon-helium mixture can significantly reduce the spatter in terms of quantity and spatial spread. For series production builds, this could allow the building of the parts closer to each other in a stable manner and without them interfering with each other and thus increase productivity.

Another beneficial effect of the argon-helium gas mixture was observed, with reference to the resulting higher density obtained for the lattice structures. The mechanical properties are not significantly

Fe	Si (wt.%)	Mn (wt.%)	P (wt.%)	S (wt.%)	Cr (wt.%)	Mo (wt.%)	W (wt.%)	V (wt.%)	C (wt.%)	O (ppm)
Bal.	1.05	0.27	0.010	0.016	3.93	1.88	2.04	1.47	0.61	284

Table 4 Chemical composition of the 1.3397 steel powder according to the supplier certificate [3]

impacted by the process gas type, but the more stable process observed with He or the argon-helium mixture might be beneficial in maintaining good material characteristics, when building larger parts.

PBF-LB of hot-work tool steel 1.3397 processed at elevated preheating temperatures

Next, Taoran Ma and Anton Dahl-Jendelin (RISE IVF AB, Sweden), Gustav Palmgren and Karin Jakibsson (Erasteel Kloster AB, Sweden) and Peter Vikner Aubert & Duval, France) reported on an investigation of the potential benefits of elevated preheating temperatures in the PBF-LB processing of hot-work tool steel 1.3397 [3].

The Additive Manufacturing of carbon-containing tool steels can be challenging, because such tool steels are highly prone to cracking and distortion during the AM process or during subsequent cooling when austenite transforms to martensite, accompanied by a sudden volume increase, inducing considerable residual stress, which in turn triggers cracking.

1.3397 tool steel is a hot-work steel and contains ~0.6 wt.% carbon. An early study on PBF-LB processed 1.3397 showed that there were cracks in the as-built specimens. In this reported study, the authors applied baseplate heating to elevated temperatures and varied scanning speed in order to control residual stress. A series of analyses was performed to study the influences of bottom heating temperature and laser scanning speed on the alloy.

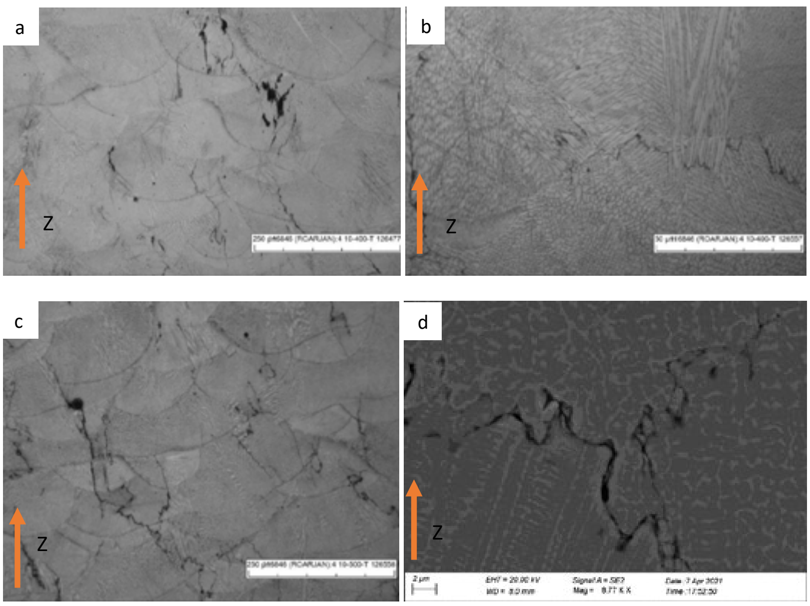

Fig. 7 (a) and (b) LOM micrographs of the as-built specimens with baseplate heated to 400°C, (c) LOM and (d) SEM micrograph of the as-built specimens with baseplate heated to 500°C [3]

Hot-work tool steel 1.3397 was manufactured with the PBF-LB process using a SLM 280 metal AM machine. The powder used in this work had a particle size distribution over the range 15–63 µm. Its composition is given in Table 4. During the PBF-LB process, the baseplate was preheated and kept at a temperature of 400°C or 500°C and the laser speed was varied between 750 mm/s and 950 mm/s. Other process parameters were set to be unvaried, with a recoating powder layer thickness of 60 µm, hatch distance of 120 µm, and laser power of 275 W. The specimen in the build chamber was protected by a continuous argon flow. Cubic specimens with dimensions of 20 mm x 20 mm x 20 mm and bar specimens with sizes of 12 mm x 12 mm x 60 mm were manufactured. Two bar specimens were saved in the as-built condition for microstructure analysis and the rest were austenitised at 1025°C for 25 min in a vacuum furnace, followed by high-pressure nitrogen gas quenching. The quenched specimens were then tempered 3 times at 560°C for 1 h in a furnace with air atmosphere. After the heat treatment, the top and bottom sections of the specimens were cut out for chemical analysis. All outer surfaces were ground before the analysis to remove the oxides. The analysis was performed by combustion combined with infrared spectroscopy (LECO).

The as-built 1.3397 steel specimens with baseplate heated to 400°C and 500°C were found to contain a dendritic/cellular structure, see Fig. 7, a typical structure for PBF-LB carbon tool steel. The microstructure was only mildly affected by etching, which indicates that it was a mixture of untempered martensite and retained austenite. The material built with the baseplate preheated to 200°C (in earlier published work) was etched much more than that preheated to 400°C. This suggests that the specimen built with baseplate preheated to 200°C contained tempered martensite, which etches more readily than untempered martensite.

The martensite start (Ms) temperature is around 280°C for this alloy. During the PBF-LB process, the alloy was kept above the Ms temperature and martensite transformation occurred only after the building finished, the baseplate heating was turned off and the specimen together with the build plate cooled down to room temperature. This is a clear difference from the microstructure of the 1.3397 steel built with baseplate heating to 200°C, which is below Ms, where martensite formed shortly after solidification and then part of the martensite was tempered by the heat from neighbouring layers and those above. Hence, tempered martensite was obvious in the microstructure. Vickers hardness values of the as-built specimens manufactured with baseplate heated to 200°C, 400°C and 500°C were ~683 ± 7, ~705 ± 27 and ~711 ± 40 HV10, respectively.

Below the top surface, a region with cracks longer than 100 µm was found, see Fig. 8. For the baseplate heated to 400°C, within the area 1.5 mm below the top surface, this region was rich in large cracks longer than 100 µm. For the 500°C case, the region with large cracks was deeper than 2.5 mm below the top surface. The cracks were oriented in the Z direction, i.e. the temperature gradient direction. Cracks were found at the interface where the orientation of cells changes, see Figs. 7(b) and (d). In the bulk, small voids and microcracks could be seen, but no large cracks (Fig. 8). Cracks do not occur evenly in the bulk, but mainly in the top region. The macrocracks are probably due to the shrinkage during cooling after the process.

The density of the alloy as a function of temperature was calculated using JMatPro software, shown in Fig. 9. The alloy shrinks from a high temperature down to around 350°C and then a sudden expansion occurs when the matrix transforms to martensite. In relation to the current process, when the building was finished, the specimens and build plate started cooling from around 500°C. There was firstly a thermal shrinkage stage from 500°C down to around 350°C, then followed by an expansion due to martensitic transformation at around 250°C. The material further shrank with deceasing temperature to room temperature. It is highly probable that cracking happened due to quick and uneven shrinkage from 500°C down to around 350°C, considering

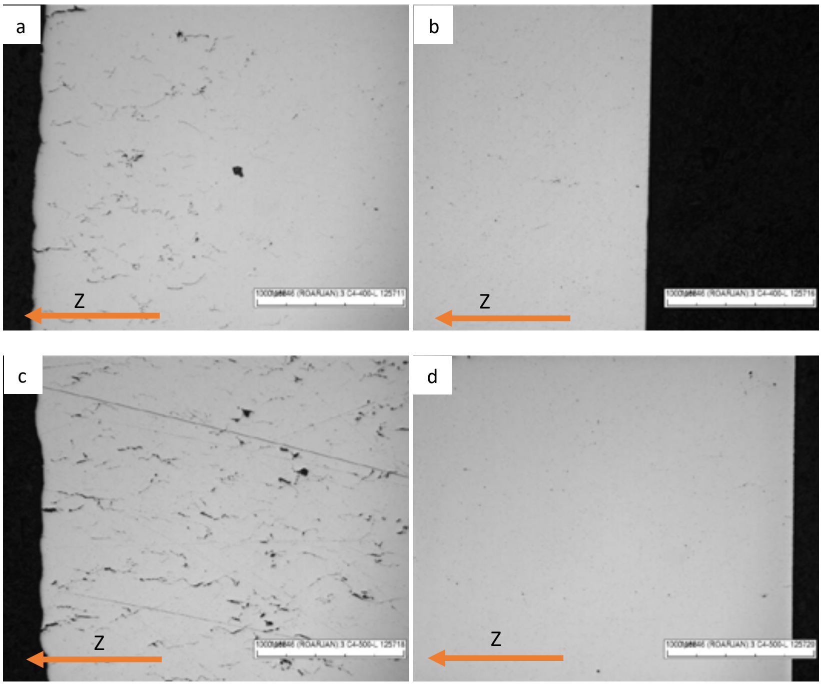

Fig. 8 LOM micrographs of the top and bulk area of the as-built 1.3397 with baseplate heated to (a) and (b) 400°C, (c) and (d) 500°C [3]

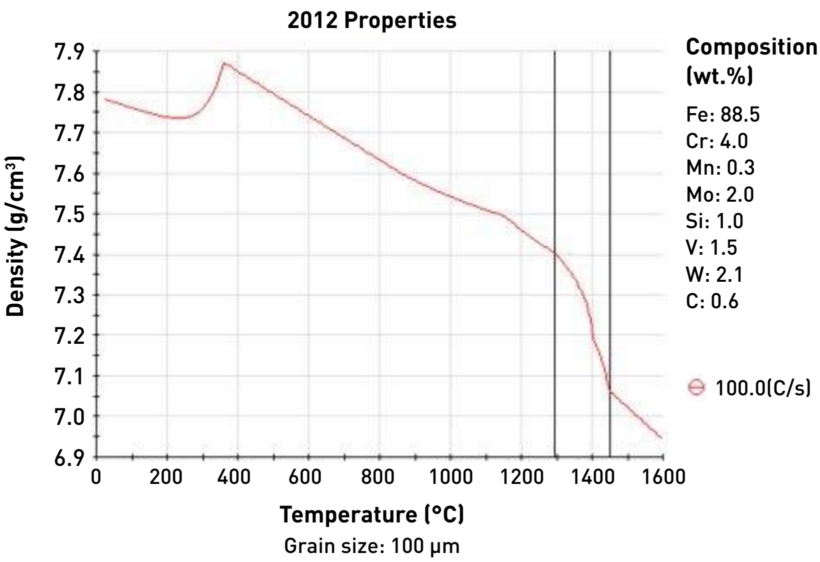

Fig. 9 Density of 1.3397 as a function of temperature, simulated by using JMatPro software. The cooling rate was set at 100°C/s [3]

	Particle size distribution				Particle shape	Powder packing		Flowability	
	D10 (±5%)	D50 (±3%)	D90 (±5%)	SPAN $\frac{D90-D10}{D50}$	Mean aspect ratio (±0.02)	Untapped apparent density / Relative density	Taped density / Relative density	Mean avalanche angle (°, ±5%)	Carney: Discharge time (sec)
316L EOS 20-50 µm	25	36	52	0.7	0.89	4.2 g/cm^3 / 52.5%*	4.7 g/cm^3 / 58.7%*	46.5	6.5
316L Sandvik -38+5 µm	10	18	32	1.2	0.87	3.9 g/cm^3 / 49.2%*	4.6 g/cm^3 / 58|.1%*	52	No flow
316L Höganäs LF-45 µm	19	34	60	1.2	0.67	3.1 g/cm^3 / 39.4%*	3.7 g/cm^3 / 47.0%*	48	13.5

* Relative densities are expressed according to the particle true density measured by Helium pycnometry. Results of phenomenological flowability tests: avalanche angle at 0.6 rpm and Carney funnel test using 50 g of powder [4]

Table 5 Particle size distribution, particle shape and powder packing of the stainless steel powders [4]

"As mentioned previously, the cracks were found at the grain boundaries where the dendrite orientation changed, which resulted in a weak region prone to cracking upon cooling accompanied by shrinkage."

that the top layers cooled down faster than the layers below, which were well surrounded by the warm powder bed. For the preheating to 400°C case, the extent of shrinkage was relatively less and hence less severe cracking occurred than for preheating to 500°C. As mentioned previously, the cracks were found at the grain boundaries where the dendrite orientation changed (Figs. 7b and d), which resulted in a weak region prone to cracking upon cooling accompanied by shrinkage.

Regarding the causes for the cracking of the material built with baseplate preheated to 200°C, the local residual stress is high and the untempered martensite is brittle. There is repeated local expansion and shrinkage, resulting in cracks initiated from weak points.

Based on this discussion, the authors have suggested that two approaches could be pursued, either to lower the baseplate temperature to 300°C to reduce the cooling shrinkage, meanwhile adding isolation powder layers at the top to slow down the cooling at the top for a more even volume change through the entire part, or to apply preheating to 200°C, but increase scanning speed to reduce the residual stress.

During the tempering treatment in air, the samples with cracks open to the surface picked up oxygen. Hence, the oxygen content measured in this work reflected the number of open cracks. The top region and specimens built with higher energy input were found to contain a larger number of open cracks, whereas the bottom region had fewer cracks. High energy input and higher preheating temperature were found to result in the most cracks, which is consistent with the microstructural analysis.

Analytical and numerical modelling of stainless steel powders spreading in AM powder bed fusion processes

Finally, M Soulier, A Burr, N Dubois, G Roux, J Maisonneuve and R Laucournet (CEA-LITEN, France) turned their attention to the analytical and numerical modelling of stainless steel powder spreading in AM powder bed processes [4].

The qualification of raw material spreadability is usually carried out by ex-situ characterisation by means of phenomenological tests including funnel tests, avalanche angle, angle of repose, shear test, and Hausner ratio. However, the suitability of these techniques to fully describe the dynamics of powder spreading under real conditions in an AM machine is often questioned. Numerically, most studies on powder spreading use the discrete element method, with a particular focus on the effects of recoater geometries and velocities, the layer thickness or the powder characteristics on powder bed density and surface roughness.

The aim of the presented study was to develop experimental and numerical tools to more accurately predict powder bed behaviour as a function of spreading parameters and powder characteristics. Three commercial 316L powders were selected as study cases, exhibiting complementary particle size distributions and particle morphologies to obtain a representative set of powders used in Powder Metallurgy. The EOS and Sandvik powders were gas atomised and showed a spherical shape. An EOS powder coarser than the Sandvik powder was selected, in order to study the effect of particle size. The Höganäs powder was water atomised. This last powder, usually dedicated to conventional PM, had a similar particle size to the EOS powder, but had high particle acicularity.

Table 5 shows the main characteristics of the three powders chosen. Their particle size distribution was measured by laser granulometry in ethanol. The particle morphology was analysed by automated image analysis on 50,000 particles. The corresponding shape indicator studied was the mean aspect ratio, defined as the width to length particle ratio. Also, the powder flowability was evaluated by the Carney funnel test and avalanche angle tests, consisting of introducing the powder in a rotating drum and recording the angle as soon as the powder initiated an avalanche. The lower the avalanche angle, the higher was the free-flowability of the powder.

The EOS and Sandvik gas atomised powders exhibited high sphericity, with aspect ratios of 0.89 and 0.87, respectively, while the Höganäs powder was defined by a significantly higher acicularity with a mean aspect ratio of 0.67.

Because of the acicular shape, the water atomised powder showed the lowest apparent density, compared with the more spherical powders. However, the Sandvik powder was the least flowable powder with the highest mean avalanche angle (52°) and no flow in the Carney funnel. Therefore, it was concluded that powder flowability is more impacted by a fine particle size than an acicular particle shape. The characterisation of the powder bed for each 316L powder was conducted on the spreading test bench set up shown in Fig. 10. Completely automated,

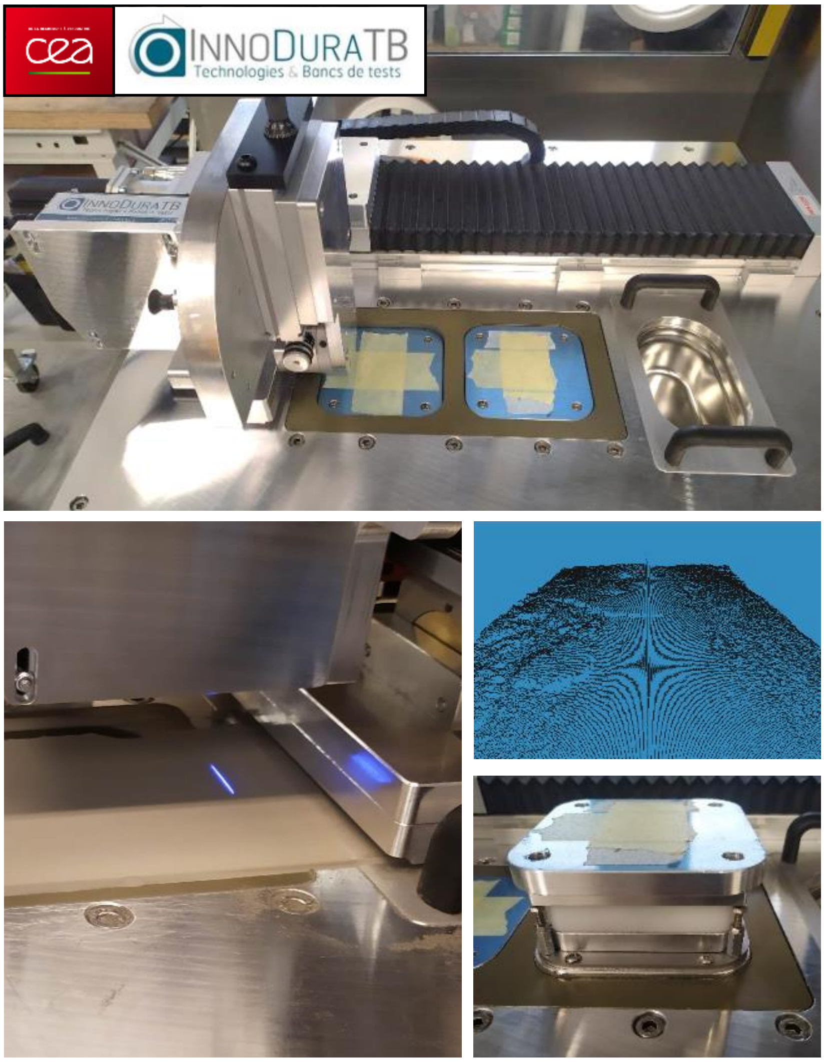

Fig. 10 The powder bed test bench developed by CEA/Innodura TB, along with details of the laser profilometer and the mass sensor. An example of powder bed surface scanned by the profilometer is also shown [4]

the bench comprised two pistons enabling powder feeding and powder discharging, with plates of 125 x 125 mm^2 and a rubber blade (10 mm width with a rectangular profile) on an accurate linear axis.

In order to characterise the powder bed surface, the spreading axis was equipped with a laser profilometrer (3200 points/16 mm line) scanning the surface to reconstitute in 3D the powder bed surface with an x/y reso-

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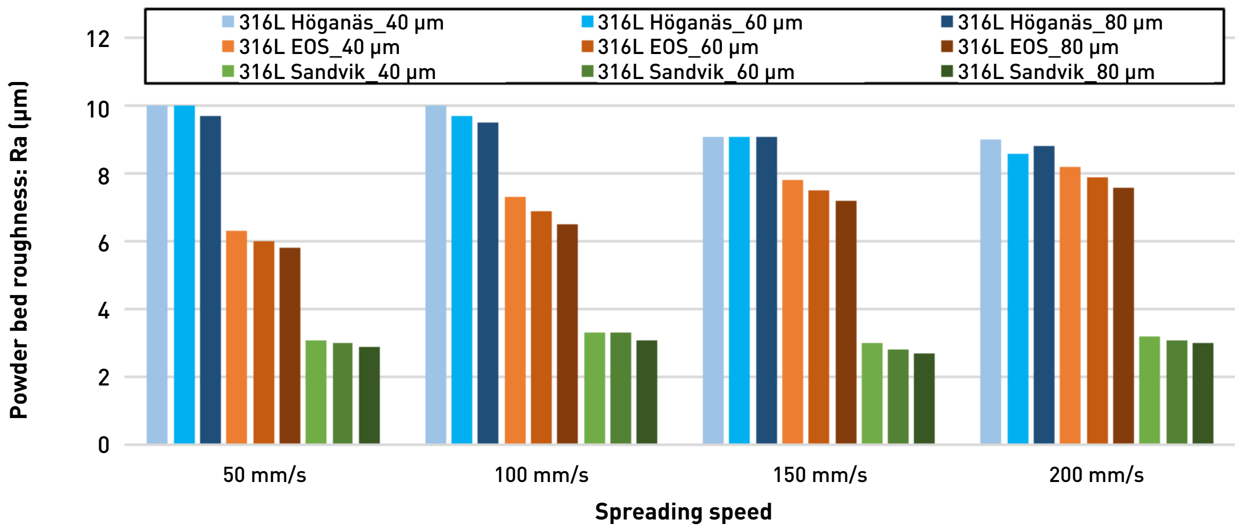

Fig. 11 Powder bed surface measured by laser profilometry [4]

lution of 5 µm and a z resolution of 0.5 µm. In addition, a mass sensor was installed under the spreading plate to calculate the powder bed density in situ, with a weighing accuracy of ±10 mg. Fig. 11 shows the powder bed roughness measured for each powder as a function of the spreading speed and layer thickness. The arithmetic average of roughness (R_a) was calculated for a scanned powder bed surface of 100 x 16 mm^2. Powder bed roughness appears to be closely linked to the particle shape, as demonstrated by the comparison between the EOS and Höganäs powders. The negative impact of particle acicularity on the roughness is attenuated by increasing the spreading speed. With a similar spherical shape, the Sandvik powder, two times finer than the EOS powder, leads to a bed roughness two times lower. This trend is confirmed by the roughness measurements performed on laser built parts using these three powders.

Fig. 12 shows the powder bed densities for the Sandvik and EOS powders, resulting from an average of 30 powder layers carried out for each one. The bed density appears to be close to the untapped powder apparent density (Table 5). The more cohesive Sandvik powder leads to a less dense powder bed compared to the EOS powder. However, this slightly lower powder bed density has no consequence on the final part density after laser melting, being fully dense with either powder. The powder bed density for the Höganäs powder could not be measured, but it was observed that this powder did not give a fully dense material after PBF-LB, despite scanning strategy optimisation.

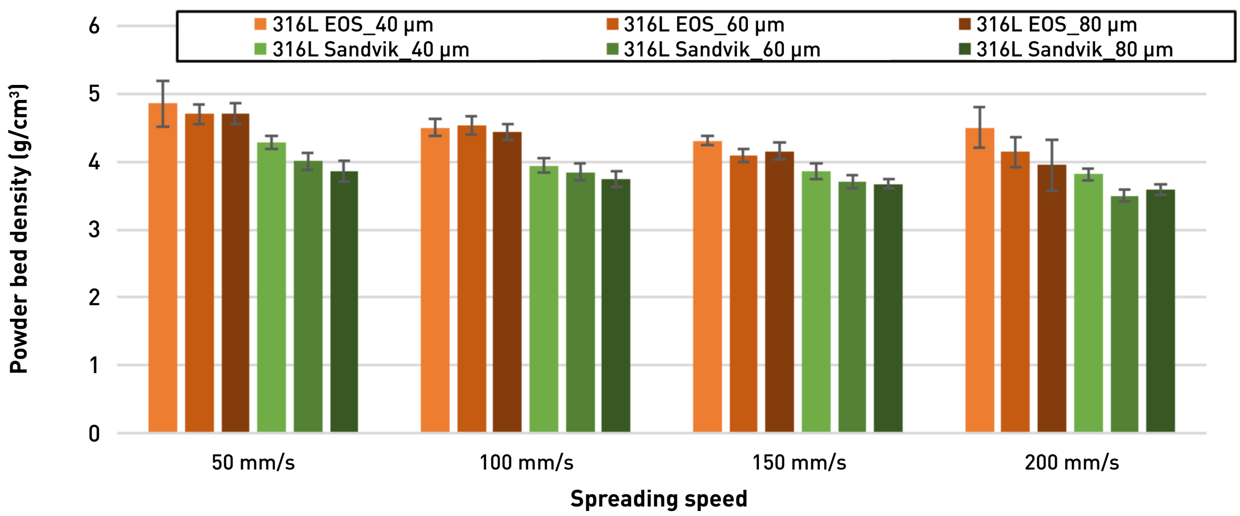

Fig. 12 Powder bed density [4]

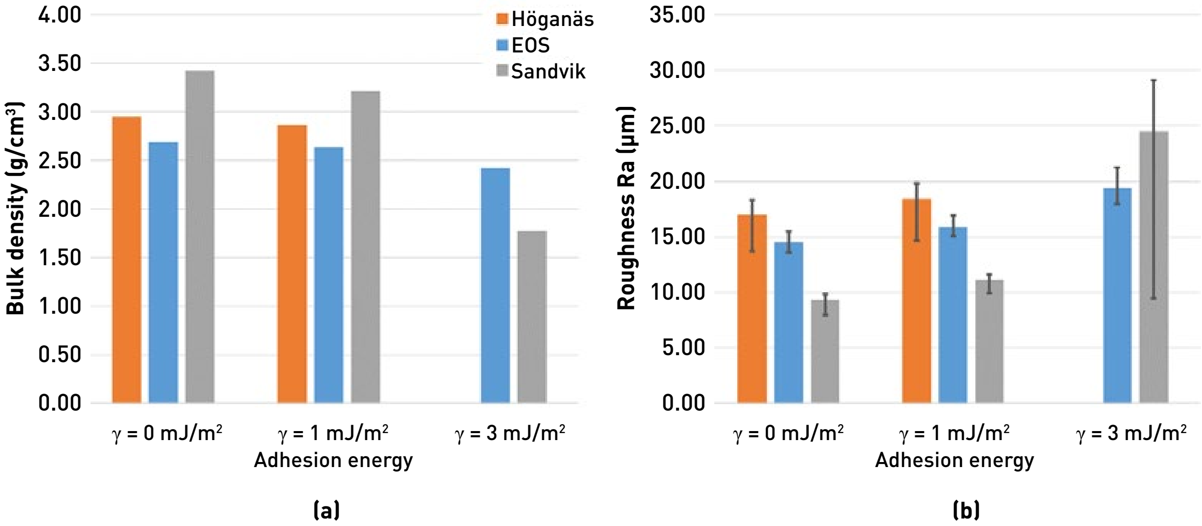

Fig. 13 (a) Bulk density and (b) surface roughness Ra for the studied powders and values of adhesion energy [4]

Next, the three powders presented were modelled numerically by the discrete element method. The code used in this work was Altair EDEM and the contact law was Hertz-Mindlin with JKR. First, particles were generated using a log-normal distribution fitted to the ones experimentally determined. A layer with a thickness of 150 μm was spread at 50 mm/s, using a periodic condition in the γ-direction. Spherical particles were used for the powders from EOS and Sandvik, but a rod of three aligned spherical particles was used for the Höganäs powder, to illustrate an aspect ratio of 0.67. In this work, only the effects of particle size distribution and adhesion energy (studied for 0, 1 and 3 mJ/m²) on the bulk density and surface roughness were studied.

The thickness of powder bed was initially determined by voxelisation of spheres at a 1 μm voxel size, and then by intersecting a squared-ray of 5 μm side-length with the powder bed surface, so as to be in agreement with the accuracy of the laser profilometer. If the ray did not intersect a particle, the height was taken as 0 (minimum of the platform height). Thickness profiles along the X and Y axes were averaged and their variabilities calculated. The roughness R_a was the mean of these values in 1x1 mm² tiles on the whole length of the powder bed.

In Fig 13b, the error bars represent the minimum and maximum roughness values to show the variability obtained along the spreading axis (X). The powder bed density was calculated from the ratio between the total mass of particles on the building platform and the nominal volume. A decrease of the powder bed density and an increase of the surface roughness were observed in Fig. 13 when the adhesion energy increased.

However, the average roughness value hides the local heterogeneities in the surface powder bed. Therefore, the thickness of the powder bed t was normalised to the nominal thickness *t0* (150 μm), giving the parameter *t/t0*. This helps in understanding the large variability between the desired thickness and the simulated results. If *t0* is large compared with the maximum particle size, rearrangement of particles is enhanced. Therefore, *t/t0* is larger for the Sandvik powder (when γ = 0) than for the Höganäs and EOS powders. Using a slow blade speed (50 mm/s) with a high layer thickness (150 μm) results in a relatively homogeneous powder bed qualitatively for the EOS and Sandvik powders (*t/t0* is uniform in the first 10 mm). However, it always ends up with a mound of powder, certainly because of the rigid wall at the end of the powder bed. Also, when the adhesion energy is too large, small aggregates appear, explaining the large error bar for the Sandvik powder in Fig 13b. Consequently, the quality of the bed is poor.

The comparison between the experiments and numerical results showed that the ranking of powders is in agreement for the roughness

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when $\gamma < 3$ mJ/m^2 and for the powder bed density when $\gamma > 1$ mJ/m^2. Hence, the numerical model is consistent with the experimental results for particle-to-particle adhesion energies between 1 and 3 mJ/m^2. However, numerical results for the powder bed densities give values roughly 30% smaller than those experimentally determined and the simulated roughness values R_a are two to three times larger than the experimental ones. Future work will therefore focus on several optimisations aimed at being more confident of simulation results in comparison with experimental ones.

The sole layer deposited during simulation is not representative of a standard spreading process, as the first layer is a particular case, subjected to strong effects of boundary conditions (direct contact with the building platform). Regarding the surface profile of the bed, the average value is disturbed by local 0 values (height of the bed). It is planned to model a powder bed consisting of several layers of powder as performed experimentally.

The numerical parameters are adapted from the literature for stainless steel 316L, but really need full calibration. In particular, the coefficient of restitution between particles and the blade (in rubber) should be adapted and may challenge the effect of adhesion energy (which should also be experimentally determined).

The particle size distribution used in the numerical part of this work consisted of a given number of discrete particle sizes. This loss of continuity can influence the packing as small particles are missed.

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[4] Mathieu Soulier, CEA-LITEN, Grenoble, France
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References

[1] Efficient Process Parameter Optimisation Procedure in Laser Powder Bed Fusion, M L Montero-Sistiaga *et al*. As presented at the Euro PM2021 Virtual Congress, October 18–22 2021, and published in the proceedings by the European Powder Metallurgy Association (EPMA)

[2] Towards Increased Quality of Ti6Al4V Medical Parts by Using Argon-Helium to Reduce Spatter Formation, Sophie Dubiez-Le Goff *et al*. As presented at the Euro PM2021 Virtual Congress, October 18–22 2021, and published in the proceedings by the European Powder Metallurgy Association (EPMA)

[3] Laser powder bed fusion of hot-work tool steel 1.3397 processed at elevated preheating temperatures, Taoran Ma *et al*. As presented at the Euro PM2021 Virtual Congress, October 18–22 2021, and published in the proceedings by the European Powder Metallurgy Association (EPMA)

[4] Analytical and Numerical Modelling of Stainless Steel Powders Spreading in Powder-Bed Processes for Additive Manufacturing, Mathieu Soulier *et al*. As presented at the Euro PM2021 Virtual Congress, October 18–22 2021, and published in the proceedings by the European Powder Metallurgy Association (EPMA)

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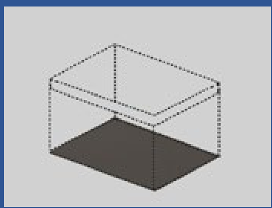

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