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THE MAGAZINE FOR THE METAL ADDITIVE MANUFACTURING INDUSTRY

METAL AM

in this issue

AM IN THE SEMICONDUCTOR INDUSTRY
STRATEGIES FOR MASS CUSTOMISATION
MATERIALISE INTERVIEW

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METAL ADDITIVE MANUFACTURING

Don't think you can do this alone, human.

When reviewing article manuscripts for an issue of *Metal AM* magazine, the most unexpected themes can rise to the fore in ways that make you step back and see things from a much clearer perspective. In this issue, that theme is the relatively untapped potential of AI and advanced software solutions in enabling the most successful possible outcomes for AM parts.

We are all now familiar with what topology optimisation can do to the most mundane structural component designs, transforming them into dynamic, flowing lightweight structures that echo nature's most beautiful forms. Generative design takes this further, creating completely computer-generated designs based on given loads, constraints and hold out areas. These structures, of course, can only be produced by Additive Manufacturing.

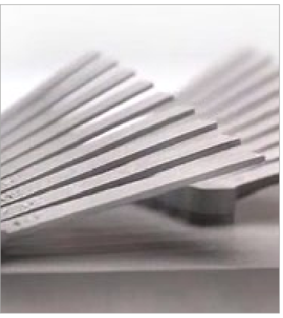
Taking things to the next level are designs whose forms go far beyond the structural by delivering additional functionality. The end result is a new generation of components that comprehensively outperform anything that has come before.

Many of these success stories are currently in the realm of thermal management, be it for AI-designed components that improve the speed and efficiency of semiconductor manufacture, or heat exchangers for industrial or motorsport applications developed with sophisticated equation-driven design software.

So while much of AM's success to date has been on the evolution and optimisation of existing component designs, only through a more holistic – and AI-driven – approach to design can we find a new path that will fully leverage the potential of today's Additive Manufacturing machines, creating parts of such complexity that no human could ever have designed.

Nick Williams
Managing Director

Cover image
A silicon wafer table with integrated advanced cooling structures (cut-away section) produced using 3D Systems' DMP Factory 500 (Courtesy 3D Systems)



36

64

123

151

166

Contents

High Performance Semiconductor Equipment Starts Here

3D Systems' advanced metal additive manufacturing, expertise, and technology transfer help you overcome your design and production challenges.

Semiconductor manufacturers are under increased pressure to deliver the next leap forward in microchip manufacturing equipment. 3D Systems' additive manufacturing technology and expertise can help you maximize performance, quality, yield, and reliability — allowing you to defy the limitations of conventional manufacturing.

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Learn more at
3dsystems.com/semiconductor

3D SYSTEMS

155 **Pedal to the metal at the Digital Manufacturing Centre: Redefining what's possible for AM in hypercars and beyond**

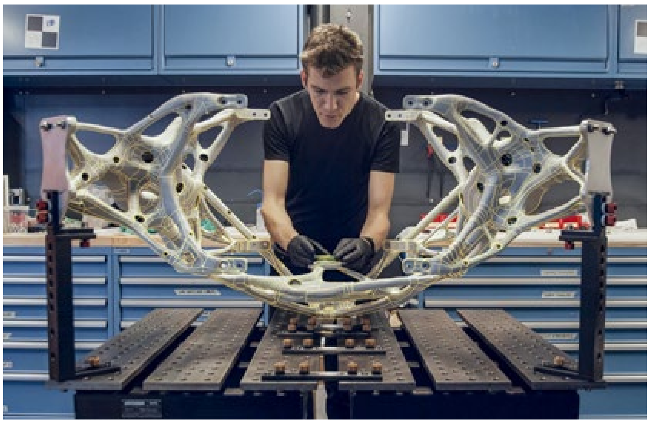
This summer, a new player arrived on the AM scene: the Digital Manufacturing Centre, or DMC. Based on the edge of Silverstone, the UK's most famous race circuit, home to numerous leading F1 teams, there could be no better place to launch a business aimed at offering AM support to the elite in performance motorsport.

Jim Hadfield speaks with the DMC's CEO, Kieron Salter, to explore how metal Additive Manufacturing is enabling innovation in the booming hypercar industry, and how a truly connected digital manufacturing operation can bring the DMC a competitive advantage in this field and more. >>>

163 **The future is Additive Manufacturing – if we take a more holistic view of the design opportunities**

The uptake of Additive Manufacturing by industry, believes Autodesk's Paul Sohi, has been both stratospherically high and confusingly low. In explaining and addressing this dichotomy, Sohi explores the multiple potentials of AM when approached by taking a more holistic view of design challenges.

Whilst there is no doubt that the popularisation of AM technology is influencing how we design products by shifting the design language to embrace more complex or nonstandard forms, Sohi believes that this is where the application of AM seems to be stagnating. So, how can we close the loop from design to manufacturing? >>>



171 **Building a case for radical collaboration plus quality standards: The pathway to growing the AM industry**

While the acceleration of metal Additive Manufacturing adoption is seen as inevitable, thanks to its advantages over conventional manufacturing processes for high-complexity, customised or on-demand parts, Sigma Labs CEO Mark Ruport believes that 'radical collaboration' is required for AM to reach its true potential. In this article, Ruport discusses how the company is targeting radical collaboration and the implementation of cohesive quality standards across the value chain to grow AM and overcome the challenges posed by true industrialisation. >>>

177 **Distributed manufacturing: Old concept, new relevance, new technology?**

In highlighting the vulnerabilities of global supply chains, events such as COVID-19 have inspired renewed interest in alternative forms of organising production. Distributed manufacturing is now seeing early use in fields such as oil and gas and for on-demand spare parts manufacturing. For the first time, large-scale on-demand manufacturing was seen in the supply of emergency PPE at the height of the pandemic. Dr Jennifer Johns discusses how AM can help to address the challenges this new business model presents, and introduces the University of Bristol's £1 million Brokering Additive Manufacturing project, which seeks to produce a revolutionary new brokering method for highly distributed and diverse manufacturing systems. >>>

Heat exchangers have become – excuse the pun – a hot topic in metal Additive Manufacturing. This is an application that can, in one go, leverage advances in equation-driven CAD design software and the capabilities of AM to produce geometries that would be impossible by any other manufacturing process.

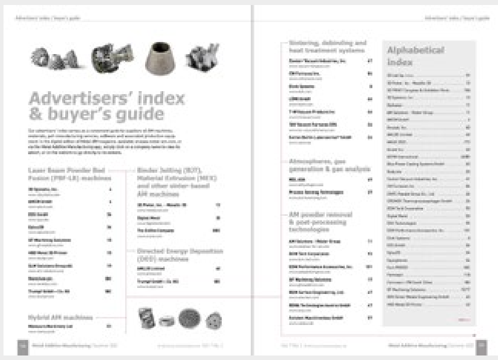
Olaf Diegel , Wohlers Associates, reports on a project exploring workflows for AM heat exchanger design using design tools from nTopology. >>>

In a rapidly evolving Additive Manufacturing landscape, choosing a machine for the production of parts by Laser Beam Powder Bed Fusion (PBF-LB) is now about far more than a cost per part calculation. In this article, Sebastian Becker, EOS GmbH, considers how a host of additional factors now need to be considered when exploring the AM machine marketplace, from the specifics of a machine's operation to software, IP protection and beyond. >>>

Regular features...

Metal AM magazine is dedicated to driving awareness and development of metal Additive Manufacturing and its related technologies. Key to this aim is our support of a range of international partner conferences.

Our advertisers' index serves as a convenient guide to suppliers of AM machines, materials, part manufacturing services, software and associated production equipment. In the digital edition of *Metal AM* magazine, available at www.metal-am.com, or via the *Metal Additive Manufacturing* app, simply click on a company name to view its advert, or on the weblink to go directly to its website.



Industry news

Relativity Space to build 90,000+ m^2 facility for production of additively manufactured rockets

Relativity Space has announced a major expansion of its operations in Long Beach, California, USA, with the signing of a new, 90,000+ m^2 (1,000,000+ ft^2) headquarters and factory at Goodman Commerce Center, Long Beach.

The new headquarters is said to be one of the largest in the private space industry and will have capacity for 2,000+ employees, a metallurgical laboratory, Laser Beam Powder Bed Fusion (PBF-LB) machines, a mission control centre, and dozens of the company's proprietary Stargate Directed Energy Deposition (DED) metal Additive Manufacturing machines, described as autonomous, scalable and 'the largest metal 3D printers in the world.' With software changes, Relativity's Stargate machines are capable of building both Terran 1, an entirely metal additively manufactured launch vehicle, and its fully reusable, entirely additively manufactured rocket, Terran R.

The announcement follows the closing of Relativity Space's $650 million Series E funding round. With this major expansion, Relativity states that it is doubling down on its 'Factory of the Future', which is centred on the Stargate metal AM machine. According to the company, its Factory of the Future fuses metal AM, artificial intelligence, and autonomous robotics, offering a radically simplified supply chain that enables the company to build its rockets with 100 x fewer parts than comparable space vehicles in less than sixty days. By using automation, Relativity's Factory of the Future was able to stay operational during the peak of the COVID-19 pandemic, keeping the company on track for the launch of the Terran 1 later this year. Incorporating AI-driven controls, Relativity's Stargate machines are said to continuously optimise production, resulting in exponentially compounded quality and time improvements, lower costs, and product designs not possible in traditional aerospace manufacturing.

"Relativity is at the forefront of an inevitable shift to software-driven manufacturing, and the opportunity to reimagine this facility for the future of aerospace is incredibly exciting," stated Tim Ellis, the company's CEO and co-founder. "Securing this space for Relativity Headquarters, which is now one of the largest facilities in private space, right here in Long Beach, is key for scaling out our Terran R programme while also continuing to tap into the unparalleled talent here to join us on our mission."

www.relativityspace.com

The new facility will be used to additively manufacture the company's Terran rockets (Courtesy Relativity Space)

A rendering of Relativity Space's new headquarters in Long Beach, California (Courtesy Relativity Space)

Volkswagen to adopt Binder Jetting in vehicle production

German automotive manufacturer Volkswagen AG has reported it is now using Binder Jetting (BJT) Additive Manufacturing technology at the company's main plant in Wolfsburg, with the aim of producing up to 100,000 AM components a year by 2025. The company has been using AM for some twenty-five years, producing over one million components with various plastic and metal AM processes, but this marks the company's first use of binder jet technology for production parts.

The first parts made using the BJT process, components for the A pillar of the T-Roc convertible, have been sent to VW's facility in Osnabrück for certification. These weigh almost 50% less than conventional components made from sheet steel, with this weight reduction alone said to make the process especially interesting for automotive production applications.

Until now, the production of larger volumes has not proven cost-effective; however, VW has worked closely with Siemens to develop software that maximises the number of components in the build chamber. Known as nesting, this technique now makes it possible to produce twice as many parts per manufacture session.

"We are very proud to support Volkswagen with our innovative 3D printing solutions. Our automation and software solutions are leading in industrial production applications. Using this technology, Volkswagen will be able to develop and produce components faster, more flexibly and using fewer resources," stated Cedrik Neike, member of the Managing Board of Siemens AG and CEO Digital Industries.

To reach this stage, Volkswagen has invested an amount in the mid-double-digit million euro range over the past five years. In addition to the software partnership with Siemens, it has expanded its existing collaboration with AM machine maker HP Inc. With its first full-scale use of BJT, the company is looking to understand which components can be produced economically and quickly, and how Additive Manufacturing can support the digital transformation of production at Volkswagen.

"Despite the ongoing challenges of the coronavirus pandemic, we're continuing to work on innovation," commented Christian Vollmer, member of the Board of Management of the Volkswagen Brand responsible for Production and Logistics. "Together with our partners, we aim to make 3D printing even more efficient in the years ahead and suitable for production-line use."

From summer 2021, the three companies intend to establish a joint expert team at VW's advanced Additive Manufacturing centre. The centre was opened in Wolfsburg at the end of 2018 for the development of complex automotive components using AM, and is also used to train employees in the use of the technology.

www.siemens.com
www.hp.com
www.volkswagen.com

SLM Solutions releases Q1 results, reaffirms positive 2021 outlook

SLM Solutions Group AG, Lübeck, Germany, has reported a generated revenue of €15.4 million in Q1 2021, down from €17.8 million in the same quarter of 2020. The company recorded an improved EBITDA of €-2.1 million (Q1 2020: €-3 million), driven by more cautious spending.

Following on from an improved order intake in the second half of 2020 in comparison to the first half of the year, the steady recovery of business was also noticeable in Q1 2021, with an order intake of €13.4 million, nearly five times higher than in Q1 of 2020 (€2.9 million). The company's order backlog also improved, by €8.1 million to €31.8 million year-on-year (March 31 2020: €23.7 million). Working capital decreased to €28.2 million from €37 million in Q1 2020, reflecting the positive effects of SLM Solutions' improved inventory management.

"With order intake gaining traction over the last quarters, SLM Solutions has had a strong start to the new year. First quarter revenue was solidly in line with our expectations," stated Sam O'Leary, CEO. "A notable portion of our backlog will be converted into revenue over the next quarters as we project a significant acceleration of our growth, especially in the second half of the year."

"A significant driver of our future growth is the commercialisation of the NXG XII 600, which continues to exceed our already high expectations in terms of customer response. Most recently, SLM Solutions signed a memorandum of understanding with a major energy OEM which, as with similar agreements with other customers, will follow a firm purchase order after achieving clearly defined technical requirements."

Based on the sound order backlog and the overall business dynamics, SLM Solutions reaffirms its positive outlook for 2021 and expects revenue growth of at least 15% compared to the previous year, as well as a year-on-year improvement in EBITDA.

Dirk Ackermann, CFO, added, "To support SLM Solutions' accelerating growth, we further strengthened our liquidity position with the issuance of the second tranche of our 2020 convertible bond. The raised capital in the amount of €15 million will help us to ramp-up production of the NXG XII 600 and expand the required sales and service network."

www.slm-solutions.com

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MetShape receives seed capital from AM Ventures

MetShape GmbH, headquartered in Pforzheim, Germany, a manufacturer specialising in a Vat Photopolymerisation (VPP) process it refers to as Lithography-based Metal Manufacturing (LMM) has received seed financing from AM Ventures, the venture capitalist arm of the Langer Group. This financing round will enable investments in new equipment, expansion of marketing and sales measures, as well as further staff growth.

MetShape spun out of Pforzheim University in 2019 and received one year of start-up funding from the state of Baden-Württemberg. Since its beginning, MetShape has established a broad portfolio of AM technologies using its VPP technology, which the company stated it has already implemented for many customer applications.

"With our holistic approach and know-how of the entire LMM process chain, we provide our customers the highest flexibility in developing and manufacturing their applications," stated Dr Andreas Baum, the company CEO and co-founder.

Johann Oberhofer, Managing Partner of AM Ventures, anticipates that two-step sinter-based AM technologies will become increasingly important for the production of larger quantities of metal components. "The key to mastering indirect AM processes is to control the oven-based sintering processes after the green part has been 3D printed," he stated. "We are convinced that the team around Dr Andreas Baum combines the necessary competencies and has extensive know-how for the development and serial production of high-quality applications."

The company works closely with the engineering company Incus GmbH and Pforzheim University on the further development of VPP technology. As evidenced in this extensive research, MetShape hopes to be at the cutting edge of technology, able to offer its customers new material developments and cooperation projects.

Baum added, "With the further development of the company, we are increasing customer benefits to the extent that we are evolving from an LMM pioneer to a competent partner for all relevant AM technologies for the production of precise small and micro components."

www.metshape.de

www.amventures.com

Markforged launches Metal X Gen 2 and Next Day Metal software

Markforged, Watertown, Massachusetts, USA, has launched the Metal X Gen 2, a new metal Additive Manufacturing machine based on its Metal X model released in 2017. The company also announced the release of Next Day Metal, new software that will be available across its entire global fleet of metal AM machines.

New features of the Metal X Gen 2 include an external 18 cm touchscreen, door position sensors, and additional chamber insulation, said to make the system more energy and time efficient than the previous iteration. Key hardware developments have also been made that improve user experience and increase operator safety.

Alongside the machine launch, Markforged has released Next Day Metal across its range of metal AM machines. This over-the-air software update reportedly offers speeds up to twice as fast as before. Wash and dry times are also said to be more accurate for smaller parts, shortening the required debind cycle time.

The company also announced that it is introducing the X7 Field Edition, a deployable carbon-fibre AM system. The X7 Field Edition allows Markforged technology to be sent to the most demanding and harsh environments, such as combat or exploration sites.

"Manufacturers are up against many challenges in today's market – from supply chain challenges, like rising supply costs and shipping delays, to increased pressure from the market to innovate faster and stay ahead of the competition," stated Shai Terem, president and CEO of Markforged. "Since Markforged shipped our first printer, we've been committed to quality and continuous improvement, always looking for simpler, smarter, and more robust ways to empower our customers to build anything they can imagine. The addition of the Metal X (Gen 2), Next Day Metal, and the X7 FE to our Digital Forge are important steps towards reinventing manufacturing today so that we are all more resilient tomorrow anywhere in the world."

Markforged has launched the Metal X Gen 2 machine and Next Day Metal software (Courtesy Markforged)

The Metal X Gen 2 and Next Day Metal for both the Metal X Gen 1 and Gen 2 are currently available. The X7 FE is available for pre-order, scheduled to ship in the autumn of 2021.

www.markforged.com

Paragon 28 acquires assets of Additive Orthopaedics

Paragon 28 Inc, Englewood, Colorado, USA, an orthopaedic medical device company focused exclusively on the foot and ankle, has announced that it has acquired the product lines of Additive Orthopaedics.

The deal includes Additive Orthopaedics' additively manufactured, patient-specific talus spacer, approved in February 2021 by the US Food and Drug Administration (FDA) as a humanitarian use device. It is reportedly the first and only patient-specific total talus replacement implant authorised for use in the US. The implant is designed to replace the talus, the bone in the ankle that connects the leg and foot, and provides patients access to a novel, joint-sparing alternative to traditional ankle fusion therapies.

The additively manufactured patient-specific talus spacer is an FDA approved alternative to amputation or fusion (Courtesy Additive Orthopaedics)

Also acquired as part of the transaction was Additive Orthopaedics' internally developed, proprietary pre-operative surgical planning application. The application is an end-to-end, fully integrated cloud-based communication tool that aligns surgeons and engineers to design patient-specific surgical plans and implants, optimising patient outcomes.

"The addition of the Additive Orthopaedics product portfolio and surgical planning capabilities provides Paragon 28 customers exclusive access to the only FDA-approved patient specific total talus replacement implant," stated Albert DaCosta, co-founder and Chief Executive Officer of Paragon 28. "The Additive acquisition also significantly accelerates the company's strategy to leverage smart tools, artificial intelligence and advanced technology to improve patient outcomes."

www.additiveorthopaedics.com
www.paragon28.com

3D Systems to sell On Demand Manufacturing business to Trilantic

3D Systems, Rock Hill, South Carolina, USA, has signed an agreement to sell its On Demand Manufacturing business to private equity firm Trilantic North America, for a purchase price of $82 million. Under new ownership, the company will rebrand as Quickparts, and will retain On Demand Manufacturing's experts and facilities in Lawrenceburg, Tennessee, and Seattle, Washington, USA; Le Mans, France; Pinerolo, Italy; and High Wycombe, UK.

"The On Demand Manufacturing business, with its focus on the rapid production of components using a multitude of digital manufacturing methods, is a solid business that has a very bright future under the stewardship of Trilantic North America," stated Dr Jeffrey Graves, 3D Systems' president and CEO. "Our sole reason for divestiture is to enable our entire focus and investment priorities to be on Additive Manufacturing, where we play a unique leadership role in enabling industrial-scale AM adoption across a range of exciting end markets."

"We will continue to collaborate with the Quickparts business as it relates to Additive Manufacturing and are confident that, with the focus this brings to both organisations, the future will be bright for all stakeholders. With a very strong balance sheet and cash position, proceeds from the sale will be used to further accelerate our investments for growth in our core Additive Manufacturing capabilities, for which we are seeing rapidly rising demand in new, extraordinary applications ranging from the human body to electric vehicles and space travel."

3D Systems previously announced its investment in a 4,600 m^2 expansion of its facility in Littleton, Colorado, USA, to grow its healthcare and industrial application development and advanced production capabilities. Through this infrastructure investment, the company will add expertise and advanced metal AM technologies to address new industrial applications such as those for aerospace, automotive, semiconductor, and energy.

The enhancements to the Littleton site will complement the work being done at 3D Systems' sites in Rock Hill, South Carolina, USA; Moerfelden, Germany; Budel, the Netherlands; and Leuven, Belgium. The company recently added metal AM technology to its site in Leuven in support of the work its application development and advanced manufacturing teams do for the semiconductor, aerospace, defence and automotive industries.

www.trilanticnorthamerica.com
www.3dsystems.com

Farsoon launches FS721M metal Additive Manufacturing machine with eight-laser option

Farsoon Technologies, headquartered in Changsha, Hunan, China, launched the FS721M multi-laser metal Additive Manufacturing machine at this year's TCT Asia exhibition, May 26–28, Shanghai, China. Available with eight 1000 W lasers (FS721M-8) or with either two or four 500 W lasers, the platform offers a build volume of 720 x 420 x 420 mm and is suitable for high-volume series production.

"Although the FS721M is the latest addition to Farsoon's metal machine portfolio, the FS721M actually grew out of an in-house development project dating back to 2017," stated Don Xu, Director of Farsoon Global Business Group and Managing Director of Farsoon Americas Corp, "Starting two years ago, we have seen increasing demands from industrial customers who are looking to adopt this system for scaled-up metal production. This is when we decided to take the next step to fully commercialise the FS721M system, offering as an accessible yet highly productive tool that is unique to the market."

The large-format metal FS721M platform is available with eight 1000 W lasers (Courtesy Farsoon Technologies)

Farsoon has designed the FS721M to incorporate high-performance, fully digital optics for controlling its lasers. The three-axis optics allow for the development of advanced algorithmic controls and customised scanning strategies. This allows the FS721M to achieve uniform performance from one laser to the next in multi-laser overlap zones, resulting in parts which have homogenous properties across the build platform. The FS721M also features continuous powder feeding, optimised gas flow and a long-lasting integrated filter module, which are said to help create a stable and uninterrupted build process further enhancing the melting process of metal powders.

Powered by Farsoon's Makestar software package, build process controls allow for real-time monitoring of the build environment including laser power, air flow, temperature, humidity and many other variables. In addition, each FS721M is equipped with in-chamber cameras which are used to monitor and record each layer. Besides logging the layer-to-layer data, the cameras also enable Farsoon's real-time recoat monitoring feature.

en.farsoon.com

Melrose reports positive start to year for GKN Powder Metallurgy

Melrose Industries PLC, UK, has published a trading update for the four months from January 1–April 30, 2021, with the company stating that it is trading modestly ahead of expectations, with the momentum seen in the second half of 2020 continuing into 2021. Sales in the period were reported to be 8% higher than in the same period in 2020.

The operating margins achieved in the first quarter of the year were reported to have continued to improve faster than expected. Cash generation for the group was also said to be encouraging, with Melrose being cash neutral in the first quarter, in what is traditionally a cash outflow period. GKN Powder Metallurgy – consisting of GKN Sinter Metals, GKN Additive and GKN Hoeganaes – is reported to have seen a strong recent trading performance, with sales in the period being up 35% compared to the same period in 2020. The division was also up 1% on 2019 figures, with margins in the first quarter significantly higher than those achieved in the second half of last year and also higher than the same period in 2019.

Melrose added that its Powder Metallurgy business is gaining market share and improving its operations, both of which are trends it expects to continue.

"We are pleased with our start to the year and, hopefully, will see this momentum continue for the rest of the year. We are encouraged by the significant improvements made to the GKN businesses being reflected in their financial performance. We are confident that GKN will be as successful as previous acquisitions, a track record illustrated recently by the announced sale of Nortek Air Management," stated Simon Peckham, CEO of Melrose.

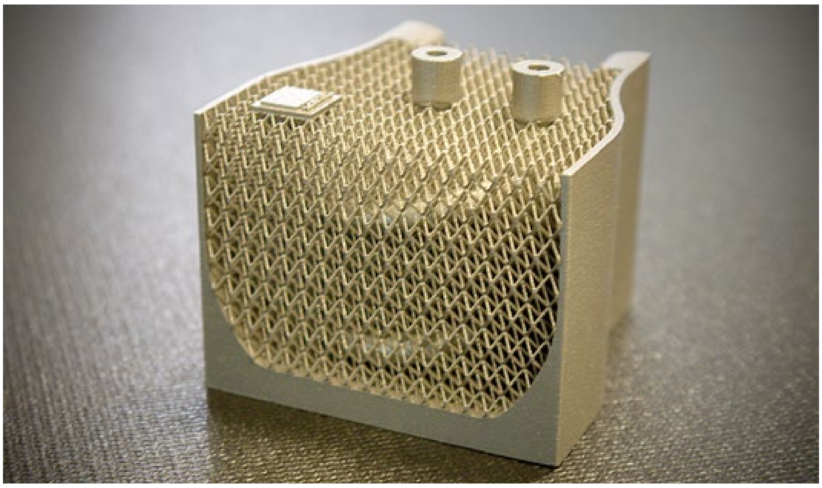
www.gknpm.com

Agile Space Industries acquires Tronix3D, rebrands as Agile Additive

Agile Space Industries, a space propulsion technologies company headquartered in Durango, Colorado, USA, has announced the acquisition of metal Additive Manufacturing company Tronix3D, which will be rebranded as Agile Additive.

The acquisition is intended to accelerate Agile's development, design, and delivery of complex, high-performance aerospace components to transform how space companies execute their most demanding missions. It will also enable the company to extend its capabilities across the aerospace supply chain to drive faster delivery and enhanced technical assurance of its propulsion products.

"Having worked with Tronix3D as a supplier, we were continually impressed with their ability to develop new proprietary processes for working with these very challenging materials and geometries of our next generation space propulsion systems," stated Jeffrey Max, CEO of Agile Space Industries. "We realised that if we integrated these competencies internally at Agile, it would further accelerate the innovation, quality and timeliness of the products that we deliver to our clients."



Agile Additive offers a range of metals, including pure nickel used for this heat exchanger (Courtesy Agile Additive)

Agile states that it has long been trusted by NASA, the US Department of Defense, Northrop Grumman, and other global aerospace leaders for its advanced propulsion technologies. The company was recently selected to provide the thrusters for Astrobotic's 2023 NASA lunar mission, which will use a SpaceX rocket. Through the acquisition, Agile will continue to deliver aerospace technologies that allow spacecraft to be lighter and faster – thus allowing them to withstand extreme temperatures, fly farther, and last longer.

Buck Helfferich, president of Agile Additive, commented, "Parts that used to be complex or even impossible to manufacture are now achievable because of our advancements in 3D printing of novel alloys. For Agile Space Industries and the aerospace industry at large, our innovations across materials, unique build geometries, and in-situ print monitoring will allow us to deliver the intricate and structurally sound parts."

www.agilespaceindustries.com
www.agileadditive.com

Norsk Titanium listed on Euronext Growth Oslo

Norsk Titanium AS, Hønefoss, Norway, reports that it has satisfied the conditions for listing on the Euronext Growth Oslo. The company's first day of trading on the exchange was May 18, 2021, under the ticker code NTI.

The listing follows a successful share issue through a private placement that raised approximately $38 million. Leading shareholders, represented on the board of directors, participated in the private placement with $15 million, and the investment company Ferd AS participated with $10 million. Norsk Titanium intends to use the proceeds from the private placement to fund planned growth initiatives.

"Today marks an important milestone for Norsk Titanium," stated Michael Canario, CEO. "The funding enabled through the Euronext Growth listing will support our ongoing development activities with our commercial customers as well as assist the transition of our technology into new markets such as defence and industrial applications. I would like to thank our advisors and the extraordinary team at Norsk Titanium who made this possible."

John Andersen, chairman of Norsk Titanium and CEO of Scatec Innovation AS, founding shareholder of Norsk Titanium, commented, "Norsk Titanium is innovating the future of metal and is uniquely positioned to disrupt the manufacturing of titanium components. We are addressing a large market opportunity, and the listing on Euronext Growth provides access to the capital required to industrialise our technology at scale."

Carnegie AS and Skandinaviska Enskilda Banken AB acted as joint global coordinators and joint bookrunners in connection with the private placement and listing. Advokatfirmaet Selmer AS acted as legal advisor to Norsk Titanium.

www.norsktitanium.com

AMEXCI establishes Finnish subsidiary to develop AM technologies

AMEXCI, Karlskoga, Sweden, reports that it is establishing AMEXCI OY, a subsidiary in Finland focused on developing Additive Manufacturing technologies. The subsidiary is funded by Sweden's Saab, an AMEXCI shareholder, with a current investment of €1.2 million.

AMEXCI OY will assemble a team of experts to work closely with companies, universities, and research institutes. Top of the new subsidiary's agenda will be collaboration with the Finnish Additive Manufacturing Ecosystem (FAME) and supporting AMEXCI's already-existing shareholder companies in order to focus on increasing the industrial adoption of innovative technologies.

In addition, AMEXCI OY will provide expertise in defining in-depth business cases for AM and developing process parameters for new metal alloys, that will give a competitive edge for industrial users. AMEXCI explains that Finland, a country with huge AM potential for metal applications, will benefit long-term from an increased domestic capacity.

AMEXCI and Saab have been working together on industrial Additive Manufacturing projects to realise a more sustainable and competitive supply chain. One of the latest successful projects was exploring AM as a temporary solution for battlefield damage repair of fighter planes, while waiting for the original parts to arrive.

Saab's investment into AMEXCI OY will provide the necessary means not only for a closer collaboration between the Swedish and the Finnish industries regarding adoption of AM technologies, but also for long-term support and a closer collaboration between AMEXCI and its shareholders.

Edvin Resebo, CEO of AMEXCI, commented, "We are excited about the opportunity for a tighter collaboration with our shareholders and customers. This will allow us to operate closer to them within the Nordic region. We are looking forward to strengthening our team with new colleagues in Finland and discovering more possibilities within the field of Additive Manufacturing. It is important to point out that this is a long-term effort, where we are aiming to create an expanding business, that will contribute to bringing new innovations to the market."

www.amexci.com
www.saab.com

Höganäs' Laufenburg metal powder production facility receives ISO 9100 certification

Sweden's Höganäs AB reports that, after eighteen months of preparation and implementation, its new atomisation plant in Laufenburg, Germany, has received ISO 9100 certification. The atomisation plant entered operation in August 2020, with the audit taking place in March 2021 and certification granted in May 2021.

The company stated that the ISO 9100 certification is an important part of its AM-grade powder business – not only for its customers in the aerospace sector, but also as a signal to the whole market of Höganäs' commitment to delivering the highest quality.

"The ISO 9100 certification will help us to further expand our future market position in the aerospace industry for Additive Manufacturing powders and win new orders from global players," stated Kennet Almkvist, who heads the Product Area Customisation Technologies.

In addition to the certification achievement, the Laufenburg site recently commissioned and qualified its new state-of-the-art Vacuum Induction Gas Atomizer (VIGA) with an integrated anti-satellite system. The VIGA system enables the site to further expand production capacities and continue to produce high-quality powders with low oxygen and nitrogen concentration, as well as highly spherical particles and minimal satellite content.

Peter Thienel, Laufenburg Site Manager, noted the great individual commitment of the facility co-workers, claiming they have learned a great deal for future projects as the certification process was demanding for the entire organisation in terms of scale and complexity. Thienel commented, "In some cases, we reached our limits. Special praise, therefore, goes to all colleagues who made the certification of our VBE [Verdüsungs-Betrieb ENAG] operation possible within the timeframe envisaged, despite the additional burdens resulting from the corona pandemic and numerous integration projects."

www.hoganas.com

Höganäs' Laufenburg, Germany, production site has received ISO 9100 certification (Courtesy Höganäs AB)

Graphmatech raises $9.8 million in investment round

Materials technology company Graphmatech AB, Uppsala, Sweden, reports that it has raised $9.8 million (SEK 84.5 million) in an investment round that is said to be fundamental to accelerate its technology development and launch graphene-based products to new markets.

"We are very pleased to see such a broad range of investors acknowledging the value of our graphene materials technology, and that both new and previous investors support our sustainability vision," stated Dr Mamoun Tahe, Graphmatech CEO and founder. "Thanks to their support, Graphmatech can continue to scale up the production capacity, launch products and increase our technological edge."

Molindo Energy, Forward Ventures and SEB Venture Debt are new investors, while existing investors ABB Technology Ventures, Almi Invest GreenTech, Walerud Ventures, and KIC InnoEnergy, continue to invest in Graphmatech. Molindo Energy led the round together with returning lead ABB Technology Ventures and Morgan Sadarangani will join the board from Molindo Energy.

Graphmatech's investment round will help the company to accelerated the development of its graphene-based products (Courtesy Graphmatech AB)

"Graphmatech will be a key player in the energy transition," commented Morgan Sadarangani, CEO and founder of Molindo Energy.

"The drive behind Graphmatech's technology is to turbocharge the transition to a sustainable society, and Almi Green Tech is honoured to support the strong Graphmatech team on this journey," said Boris Gyllhamn, Investment Manager, Almi Invest GreenTech AB.

Kurt Kaltenegger, Head of ABB Technology Ventures, added, "By making it possible to leverage the properties of graphene on an industrial scale, Graphmatech's technology offers tremendous potential to enable the sustainable electrification of industry, Additive Manufacturing and the next generation of energy storage. For ABB Technology Ventures, it is a privilege working with such a talented team lead by Mamoun and to contribute to the next phase of Graphmatech's growth journey."

www.graphmatech.com

Nikon to acquire majority ownership of Morf3D

Nikon Corporation, Tokyo, Japan, has acquired majority ownership of metal Additive Manufacturing company Morf3D Inc., El Segundo, California, USA. Morf3D specialises in AM and engineering for the aerospace, space and defence industries.

Nikon reportedly manufactures some of the most precise equipment in the world, with its products being used in applications ranging from advanced semiconductor manufacturing and mass production of panels for televisions and smart devices, to medical systems, automotive and satellites. In July 2019, the company established its Next Generation Project Division to accelerate the launch of new growth businesses, including materials processing technologies.

Yuichi Shibazaki, corporate vice president and General Manager of Next Generation Project Division of Nikon stated, "Morf3D has proven leadership in metal additive technology, a strong innovation pipeline and highly specialised aerospace manufacturing qualifications. It also brings a team of experts accustomed to partnering with customers to achieve their unique requirements. This combination is well-aligned with Nikon's vision for accelerating industrialisation of AM through innovation, and we look forward to working together to deliver exciting next-generation AM solutions to customers globally."

Nikon states that it intends to drive industrialisation of digital manufacturing by leveraging synergies resulting from strategic investments and alliances with industry-leading companies worldwide.

"Nikon's investment and cutting-edge technology accelerates Morf3D's position as an innovation leader in advanced manufacturing for the aerospace, space and defence markets," added Ivan Madera, Chief Executive Officer at Morf3D. "Our unique partnership is well-positioned to bring forth the highest level of quality, service and technological advancements that will drive the industrialisation of Additive Manufacturing."

www.morf3d.com

www.nikon.com

Ipsen USA reports significant momentum in first half of 2021

Ipsen USA's Vacuum Technology Excellence Center has reportedly surpassed its record 2018 pre-pandemic equipment sales pace during the first five months of 2021. While standard furnace sales have steadily recovered since late 2020, the furnace manufacturer cites a spike in the purchase of special equipment, including debind & sinter furnaces, vacuum aluminium brazers, units with oversized work zones, and high quench pressure furnaces.

Despite varying degrees of uncertainty across segments of the heat treat market, a diverse product portfolio has helped bolster Ipsen's global position as a provider of thermal processing equipment and related services. Recent orders include contracts from Asia, Canada and the United States, across industries such as Additive Manufacturing, aerospace, commercial heat treating and medical.

"Most of these projects have been in development for many months, some for years, and as the global economy showed early signs of recovery, many customers were anxious to act on their overdue investment plans," stated Patrick McKenna, Ipsen USA's president and CEO.

www.ipsenusa.com

Sciaky awarded research funding from NASA

Sciaky, Inc, a Chicago, Illinois, USA subsidiary of Phillips Service Industries, Inc., has received a Small Business Innovation Research (SBIR) award from NASA. The company plans to use the award to enhance its wire-based Directed Energy Deposition (DED) technology, which it refers to as Electron Beam Additive Manufacturing (EBAM), with new machine-learning algorithms that will automatically identify and eliminate potential defects in titanium (Ti6Al4V) AM parts.

The machine-learning algorithms will utilise Sciaky's patented Interlayer Real-time Imaging and Sensing System, also known as IRISS®, to monitor titanium deposition, identify anomalies, and fix them. These adaptive control features may help manufacturers deliver consistent results, from the first part to the last.

Reportedly the most widely-scalable metal AM solution in the industry (in terms of work envelope), Sciaky's PBF-EB systems can produce parts ranging from 203 mm to 5.79 m in length, with gross deposition rates up to 11.34 kg of metal per hour.

"Sciaky is proud to partner with NASA and enhance process control for titanium 3D printing," stated Scott Phillips, president and CEO. "This new capability will further solidify why EBAM [PBF-EB] is at the forefront of industrial Additive Manufacturing advancements."

www.sciaky.com

Eplus3D releases the EP-M300 metal AM machine

Eplus3D, Hangzhou, China, has launched its new metal Additive Manufacturing machine: the EP-M300. The new machine has the option of either single or dual lasers, at 500 W or 1000 W, with precise beam quality control. It has a build volume of 305 x 305 x 450 mm, making it suitable for large parts and batch production.

The EP-M300 features a gas flow management and optimised filter system which enable a stable building environment, while its sealing capability optimises oxygen content. The recoating strategy reportedly shortens coating time. Real-time monitoring of the production environment and building process are also offered.

Eplus3D's newest AM machine, the EP-M300, is now available via the company's website (Courtesy Eplus3D)

Quantitative powder feeding and coating allow for less powder waste, while powder recycling systems and a glove box structure minimises powder contact; intelligent software enables less human intervention overall.

The machine also features a filtration system which increases the filter lifetime and, during the filter changes, operations are able to carry on as usual.

www.eplus3d.com

Cumberland Additive establishes new facility in Neighborhood 91

Cumberland Additive, headquartered in Pflugerville, Texas, USA, reports that it has expanded into the Neighborhood 91 (N91) Additive Manufacturing production campus located at Pittsburgh International Airport, Pennsylvania. The company states that the new facility will be an opportunity to grow its core competencies in metal AM and CNC machining, whilst benefiting customers with the turnkey value-added solutions offered by the Neighborhood 91 AM ecosystem.

Both Cumberland locations will continue to serve major markets such as aerospace, defence, space, energy and nuclear industries via its Powder Bed Fusion (PBF) series production and engineering design services.

"Consolidating the supply chain for AM at the innovative Neighborhood 91 production campus helps us mitigate risks, costs, and complexities for our customers," stated John Jenkins, president, Cumberland Additive "We're excited to be part of the Neighborhood to work together to further ignite the industry."

In anticipation of the move, Cumberland is developing a relationship with N91 anchor tenant Wabtec Corp, a global provider of equipment and services for the freight and transit rail industries, to support the company's CNC machining needs for complex AM parts. This relationship hopes to enable Wabtec and Cumberland to leverage each other's technical knowledge and manufacturing capabilities to unlock the value of AM for their respective non-competing markets.

"We are pleased to welcome Cumberland Additive to Neighborhood 91," said Philip Moslener, vice president, Advanced Technologies, Wabtec. "Cumberland is an established Additive Manufacturing supplier who brings a unique expertise and skillset. Their addition to Neighborhood 91 will build upon the collaborative spirit of this community and accelerate the development, adoption and application of additive technology."

By providing a physical location at N91, Cumberland plans to work with local universities and workforce development agencies to train workers to support the growing AM industry. Company chairperson, Dawne Hickton, a Pittsburgh native, understands the tremendous opportunity for the company, "Pittsburgh has always had a strong manufacturing culture, and Cumberland will be able to tap into this skilled workforce to quickly grow its production capacity."

One of the original champions behind Neighborhood 91, John Barnes, founder of The Barnes Global Advisors (TBGA), sees the addition of Cumberland as fulfilling the next step in the evolution of the campus, "As a part manufacturer, Cumberland Additive joins Wabtec as an anchor tenant forming the foundation of the Neighborhood 91 supply chain strategy. These manufacturers will drive the need for the next tenants who will provide powder, thermal treatment, testing, and analysis on campus."

Christina Cassotis, CEO, Pittsburgh International Airport, added, "Cumberland's announcement is another example of how the vision for Neighborhood 91 to be a global headquarters of Additive Manufacturing is becoming a reality. Cumberland is another manufacturing anchor tenant – choosing to expand in Pittsburgh at Neighborhood 91 – which will help attract more companies. I'd like to welcome Cumberland and look forward to a continued partnership."

Cumberland expects to be fully operational by Q4 2021. This expansion also enables a focus on large-format machines, including the EOS M 400-4, an SLM®500 and Arcam EBM Q20plus for metals.

www.cai-3d.com
www.neighborhood91.com

ICD Applied Technologies adds range of metal powders for AM

Having recently entered the Additive Manufacturing and net shape manufacturing sector, ICD Applied Technologies Ltd, a subsidiary of ICD Group, located in Sheffield, South Yorkshire, UK, has added a range of metal powders to its offering.

As part of the company's ongoing development of processes centred around near net shape manufacturing, ICD Applied Technologies has begun to offer a range of metal powders to not only support its own development, but also the wider AM market.

Current powder capability and stocks include IN718, IN625, CoCr, steel and titanium grades, along with a wide range of pure metal powders. Many of the grades are available for immediate delivery, with multiple particle size distributions offered in quantities to suit customer requirements.

Mathew Marsh, Commercial Director at ICD Applied Technologies, stated, "We are in a very unique position by utilising ICD Alloy & Metals and ICD Europe's access to premium metal supply chains to support powder production, ICD Applied Technologies can supply and support many grades of high-quality metal powder cost effectively and in a very flexible manner."

www.icd-at.com

ICD Applied Technologies now offers a range of metal powders (Courtesy ICD Applied Technologies)

Hyperion expands portfolio of titanium metal powder technology

Hyperion Metals Limited, Belmont, North Carolina, USA, has entered into an agreement with Blacksand Technology, LLC, West Valley City, Utah, to investigate the commercial development of spherical titanium metal powders using Blacksand's Granulation-Sintering-Deoxygenation (GSD) technology.

This follows on from the previous agreement with Blacksand for the hydrogen assisted metallothermic reduction (HAMR) technology, which, when combined with GSD and Hyperion's Titan Project, has the potential to provide a sustainable, zero carbon, low-cost and fully integrated titanium spherical metal powder supply chain in the US. The Titan Project covers nearly 6,000 acres of titanium, rare earth minerals, high-grade silica sand and zircon-rich mineral sands properties in Tennessee.

"Titanium metal is the superior metal for a wide range of advanced applications, from aerospace to defence, and it should also be the logical choice for industrial and civilian applications," stated Anastasios Arima, CEO and MD of Hyperion Metals. "Titanium's widespread adoption has been held back in sectors such as consumer goods and electric vehicles due to its high cost."

The combination of the HAMR and GSD technologies together with advances in metal Additive Manufacturing may offer Hyperion a pathway to dramatically reduce both the cost and carbon emissions of titanium metal components. The company hopes to utilise these sustainable technologies in order to accelerate the rapid penetration of titanium in current and widespread mobility. Consumer vehicles, trains and drones can open up as high-growth markets for titanium in order to lighweight, thus increasing energy efficiency.

HAMR has demonstrated potential to produce titanium powders with low-to-zero carbon intensity, significantly lower energy consumption, significantly lower cost and at product qualities which exceed current industry standards. The GSD technology is a thermochemical process, which combines low-cost feedstock material with high-yield production, and can reportedly produce spherical titanium and titanium alloy powders at a fraction of the cost of comparable commercial powders.

Arima continued, "We aim to scale and commercialise these breakthrough technologies, make the US the global leader in titanium production and deliver technological leadership in titanium applications for aerospace, space and defence."

Hyperion has secured options for the exclusive license to produce low-carbon titanium metal and spherical powers using HAMR & GSD, technologies which were invented by Dr Z Zak Fang and his team at the University of Utah with government funding from Advanced Research Projects Agency – Energy, a US government agency devoted to the promotion and funding of advanced-energy research.

Dr Fang stated, "We look forward to commercialising the HAMR and GSD technologies with Hyperion Metals. These technologies have produced titanium metal and powders that consistently met the purity requirements defined by industry standards and they have the potential to significantly lower the costs and carbon emissions of producing titanium metal and powders."

"These technologies have the capacity to drastically alter the titanium, stainless steel and aluminium markets and increase the range of applications for high performance, lightweight and low-cost titanium parts."

Hyperion has also signed a Memorandum of Understanding (MoU) to establish a partnership with uranium producer Energy Fuels, Lakewood, Colorado, that aims to build an integrated, entirely-American rare earths supply chain. The MoU will evaluate the potential supply of rare earth minerals from Hyperion's Titan Project to Energy Fuels for value added processing at the company's White Mesa Mill, reportedly the only fully-licensed and operating conventional uranium mill in the US.

www.hyperionmetals.us
www.blacksandtechllc.com

3D Systems acquires Additive Works

3D Systems, Rock Hill, South Carolina, USA, has signed an agreement to acquire software company Additive Works, headquartered in Bremen, Germany. In a further investment, the company also signed a deal to acquire bioprinting solutions developer Allevi, based in Philadelphia, USA. Building upon the company's healthcare and software businesses, the targeted investments were said to address rapidly-expanding application opportunities for Additive Manufacturing in medical and high-reliability industrial applications.

"We continue to deliver on our four-phase plan with an increasing focus on investing for accelerated growth and profitability," stated Dr Jeffrey Graves, 3D Systems' president and CEO. "I'm excited by the expertise, capabilities and technologies we are adding to the 3D Systems portfolio with Allevi and Additive Works. Through these investments, we are enriching our solutions portfolio to address a much broader healthcare market, including the extremely exciting market for regenerative medicine, while accelerating the adoption rate for AM across industrial applications."

Since its beginning in 2015, Additive Works has focused upon simulation-based optimisation and automation of the AM build preparation and workflow. Using sophisticated algorithms, Additive Works' software allows engineers to rapidly determine optimum print set up, such as part orientation and support structures, as well as directly adapt the process set up for effective thermal management and distortion compensation. This highly-automated simulation software – which interfaces with leading CAD systems, such as 3D Systems' 3DXpert – enables increased productivity by reducing set-up time whilst improving product yield, throughput, and component performance. The result is a fast and reliable manufacturing process, reduced part cost, and improved component performance.

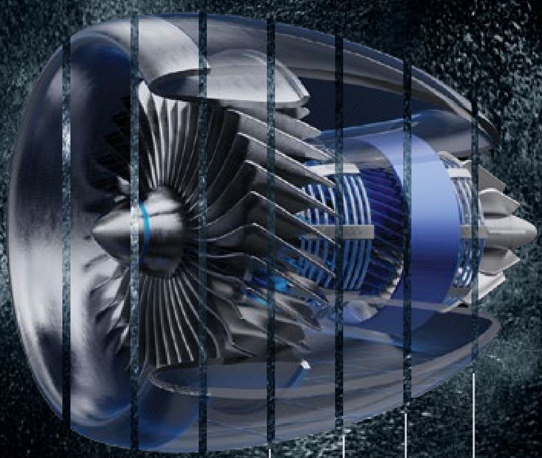
By integrating Additive Works' simulation knowledge into 3D Systems' software team, the company aims to enhance its AM software portfolio and innovation capacity, driving accelerated AM adoption across the industrial and healthcare markets that the company serves. This includes Additive Works' Amphyon for experts as well as the Amphyon plugin for CAD users – both of which will continue to be sold and supported to customers as a standalone offering.

"We're excited to join 3DSystems and continue our journey," added Nils Keller, CEO and co-founder of Additive Works. "As a hardware, materials, and software provider across different AM technologies, 3D Systems is a perfect partner for us. This is a big step towards leveraging our simulation technologies, by linking material, process and intelligent software tools in a way it has never been done before."

www.3dsystems.com | www.additive.works

CNPC POWDER

Specialized in Metal Powder



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Low Oxygen and Low Nitrogen Levels

High Efficiency for Targeted Particle Sizing

Higher Production Output with a much Shorter Production Cycle

CNPC POWDER's innovative Atomization process for Powder Bed Fusion (PBF) metal Additive Manufacturing produces metal powders with the material characteristics that meet the toughest aerospace applications.

Our Aluminum powders allow for the creation of parts that reduce weight while increasing value and performance for end users.

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CNPC POWDER, GENERATING INTELLIGENT MATERIALS.

LIGHTWEIGHT, HIGH-STRENGTH

Al

WWW.CNPCPOWDER.COM

Solukon partnerships expand reach of its depowdering system

Solukon Maschinenbau GmbH, Augsburg, Germany, a developer of powder removal systems for use in metal Additive Manufacturing, has reported a number of collaborations and partnerships over the last quarter, aimed at improving process workflow, system integration and market reach.

Improving automation with Festo
To identify by how much the level of automation in the depowdering stage can be increased, the company has teamed up with industrial automation solutions supplier Festo, Esslingen, Germany.

Based on its proprietary Smart Powder Recuperation (SPR®) technology, Solukon's powder removal systems remove the powder residues from complex additively manufactured metal components through an automated process of swivelling and vibration excitation, which can be standardised and is reproducible. With the advanced frequency system, the flow of the powder can be continually controlled so that narrow openings and channels can be depowdered – including components with complex voids and channels, such as heat exchangers.

Any automated depowdering process, however, can sometimes struggle to remove powder from component surfaces, particularly when dealing with difficult-to-handle materials. In order to dislodge fine deposits, a light and direct airflow is utilised. This method of blowing air can also be used through the channels in order to ensure that they are also free of residue. Currently, this dislodging process is a manual procedure that Solukon carries out using glove ports.

The partners hope that the end result, fully-automated and residue-free depowdering, should lead to accelerated and reproducible processes and eliminating manual rework and reducing costs.

ExOne's new depowdering station
The ExOne Company, North Huntingdon, Pennsylvania, USA, also recently partnered with Solukon to develop a depowdering station for use with its X1 160Pro production metal Binder Jetting (BJT) Additive Manufacturing machine.

With the launch of the new X1 160Pro, which began shipping to customers in the first quarter of 2021, new solutions for powder handling had to be developed for much larger volumes of powder use and reuse within the manufacturing environment, states the company. Together, the new X1DPS 160 depowdering station was developed for use with the X1 160Pro, and is now being manufactured by Solukon in close proximity to ExOne's facility in Gersthofen, Germany, where the X1 160Pro is manufactured.

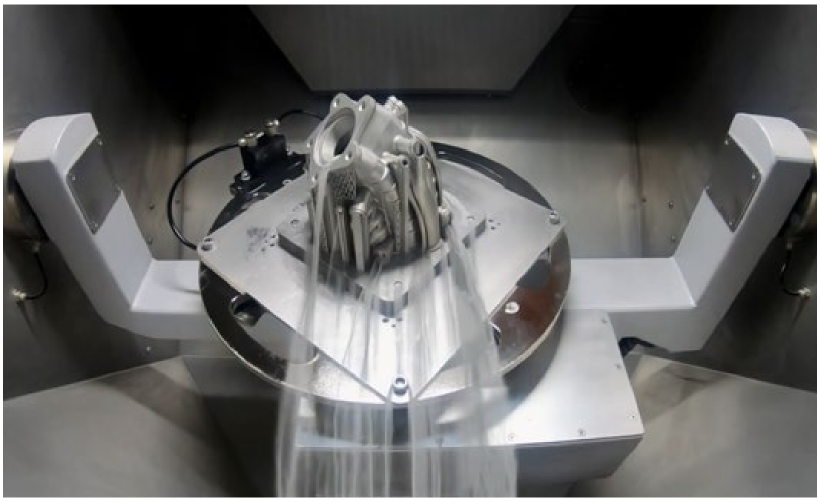
SLM Solutions brings Solukon to its application centre
SLM Solutions Group AG, Lübeck, Germany, also entered into a partnership with Solukon in which the AM machine maker will utilise Solukon's flagship machine, the SFM-AT800-S, for the post-processing of parts in the company's application centre in Lübeck.

"This alliance brings added value to our customers for their internal manufacturing processes and is an important step towards holistic factory planning," stated Gerhard Bierleutgeb, EVP Global Services & Solutions at SLM Solutions. "We particularly like the flexibility of the machine. Not only can it be used with different materials, but the processing of a wide range of parts is possible. We can also easily depowder large components that have been manufactured on the SLM®800."

Distribution deals in Canada, UK and Ireland
Solukon also announced that Machine Tool Systems Inc., Toronto, Ontario, Canada, will act as its distributor in Canada. The company specialises in AM solutions and provides a range of third-party products. Machine Tool Systems also represents machine maker EOS, among others.

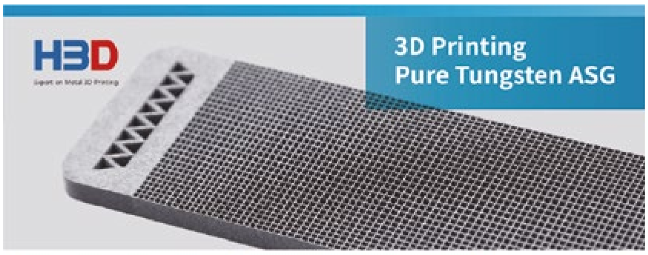
Turbex, based in Alton, UK, was also announced as distributor in the UK and Ireland. Turbex has delivered cleaning equipment for hundreds of UK businesses for nearly forty years, with customers in a range of industries including aerospace, automotive, medical, and energy.

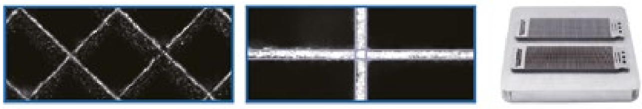
www.festo.com
www.exone.com
www.slm-solutions.com
www.machinetoolsystems.com
www.turbex.co.uk
www.solukon.de



Solukon's depowdering systems incorporate its Smart Powder Recuperation technology (Courtesy Solukon Maschinenbau GmbH)

HBD-100 Provides a Complete Solution for Medical Printing - Pure Tungsten ASG





Pure Tungsten Anti-Scatter Grid(ASG): X-ray grid for high-end radiography systems

Compared with traditional 2D molybdenum or 1D ASG, tungsten 2D ASG has significant advantages. 1. The high density of tungsten enhances the absorption of spilled X-ray scattering, and improves the CT images quality while ensuring the patients safety. 2. The 3D printing technology of the digital manufacturing mode allows more freedom of design and realizes mass production of high-quality pure tungsten gratings.

DMLS Benefits:

With sufficient design freedom, the ASG can adjust the shape of the beam to reduce X-ray scattering and ensure excellent CT imaging quality;
Good heat resistance, can effectively shield radiation;
Improve and simplify the assembly process, increase efficiency and reduce costs;
Digital manufacturing accelerates product manufacturing and technological innovation.

HBD Main Strengths:

With rich experience in tungsten processing capabilities by DMLS technology, HBD has created a unique forming process that can achieve ultra-thin wall, high precision, and high density, which can nearly completely remove impurities and ensure the surface accuracy of printing parts.
Meanwhile, HBD offers design support (Analyzing the designed parts to determine whether they are suitable for printing, optimization of components & functions)

HBD-100 Features for Printing Pure Tungsten:

1. Forming size: 105*105*100mm; 325*325*400mm (HBD-350)
2. Accuracy: +-0.02mm
3. Wall thickness: 0.1-0.2mm (minimum 0.08-0.1mm)
4. Density: reaches 99%

Currently, 3D printed pure tungsten components are not only applied in medical shields, CT-ray tubes, X-ray tubes, etc., but also in automotive and nuclear energy application etc. Now that HBD has completed the delivery of dozens of machines, the market has verified that all can meet the needs of large-scale production with easy post-processing and greatly improve the competitiveness of users.

https://www.hb3dp.com

Admaflex 130 software upgrade released

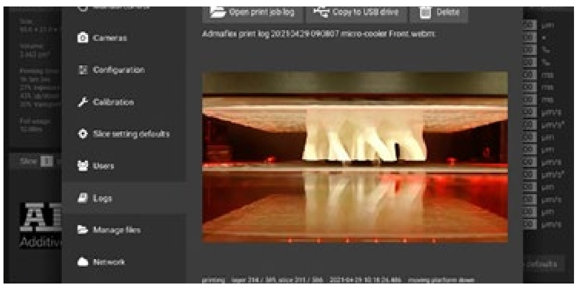
Admatec, Goirle, the Netherlands, has released software version 1.2.1.1 for its Admaflex 130 Vat Photopolymerisation (VPP)-based AM machine, suitable for both ceramics and metals. The machine is an open system that comes standard with complete software, enabling full control of the AM process with an interface which allows the user to slice the part, add support structures as needed, apply offsets, customise and optimise parameters before and during the manufacturing process.

The new automatic support generation feature is said to be well suited for geometries that do not have a flat side, such as medical implants and jewellery. The automatic support generation software allows a user to create different types of support structures quickly and easily. The number of supports can be chosen by varying the support angle and, between the support and the model, a gap can be created, allowing easy removal of the part.

The video-based monitoring features enable the creation of time-lapse videos of the manufacturing job. A video player has also been added, allowing users to view any recording made by the machine directly on the machine. The video player supports scrubbing through the video, pausing the video at any point and changing the playback speed. The manufacturing action in the video is also displayed together with time and layer information.

When the Admaflex machine is connected via Ethernet to a network, via any laptop or desktop PC, users have remote access to the machine for easy exchange of build- or log files. Remote connection capability also allows monitoring of the manufacturing job, including real-time video capture. New in the web interface is the option to pause the current job – this enables users to immediately react to what is happening on the machine from anywhere. If an issue is noticed and the user is not near the machine, the job can be paused, allowing the chance to get to the machine in order to fix the problem, and then continue the manufacture.

www.admateceurope.com



Admaflex 130 1.2.1.1 offers automatic support generation, video-based monitoring and remote process monitoring (Courtesy Admatec)

BEAMIT develops AM process for high-performing Al2024 RAM2C alloy

The BEAMIT Group, Fornovo di Taro, Italy, has developed an Additive Manufacturing process for using Al2024 RAM2C aluminium alloy. The ultralight aluminium alloy is reported to perform well at high temperatures, making it ideal for applications in the motorsport, automotive and aeronautical sectors.

The development was in response to increasing demand for aluminium alloys that combine the ability to maintain high-performance levels, irrespective of the temperature, with extremely light weights. The first step of the project was in collaboration with US-based Elementum 3D, with BEAMIT choosing to print with Elementum 3D's Al2024-RAM2C material, a 2000 series aluminium alloy composition modified with their patented RAM additions.

"Our priority is to offer customers advanced materials and processes so they can transfer these innovations directly and effortlessly to their products," stated Mauro Antolotti, president of the BEAMIT Group. "This continually evolving advancement is an integral part of our group's long-term strategies and supported by a strong, well-organised team focused on achieving even more competitive results."

The 2024 RAM2C aluminium alloy is reputed to perform better at both room and high temperatures than other alloys currently in use; it is also very tough and lightweight, characteristics that make it well suited for applications in the motorsport and automotive sectors in components like the suspension, parts of the chassis and structural parts of the powertrain. As processed with conventional technologies, the alloy is also commonly used for the structural parts of aircrafts; the switch to AM processing here would reportedly bring down energy consumption and costs.

Until now, 2000 series aluminium alloys, including 2024, were known for their inability to be processed via Additive Manufacturing due to their composition: the elements in alloys (such as copper, zinc and magnesium) solidify at completely different temperatures, making it difficult to melt them with a laser to create solid elements. After processing, aluminium alloys need to be subjected to heat treatments to achieve maximum levels of mechanical performance, as varying heat treatments can affect how the material performs. A custom cycle was built for the 2024 RAM2C alloy to achieve the best properties. The R&D team developing these solutions also developed different post-processes, enabling customers to have modular solutions with customised properties.

Alessandro Rizzi, BEAMIT Group Material and Special Processes Manager, clarified, "It is very difficult to process 2000 series aluminium alloys via L-PBF [Laser Beam Powder Bed Fusion], so developing this material really motivated us. Furthermore, the role of heat treatments became fundamentally important for Al2024 RAM2C and enabled us to experiment different ones to find repeatable stable processes and guarantee maximum performance, including in-air and HIP-Q treatments."

The BEAMIT Group is now working on parameterising the high-pressure heat treatment process in collaboration with its subsidiary post-production processes provider PRES-X.

www.beam-it.eu | www.elementum3d.com

BEAMIT has developed an AM process for Al2024 RAM2C aluminium alloy (Courtesy BEAMIT Group)

SLM Solutions reduces support structures with Free Float software

SLM Solutions Group AG, Lübeck, Germany, has launched Free Float, a software solution intended to reduce or remove support structures and enable new designs which reduce material usage. During the product's virtual launch, Sam O'Leary, CEO, stated that a basic subscription to the software will be available at no cost.

Support structures have been an inherent part of the Additive Manufacturing process, explained SLM, with the design of the main component often limited due to necessary supports. These could make up a substantial section of the overall part volume, and yet needed to be removed during the post-processing phase, thereby increasing material usage and cost.

Free Float is said to enable the Additive Manufacturing of overhangs at 10° in long range geometry and 5° in short range (Courtesy SLM Solutions)

In 2017, SLM saw its first glimpse at what would become Free Float as a by-product of a research project. After some four years of further research and development, Free Float was officially born, establishing thermal management that decreases net build time whilst simultaneously enhancing part quality. This enhancement can be noted particularly in overhang areas – these can now 'free float' like the branches of a tree, added SLM.

In line with the company's open architecture philosophy, Free Float was designed to be retrofittable on many previous systems, including the SLM®280 Production Series, the SLM 280 2.0, the SLM 500, the SLM 800, and the NXG Xll 600.

www.slm-solutions.com

Desktop Metal qualifies 316L stainless steel and 4140 low-alloy steel for its Production System

Desktop Metal, Inc, Burlington, Massachusetts, USA, has qualified the use of 316L stainless steel and 4140 low-alloy steel for use in its Production System™ metal Binder Jetting (BJT) Additive Manufacturing platform.

Known for its corrosion resistance and excellent mechanical properties at extreme temperatures, 316L stainless steel is well suited to applications in the most demanding conditions, such as parts exposed to marine or pharmaceutical processing environments, food preparation equipment, medical devices and surgical tooling.

Desktop Metal is reportedly the first company to qualify 4140 low-alloy steel for use with metal BJT systems, enabling its use in mass production end-use part applications. Considered one of the most versatile low-alloy steels, 4140 is characterised by its toughness, high tensile strength, and abrasion and impact resistance. It is a critical, all-purpose and heat-treatable steel used extensively in a variety of automotive, oil and gas, and industrial applications, such as gears, downhole tool components, couplings, spindles, bolts and nuts, and many other mechanical parts.

Desktop Metal's materials science team has validated that 4140 low-alloy steel, built on Production System technology and sintered by Desktop Metal, meets MPIF 35 standards for structural Powder Metallurgy parts.

"4140 has been a challenging material for metal Binder Jetting because of its low alloyed content, tight carbon control requirements, and low ignition energy, which together require advanced binder chemistry, as well as extensive printing and sintering optimisation and atmospheric controls for safe processing," added Myerberg.

"We are excited to be the first to qualify 4140 for metal Binder Jetting to enable this versatile material for the AM industry. With the speed of the Production System, businesses can now use Binder Jetting to print complex 4140 parts at competitive costs while maintaining the strength and mechanical properties of traditionally manufactured alternatives. This is a game-changing solution for manufacturers who have been tied to time-consuming and expensive machining and conventional tool-based manufacturing processes," Myerberg stated.

The Production System platform materials library now includes 17-4 PH stainless steel, 316L stainless steel and 4140 low-alloy steel, each of which have been qualified by Desktop Metal. The platform also supports several customer-qualified materials, including silver and gold, and the company plans to add additional metals to its portfolio, including tool steels, stainless steels, superalloys, copper, and more.

www.desktopmetal.com


SANDVIK

AddUp launches FormUp 350, a modular PBF-LB AM machine

French company AddUp, a joint venture created by Michelin and Fives in 2016, has launched the FormUp 350, its latest metal Additive Manufacturing machine based on Laser Beam Powder Bed Fusion (PBF-LB) technology. The AM machine is said to be suitable for all types of metal powders with fine or medium granulometry.

The four 500 W lasers are all equipped with a three-axis optical chain, which enables positioning accuracy and good laser beam quality. The machine's bidirectional coating system is reportedly 40% faster than monodirectional powder spreading and helps to avoid the soiling of laser protection glass during manufacturing.

This new machine relies on a modular, scalable architecture, which is intended to stave off machine obsolescence as it allows for upgrades and replacements to be made without needing to replace the machine entirely. Optimised sealing of the production chamber to reduce inerting times by fifteen minutes are sufficient to reach an oxygen level of 500 ppm.

The modular FormUp 350 is offered in four configurations (Courtesy AddUp)

This modularity also allows operators to work safely, using an autonomous powder module developed exclusively with AZO which enables the storage, conveyance, recovery and sieving of powders in a close-circuit, inert atmosphere. Exposure to fumes and smelting resides is controlled via an automatic passivation filter system which ensures safe waste disposal with the use of calcium carbonate powder. This filter, with a replacement interval greater than a year, greatly reduces the waste's flammability. All machine parameters are accessible to the user, who is able to create specific 'recipes' in balancing productivity and part detail, suitable to their industry's need.

The machine's software, AddUp's NCore, is capable of processing production files of over 80 GB in one go. AddUp Dashboard is able to track eighty manufacturing parameters and the automatic editing of production conformity reports. A system has also been developed for monitoring fusion quality, continuously measuring the laser's power and the temperature of the fusion. This also allows in-situ analysis of powder spreading, checking for defects on the powder bed and triggering a second coating, when necessary. There is also a system of referencing platforms by probes allowing in a few seconds to adjust the positioning of the manufacturing trays and check their flatness.

The FormUp 350 is said to be the only machine on the market with an interchangeable coating device, offering two powder spreading systems: a scraper or a roller. The roller system is said to provide better repeatability for certain medium powder applications, but also allows the use of fine powders in unsupported manufacturing of cantilevered parts and improved surface finishes. A heating plate up to 200°C reduces stress concentrations and the risk of part deformation. A cooling system for the machine's Z-axis lowering the temperature of the platform at the end of production, allowing parts to be unloaded more quickly (two hours to cool down from 200°C to 65°C).

The FormUp 350 is available in four configurations, each with its own set of modules and capabilities: starter, efficiency, productivity and advanced.

www.addupsolutions.com

PM parts maker Poral enters metal Additive Manufacturing market

Poral has added metal Additive Manufacturing to its list of capabilities (Courtesy Poral SAS)

Poral SAS, Le Pont-de-Claix, France, a manufacturer of Powder Metallurgy structural parts, sintered porous metal filters and self-lubricating bearings, has added metal Additive Manufacturing to its list of capabilities. Establishing a fourth brand under the name Additive Metal®, the new division will complement the company's existing divisions, Oloron Frittage (PM parts), Poral Filtration, and Metafram Metagliss (bearings and friction plates).

The announcement follows on from several years of research and development in collaboration with France's CETIM (Technical Centre for Mechanical Industry) and CEA (Alternative Energies and Atomic Energy Commission). Poral also announced that it has signed a partnership with Desktop Metal, Burlington, Massachusetts, USA, to develop metal Binder Jetting (BJT) capabilities.

Poral's customers include the automotive, aerospace, nuclear, chemical, mechanical industry, sport and luxury markets. The company has two production facilities, one in Voie des Collines, Pont-de-Claix and another in ZI de Légugnon, Oloron-Sainte-Marie, and has been awarded the 'La French Fab' label, a government designation which aims to bring together the country's industrial ecosystem in order to revive and transform the face of French manufacturing.

www.poral.org

AMT's A20X aluminium powder secures aerospace recognition

Aluminium Materials Technologies (AMT), Worcester, UK, has secured aerospace recognition with publication of the AMS7033 standard for its high-strength, high-temperature A20X aluminium powder for Additive Manufacturing. The AMS7033 specification covers the aluminium alloy in the form of pre-alloyed powder, enabling the AM of aerospace components from A20X.

AMT explained to *Metal AM* magazine that it became an Eckart/Altana company in September 2020, and with Eckart being one of the top three aluminium atomisers in the world the combined expertise has boosted the development of the A20X powder.

The atomised alloy is compatible with the majority of leading AM machines and is actively being used in environments that require A20X's high temperature and high strength properties. Components that have been additively manufactured demonstrate excellent fatigue properties and resistance to stress corrosion cracking.

Based on the patented MMPDS aerospace-approved aluminium alloy A205, the A20X (2A05.50) atomised alloy powder has the same composition as its parent. A20X is now in flying component production with aerospace OEMs, T1 suppliers, AM bureaus and numerous universities.

The publishing of AMS7033 is reported to be the culmination of extensive and in-depth discussions with Additive Manufacturing experts, including members from leading aerospace companies, who ensure the specification's veracity. The company believes that the granting of AMS7033 further illustrates that A20X powder is a leading aluminium powder in the aerospace market.

www.a20x.com

AMT has secured aerospace recognition with the publication of AMS7033 standard for its A20X aluminium powder (Courtesy AMT)

Objectify Technologies partners with Air Works to bring AM to India's aviation, aerospace and defence industry

Additive Manufacturing service provider Objectify Technologies, New Delhi, India, has partnered with Air Works, a large independent MRO and aviation service provider in India, to expand the company's portfolio beyond aviation into the aerospace and defence sectors using AM. Air Works also hopes to leverage this partnership in order to transition from aviation services to aviation solutions provider.

In line with Air Works' planned expansion, the companies intend to identify and pursue business opportunities in the aerospace and defence industries, including the global requirements of commercial private jet owners or operators. Objectify Technologies will contribute its design and manufacturing capabilities. The arrangement also provides a basis for both parties to further explore opportunities in other base materials, manufacturing technologies, and industry segments in the future.

"Our partnership with Objectify Technologies reflects our commitment to always offer the latest and the best-in-class solutions to our customers in the aviation fraternity," stated D Anand Bhaskar, MD & CEO, Air Works. "I am confident that this collaboration will benefit the entire spectrum of our customers across business and executive aviation, commercial airlines and the defence sector."

Ankit Sahu, Director of Objectify, commented, "3D printing technology and materials are increasingly gaining relevance across industries, given their good strength-to-weight ratio, excellent dimensional accuracy, strength and stiffness, lightness, wear resistance, good thermal performance, and non-corrosiveness."

"As a pioneer, Air Works occupies a fundamental place in the Indian aviation ecosystem, and we are proud and privileged to partner with the country's leading aviation services provider having a domain experience of over seventy years," Sahu continued. "Our alliance with Air Works will put us in an enviable position to address the challenges of not just aviation but also those of the fast-growing aerospace and defence sectors using our collective synergies."

www.objectify.co.in
www.airworks.aero

Norsk Titanium expands into the industrial application market in collaboration with Hittech Group

Norsk Titanium AS, headquartered in Oslo, Norway, has announced an expansion of its customer base into the industrial application market sector, following collaboration with the Hittech Group, based in Den Haag, the Netherlands. The production of the first industrial component in this partnership will support a Hittech customer in the growing semiconductor equipment market.

Norsk expects significant near-term investment by manufacturers in the semiconductor market as the company seeks to modernise its supply chains. The move is said to represent Norsk's first step to support these modernisation efforts with a faster, more cost-efficient and environmentally friendly approach.

Using Norsk's Rapid Plasma Deposition (RPD) process, a form of plasma-based Directed Energy Deposition (DED), Norsk engineers have designed a titanium alloy preform that will reduce Hittech's raw material needs by over 45% as compared to legacy wrought product used to fabricate the end component currently. Leveraging the RPD industrial process enables Norsk to create a near-net shape design while maintaining the required quality controls and material properties Hittech needs for this critical component.

Utilising nearly the full 90 x 60 cm build envelope of Norsk's G4B machine, the resulting RPD form will weigh nearly 100 kg. Delivery of a first test piece is expected by year-end, with serial production planned to begin in 2022.

"We are delighted to collaborate with Hittech in the transition of the design of this component to RPD material," stated Michael Canario, CEO of Norsk. "Hittech has been a strong supporter of our technology, and we are delighted to have reached this phase in our partnership. We look forward to exceeding their affordability targets with a more efficient and cost-effective method of manufacturing titanium."

www.norsktitanium.com
www.hittech.com

Norsk expects significant near-term investment by manufacturers in the semiconductor market as the company seeks to modernise its supply chains (Courtesy Norsk Titanium)

CNPC Powder receives financing boost from Chinese industrial fund

CNPC Powder, headquartered in Vancouver, British Columbia, Canada, has announced the successful closure of A Round Investor Funding, reportedly securing tens of millions in financing from an emerging industry fund in China. The round of funding will be used to construct new production facilities, to further improve the fully automatic (AMP) production lines and focus on additional R&D for new products and technologies.

CNPC Powder's new funding is also intended to enable the company to improve workflows and enhance real-time monitoring of equipment, enable improved statistical analysis and implement more advanced QA, CRM and ERP industrial software systems. The company hopes that all of this will translate into an annual production capacity of 1,000 tons of metal powder for Additive Manufacturing.

Given the increasing market demand for lightweight applications, aluminium alloys have become the research hotspot for global metal AM manufacturers. Within this competitive market, CNPC Powder's aluminium alloys are reported to feature highly spherical particles with few satellites, resulting in a highly fluid powder with low oxygen content.

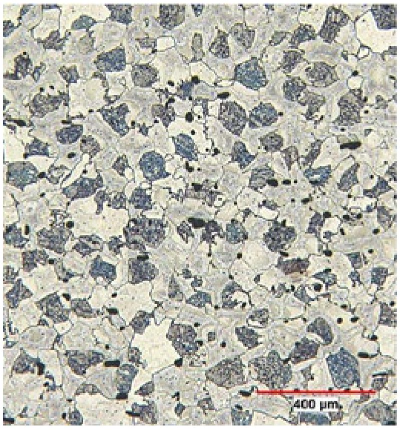
As well as the aluminium market, the company is also actively developing and improving technologies for the production of copper, titanium, nickel and cobalt alloys, as well as other conventional metal AM materials. This new round of funding will also be used to further accelerate the commercialisation of these materials for the AM market.

CNPC Powder states that promoting the industrialisation of high-quality, low-cost AM metal powders will continue to be its goal, as it continues to work with industry partners and begins cooperation with well-known global metal AM companies.

www.cnpcpowder.com

GKN Additive adapts DP600 low-alloy steel for Additive Manufacturing

GKN Additive, Bonn, Germany, has adapted DP600, a low alloy dual-phase steel widely used in the automotive industry, to its range of metal powders suitable for Additive Manufacturing. The DP600-like material is available in a Dual Phase Low Alloy (DPLA) for Laser Beam Powder Bed Fusion (PBF-LB) as well as a Free Sintering Low Alloy (FSLA) for Binder Jetting (BJT).



The cross-section of the FSLA material shows the dual-phase microstructure after heat treatment (dark: martensite / bainite; light: ferrite). Using heat treatment, the proportion of the different phases and the grain size can be adjusted to achieve unique physical properties (Courtesy GKN Additive)

The new powder is reported to offer similar mechanical properties to DP600 (HCT600X/C), such as higher ultimate tensile strength (UTS) and low yield strength (YS) to UTS ratio. GKN has further enhanced the material with regard to spreadability, laser absorption (for PBF-LB) and sinterability (for BJT).

"Traditional DP600 offers specific standardised mechanical properties, achieved by heat treatment," stated Christopher Schaak, Technology Manager for Binder Jetting at GKN Additive. "The dual-phase steel AM materials developed by GKN Additive, on the other hand, are very flexible in their characteristics, as their mechanical properties can be tuned more widely by the heat treatment after the laser or Binder Jetting process."

This flexibility makes the material suitable for a wide variety of different applications, enabling its use in automotive and other industrial sectors. For manufacturers in the automotive sector for example, these two materials offer a new level of design freedom and potential for weight reduction.

"With these AM processes, manufacturers in the automotive industry can construct body parts differently than what was possible with traditional sheet metal parts. If you look at a tailored blank, many sheet- metal parts and support parts need to be formed and joined together to achieve a certain stiffness. By using structural components printed with AM on the other hand, you would need less process steps and less material, leading to cost optimisation and a weight reduction," explained Schaak.

Furthermore, the time it takes for a new product to enter functional validation can be significantly shortened through Additive Manufacturing processes. "Our customers want to know what the new AM material can achieve in their respective use case," added Sebastian Bluemer, Technology Manager Laser AM at GKN Additive. "It's faster to print parts with AM than to retool complete traditional production lines and manufacture the parts the conventional way. This means that AM is a good solution to quickly and functionally validate a material and a component, and to analyse faster and more efficiently, whether the material can help with a specific application or not."

www.gknpm.com/additive

Protolabs receives DNV AM certification to meet needs of Oil & Gas sector

As part of quality assurance provider DNV's recently-launched service for Additive Manufacturing, Protolabs, headquartered in Maple Plain, Minnesota, USA, has achieved a 'Qualification of Manufacturer' certification. Protolabs is among the first manufacturers in the EMEA region to achieve the certification, and reportedly the first certified manufacturer using Powder Bed Fusion in its AM process.

"Trust is, rightly, an important necessity for the Oil & Gas industry and also the wider energy sector," commented Daniel Cohn, General Manager and 3DP Lead for Protolabs EMEA. "But now assurance can be given with the work we've conducted under the keen eye of DNV – the independent expert in risk management and assurance for the sector. Audits of our manufacturing facilities and processes prove that we comply with the general demands of the Oil & Gas industry so we can now move forward with even greater support for the sector as a whole."

The certification applies to Protolabs' Laser Beam Powder Bed Fusion (PBF-LB) AM technology, referred to by the company as Direct Metal Laser Sintering, specifically for the superalloy Inconel 718. The combination of the superalloy and the company's knowledge enables the rapid production of complex geometries for parts exposed to the harsh environments typical of the sector.

Achieving the certification is a process of technical evaluation of a number of probes within the machinery in combination with the material, individually and the system as a whole. The independent certification provides reliable proof that the probes meet the high-quality standard set out by DNV.

www.protolabs.com

Sauber's F1 technology used in production of additively manufactured classic car parts

The team at Sauber were recently challenged to build a replacement gearbox housing for a 1950s Ferrari 340 America Barchetta (Courtesy Sauber Engineering)

Sauber Engineering AG, part of the Sauber Group, is looking to enter the classic car component supply business with a service capable of providing reverse engineering and Additive Manufacturing of key components.

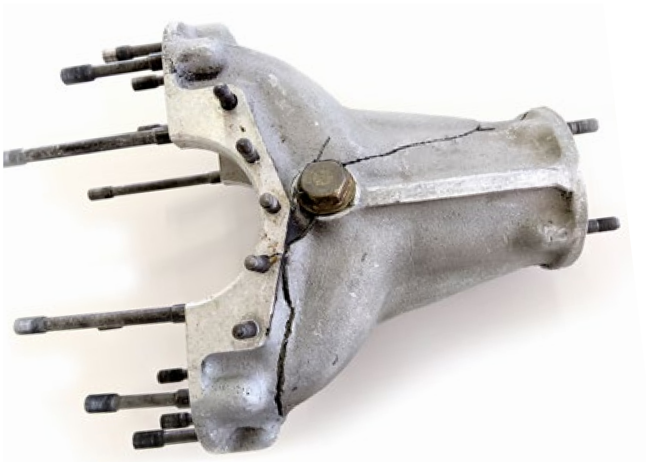
With an automotive history dating back over forty years, Sauber will apply its expertise and technology used in Formula 1 to manufacture parts for classic vehicles, where an aftermarket supply chain is limited, or no longer exists.

Talking to *Metal AM* magazine, Christoph Hansen, Director Technology & Innovation at Sauber Engineering, was keen to explain the reasoning behind the project. "At Sauber, we have a wealth of knowledge and understanding of automotive engineering. Blend this with our experience in Additive Manufacturing for high-performance F1 components, and we can offer the historic vehicle sector something unique – a one-stop-shop to replace broken or damaged components that would otherwise mean the end for that car."

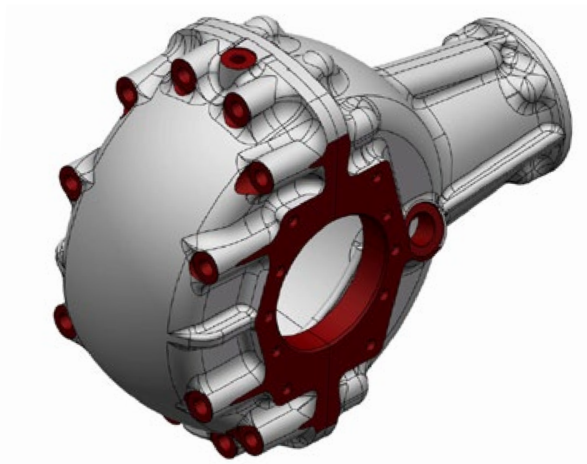
Sauber has both polymer and metal AM machines at its facility in Zürich, Switzerland, and has been using them for a number of years to produce both prototype and functioning components. "We can now offer the classic car owner a range of options, from simple plastic covers, up to complete gearbox housings or engine parts," added Hansen.

The team at Sauber were recently challenged to build a replacement gearbox housing for a classic 1950s Ferrari 340 America Barchetta. The defective component, used on the rear axle of the car, is no longer in production and, due to the scarcity of the car, no donor parts could be sourced. "This is common with many older historic vehicles," stated Jonathan Herzog, Head of Project Management & Sales. "The older the car is, the harder it is to find replacement or even substitute parts. As you can imagine, it is also extremely difficult, if not impossible, to obtain the engineering drawings for these parts."

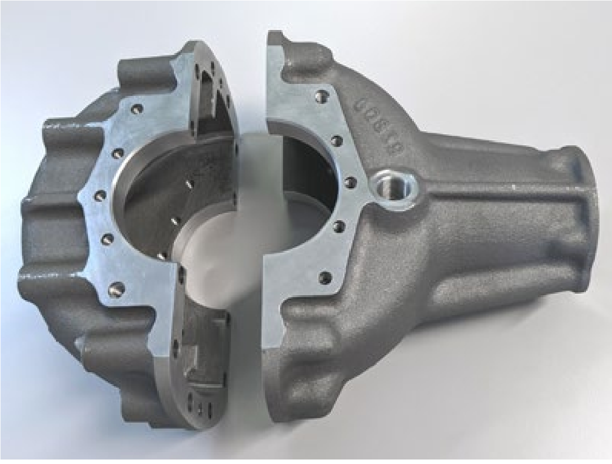
This is where the wealth of automotive knowledge at Sauber is essential. "We know what tolerances a gearbox needs to be built to, we know what materials are best to use. We can then apply our experience to design the part, making it not only work, but making it perform better



The original gearbox housing on the Ferrari was severely damaged (Courtesy Sauber Engineering)



A reverse engineered casing was optimised for the AM process (Courtesy Sauber Engineering)



The redesigned gearbox casing was built at Sauber Engineering's Zürich facility (Courtesy Sauber Engineering)

After the build, the gearbox casing was machined to required tolerances (Courtesy Sauber Engineering)

than the original," continued Herzog.

In some cases, of course, a component can be repaired, but this was not possible with the Ferrari gearbox. "The gearbox was badly damaged and split across the casing. Our only option was to reverse engineer the housing, which involved a full 3D scan of the structure and then optimisation of the CAD file to produce a design that could be additively manufactured," added Hansen.

The gearbox housing was built in-house using a MetalFAB1 system from Additive Industries. The MetalFAB1 is a Laser Beam Powder Bed Fusion (PBF-LB) machine capable of producing parts from a wide range of metals, including maraging or tool steel, aluminium, Scalmalloy, titanium and nickel alloys.

"The Ferrari gearbox was built from aluminium (AlSi10Mg) and took around five days of printing using our own in-house developed high-speed parameter set. It then underwent a number of post-processing operations and inspections. Thanks to our design optimisation, the final part was actually lighter and more reliable than the original casing," noted Hansen.

"Our aim with Sauber's new historic car parts business is to keep these old classics alive, on the road and being used for what they were designed for. By using today's technology we can achieve this, ensuring these important and much loved historic cars do not disappear," concluded Herzog.

www.sauber-group.com/de/engineering

Vertex Manufacturing selects Velo3D to meet demand for 'impossible' parts

Velo3D, Inc, Campbell, California, USA, has been selected by Vertex Manufacturing, a provider of CNC machining and manufacturing services, based in Cincinnati, Ohio, USA, to help meet the growing demand for 'impossible' metal additively manufactured parts.

Vertex was established by AM pioneers Greg Morris, Steve Rengers and Tim Warden, previously of Morris Technologies Inc. (MTI), and is AS9100, ISO13485 and ITAR registered and certified. At MTI, Morris, Rengers and Warden are known for their work with GE Aviation's additively manufactured LEAP Engine fuel nozzle used in commercial aviation. Where Morris Technologies primarily focused on prototyping use cases, Vertex was created with a mission to help customers who need advanced manufacturing solutions for both development and production programs. They offer a range of services including advanced multi-axis CNC machining, AM, rapid castings and final inspection of manufactured parts.

"With unique technology providing the capability to create production parts that would be impractical or impossible using other methods, our new Additive Manufacturing solution from Velo3D means customers will have even more freedom to design and engineer some of the most complex geometries imaginable," stated Greg Morris, Vertex's CEO. "This is the essence of why Steve, Tim and I started Vertex Manufacturing – to help customers leverage the most advanced manufacturing technologies and push the boundaries of what is possible."

Vertex will use its first full-stack VELO3D Sapphire® AM machine to build metal parts in Inconel 718, a nickel-base superalloy known for its superb tensile strength when subjected to extreme pressure and heat. It will be installed alongside other advanced manufacturing systems such as a Makino a61nx CNC machining center. Vertex said it plans to add additional Velo3D solutions in the future.

www.vertexmanufacturing.com
www.velo3d.com

ExOne reports increased sales of its X1 25Pro metal AM machine in Q1 2021

The ExOne Company, North Huntingdon, Pennsylvania, USA, has reported financial results for the first quarter ended March 31, 2021, with a revenue of $13 million, a decrease of 3% from a record year-ago quarter, largely due to COVID-19-related installation challenges.

The decrease was driven by a 22% decrease in revenue from Additive Manufacturing machines as a result of a decrease in volumes (fourteen units in Q1 2020 compared to seven in Q1 2021) offset by a favourable mix of metal AM machines sold, with increased sales of the X1 25Pro machine in Q1 2021. However, the decrease in AM machine revenue was offset by an increase in recurring revenue (additively manufactured and other products, materials and services) of 15% compared to the year-ago period, led by an increase in revenue from funded R&D services, largely in support of future production metal equipment sale opportunities, as well as aftermarket revenue associated with the company's global installed base of AM machines.

"The ExOne team is pleased to report record levels of both recurring revenue and machine order backlog, which shows the strength of our product offerings, adoption model, and momentum," stated John Hartner, ExOne's CEO.

He added, "While our first-quarter results reflect the difficult operating environment that continues to persist as a result of COVID-19, we are seeing signs of an economic rebound, particularly in the US market where we saw a higher concentration of sales and backlog growth during the first quarter. We look forward to entering the post-pandemic period with new tailwinds as manufacturers look to de-risk supply chains and improve the sustainability of their products with new designs that require our industrial 3D printing solutions to execute."

The company's gross margin was 15.4%, compared to 27.1% in the first quarter of 2020. The decrease was primarily due to the continued impact of operating inefficiencies and challenges driven by the COVID-19 operating environment, including unfavourable product warranty experience, as well as low contribution margin on X1 25Pro system sales following their initial introduction to the market.

Research and development expenses were $2.6 million, compared to $2.5 million in the first quarter of 2020. The increase was primarily due to additional material costs associated with systems and materials development of Binder Jetting technology. This includes the planned introduction to the market of the X1 160Pro production metal AM machine and InnoventPro advanced entry-level metal AM system in 2021, with inert atmosphere processing capabilities for the X1 160Pro for high-value reactive materials to be introduced in 2022.

Adjusted earnings before interest, taxes, depreciation and amortisation EBITDA, a non-GAAP measure, was a loss of $5.2 million, compared with a loss of $3.8 million in the first quarter of 2020. Cash, cash equivalents and restricted cash as of March 31, 2021, increased to $138.3 million, from $50.2 million on December 31, 2020. The increase was driven by cash inflows from financing activities of $95.3 million, primarily as a result of an under-written public offering of common stock completed in February 2021.

Hartner concluded, "With signs of a broader economic recovery on the horizon, a record contractual backlog and expanded product portfolio and distribution network, we see the remainder of 2021 as the beginning of our next phase of growth. While there are still some remaining execution challenges as a result of COVID-19, particularly in Europe and Asia, we feel confident that our operating plan for 2021 is well supported. In addition, our improved liquidity position gives us the ability to strategically invest in additional growth opportunities."

www.exone.com

PyroGenesis ships first commercial samples of NexGen plasma-atomised titanium AM powder

PyroGenesis Canada, Inc, Montreal, Québec, Canada, reports that since starting operation of its Additive Manufacturing NexGen™ powder production line, it has now shipped its first commercial samples of plasma-atomised titanium powder to a client serving the aerospace industry.

"These are the first samples shipped using PyroGenesis' cutting-edge Additive Manufacturing (AM) NexGen™ powder production line," stated P Peter Pascali, CEO and chair of PyroGenesis.

The company explains that the NexGen production line incorporates several revolutionary improvements, such as the highest published production rate known to management, and lower CAPEX, lower OPEX, while also providing a narrower particle size distribution. PyroGenesis is currently filling orders from several major top-tier aerospace companies and OEMs.

Massimo Dattilo, vice president of PyroGenesis Additive, commented, "This shipment represents the first of many expected shipments of PyroGenesis' titanium powder. We are now in a position to fulfil the backlog of demand for our powders and we anticipate that these shipments will lead to further qualification steps and/or commercial orders. While waiting for our cutting-edge NexGen powder production line to come on stream, we have developed solid relationships with many major players in the aerospace, biomedical, and automotive sectors. Separately, and as we have mentioned in the past, the NexGen powder production process has resonance beyond titanium alloys, and we are eager to begin addressing these markets as well."

www.pyrogenesis.com

Verder Group's Qness and ATM merge to form QATM

Hardness testing machine manufacturer Qness GmbH, headquartered in Salzburg, Austria, has merged with German materialography brand ATM to become QATM. The two companies have worked together under the umbrella of the Verder Group's Scientific Division since the group's acquisition of Qness in 2018, three years on from the inclusion of ATM.

QATM will function as a combination of the widespread knowledge, ideas and customer-oriented support of the two teams. The product portfolios of ATM and Qness will be merged, allowing customers to have one dedicated contact person for future materialography and hardness testing projects.

www.qatm.com

Optomec receives US Air Force award to repair turbine blades with AM

Optomec, Albuquerque, New Mexico, USA, has been awarded a $500,000 process development contract from the Air Force Sustainment Center at Tinker Air Force Base, Oklahoma, USA, to repair jet engine components used in the F-15 and F-16 fighters. The company will use its LENS® technology, a metal Additive Manufacturing process based on powder-fed Directed Energy Deposition (DED).

The work will focus on developing optimised process parameters and procedures in order to repair the turbine blades using AM, produced with both titanium and nickel-base superalloys. These AM 'recipes' and 'libraries' will be implemented in conjunction with the delivery of an advanced automated turbine blade repair machine. The programme has a projected ROI of 184%, with a payback period of less than two years, and could reportedly save the US Air Force millions of dollars as it maintains its fleet of more than 5,000 aircraft with an average age of twenty-eight years.

Optomec's AM repair processes are currently used in high-volume production for other turbine engine parts globally, having repaired more than 10 million components over the last twenty years. This project is expected to extend Optomec's capability with regard to high-volume titanium repair which must be conducted in oxygen-free environments to ensure proper metallurgy and mechanical performance. Titanium demand in aircraft engines is said to be increasing in both the military and commercial aviation markets.

"The turbine industry has already widely adopted Optomec's automated DED solution for high volume nickel alloy repair of aviation parts; meanwhile Optomec has worked out the process recipes for titanium repair," stated Jamie Hanson, VP of Business Development. "This solution essentially takes Optomec's titanium repair process to high volume levels where it will have a major impact on lowering maintenance costs as engine OEMs use more and more titanium."

Optomec states that it offers dozens of turn-key process recipes for a variety of common alloys and applications. These process recipes help production customers shorten the adoption time for implementing AM solutions to the plant floor, saving customers an average of six months of process development.

www.optomec.com

Optomec will repair jet engine components used in the F-15 and F-16 (seen here) fighters using Additive Manufacturing (Courtesy Lockheed Martin)

Tekna to supply Airbus with titanium powder for AM

Tekna Holding AS, Sherbrooke, Québec, Canada, reports that it has been selected by Airbus to provide titanium powder for Additive Manufacturing applications. The multi-year supply agreement positions Tekna as one of the key powder suppliers for Airbus – including its Defense and Space and Helicopters divisions – as well as its related supply chain for titanium alloys.

"The quality of our Ti64 product, and the processes we developed to ensure this consistent high quality, were contributing factors to Tekna winning the bid," stated Rémy Pontone, VP Sales & Marketing at Tekna. "We expect our titanium powder sales to ramp up over the coming years through this long-term agreement with both Airbus and its enabled suppliers."

Luc Dionne, Chief Executive Officer at Tekna Canada, added, "We are very pleased to have been selected by Airbus, knowing the high standards of quality, reliability and supply chain solidity they expect from their suppliers. We are proud to add them to our long list of major aerospace customers and we look forward to a long-lasting relationship with Airbus."

Tekna recently accepted an invitation from the National Center for Advanced Materials Performance to participate in a major aerospace qualification programme. The generated data will be posted in The Metallic Materials Properties Development and Standardization Handbook, which is an accepted source for metallic material, recognised by the US Federal Aviation Administration, the US Department of Defense and the National Aeronautics and Space Administration. Parts produced with Tekna's powder material, qualified under this programme, will automatically pass the initial design phase and analysis by those entities.

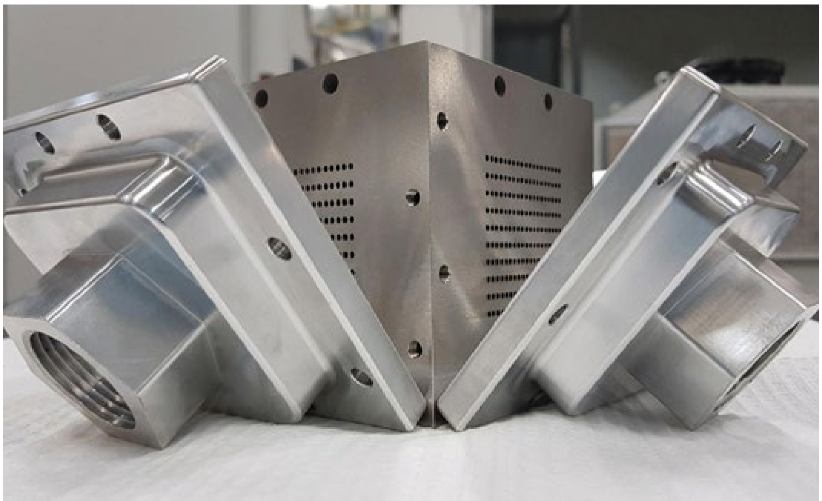
www.tekna.com
www.airbus.com

ZEISS works with Brazil-based partners to evaluate AM processes for the oil and gas industry

ZEISS Group, headquartered in Oberkochen, Germany, reports that it is collaborating with the non-profit, private research and technology organisation SENAI, based in Brazil, and with the energy company Petróleo Brasileiro S.A. (Petrobras), also based in Brazil, which specialises in oil and gas. The aim of the research alliance is to develop and validate methodologies for the manufacturing and qualification of static as well as dynamic critical components for the oil and gas industry within the next two years.

The research will focus on the evaluation of Laser Beam Powder Bed Fusion (PBF-LB) as well as Laser Beam Directed Energy Deposition (DED-LB) Additive Manufacturing processes that are already used in the production and repair of components such as valves, flanges and heat exchangers.

Of significant importance for economical production of these parts, according to Dr Edson Costa Santos, Senior Application Development Manager Additive Manufacturing Process & Control, ZEISS IQS Germany, is "a precise understanding of powder ageing and the influence of powder degradation on defects in the final parts." By using multiscale multitool computed tomography strategies, the research alliance are applying a scientific and technical approach for rapid parameter development and process stability.



A compact heat exchanger made from stainless steel AISI 316L additively manufactured in SENAI Innovation Institute for Manufacturing Systems and Laser Processing (Joinville-SC) in a project with UFSC, and Petrobras (Courtesy Petrobras/SENAI/ZEISS Group)

As part of the jointly defined roadmap, the partners are specifically collaborating on the:

- Selection of high-added value and critical components of the oil and gas industry for on- and off-shore environments
- Raw material (powder) processability, recyclability, traceability, and quality control
- Faster development and optimisation of processing parameters for laser-based AM of parts by employing a new and robust experimental method
- Application of mechanical, wear, and non-destructive tests (NDTs) on the AM parts

By 2023, the international consortium aims to achieve tangible impacts in the Brazilian AM market through intensive results and technology transfer and to positively change the supply chain of the oil and gas industry in the medium to long term. The companies explain that as the parts needed in this market are often produced locally and on demand, the companies will then also act more sustainably.

www.sc.senai.br/pt-br/institutos-senai-de-inovacao

www.zeiss.com

VBN Components receives US military order for Vibenite alloys

Wear-resistant materials from VBN Components, Uppsala, Sweden, have attracted the interest of the US Armed Forces, which has chosen to evaluate three of the company's alloys, known as Vibenite®. The alloys have been chosen for the reputed high performance and long lifetime of the resultant additively manufactured metal components.

"This order is of significant importance to us as it may lead to follow-up orders from sub-suppliers of the United States Armed Forces, but also from many other actors – for instance, in Europe," stated Johan Bäckström, CEO of VBN Components AB.

Since its establishment in 2008, VBN Components has focused on developing wear-resistant metals with better properties than those conventionally manufactured. Amongst the Vibenite materials, the company has reported 'the world's hardest steel' and 'the world's only 3D printed cemented carbide'.

www.vbncomponents.se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KBM Advanced Materials launches portal to sell powders for AM and MIM

KBM Advanced Materials, LLC, Fairfield, Ohio, USA, has formally launched operations to finance, sell and distribute metal powders to companies in the Additive Manufacturing, Metal Injection Moulding and broader advanced manufacturing markets across the USA. The company plans a rollout to the European market in Q4 of 2021 and to Asia early in 2022.

The distribution network established by KBM will allow it to become a bridge between a dispersed advanced manufacturing customer base and large metal powder producers. The business model will enable exceptionally fast quoting and shipping, with a goal of providing products to customers within days. Producers can also schedule their production equipment to larger regular blanket orders from KBM.

In addition, KBM will provide an e-commerce platform for customers that is not currently available at scale from any producer or supplier. The powder will be sold under the powder producer's brand names; the brand equity and recognition of the producers will be retained and enhanced as access to their products is increased. Currently KBM has inventory agreements with Carpenter Additive, Philadelphia, Pennsylvania, USA; Höganäs AB, Sweden; and Tekna, Sherbrooke, Québec, Canada.

"It is essential to us that we partner with companies that are established industry leaders in order for our customers to have the confidence that they are receiving the best possible product and service," stated Kevin Kemper, CEO, KBM. "Our current catalogue of powder producers are some of the most trusted in the industry."

Support for KBM includes equity investment from Koch Metallics, LLC, a subsidiary of Koch Minerals & Trading, LLC, headquartered in Wichita, Kansas, USA, and Sumitomo Corporation of Americas, New York City, is acting as a supply chain partner.

Hap Palmer, VP, Koch Metallics, commented, "Koch is excited to partner with KBM, as they look to transform the Additive Manufacturing supply chain. The team at KBM Advanced Materials thoroughly researched the market and provided a business plan that left no doubt as to their ability to revolutionise the Additive Manufacturing and MIM metal powder marketplace. This investment opportunity supports Koch's mission to create a mutually beneficial partnership that will build more efficient supply chains in exciting and growing industries."

www.kbmadvanced.com

Impact Innovations launches new cold spray system

Impact Innovations, Rattenkirchen, Germany, has released its latest cold spray system: Impact EvoCSII. The basis of the system's 'plug and play' design was drawn from the experiences of the last decade. The company states that it is now able to offer its customers consistently high quality for single part and series production, based on a durable, maintenance-friendly system architecture through intelligent process control.

The Impact EvoCSII's increased sensors allow for greater in-situ monitoring (Courtesy Impact Innovations)

Due to the parallel operation of up to four Impact Powder Feeders, the new Impact EvoCSII is well suited for serial production. It is also possible to operate two Impact Spray Guns in parallel, for double-sided coating or simply higher capacity. Due to a higher number of sensors, data recording and an integration in higher-level control, the process reliability has increased significantly from previous iterations.

The EvoCSII system has a modular system structure, which can also be expanded as required at a later point in time, while offering compatibility for all existing additional components. Furthermore, the necessary interfaces for future developments have already been integrated into the open interface system, which hosts new software architecture with a simplified operating concept.

www.impact-innovations.com

Wayland Additive sells its first Calibur3 machine to Exergy Solutions

Wayland Additive, Huddersfield, UK, has announced the first sale of its Calibur3 metal AM machine to Exergy Solutions Inc, Calgary, Canada. Exergy is an engineering consultancy offering end-to-end, lab and pilot-scale equipment, with clients in a variety of sectors including oil & gas, mining, manufacturing and R&D. The company opened its X-Lab in 2019, offering industrial AM and post-processing solutions, as well as a wireless augmented and virtual reality studio.

"We are extremely pleased with the response to the launch of our Calibur3 machine, and to be able to announce our first sale to Exergy is very exciting," stated Peter Hansford, Director of Business Development at Wayland Additive. "We are in advanced discussions with a number of companies interested in our ground-breaking metal AM process, all of which recognise that NeuBeam™ affords them access to numerous production alternatives."

Hansford continued, "Most importantly, the charging issues that make electron beam (EBM) processes so unstable have been fully neutralised with NeuBeam™. Moreover, NeuBeam is a hot 'part' process rather than a hot 'bed' process, like traditional eBeam processes. This efficiently creates parts that are free of residual stresses because the high temperatures are only applied to the part and not the bed, ensuring free-flowing powder post-build (no sinter cake) and stress-free parts with reduced energy consumption."

Dr Dave Waldbillig, Director of Advanced Manufacturing, Exergy, added, "The investment in Wayland's technology means that we can present a compelling solution to our customers' wear challenges. The partnership combines the high wear resistance and toughness of the Vibenite® series of materials from VBN Components, with the larger build volume and speed of the NeuBeam process, and Exergy Solution's application engineering support."

www.waylandadditive.com
www.exergysolutions.com

Exergy Solutions has purchased the first Calibur3 metal AM machine from Wayland Additive (Courtesy Wayland Additive)

Alphacam signs exclusive distribution agreement with Tritone

Additive Manufacturing services provider Alphacam GmbH, Schorndorf, Germany, has signed an exclusive distribution agreement with Tritone Technologies, Petach-Tikva, Israel, to offer its Tritone Dominant AM machine in Germany, Austria, Switzerland and Lichtenstein.

The Tritone Dominant uses a sinter-based AM process that enables industrial production of high-quality metal parts. The system is based on Tritone's patented MoldJet® technology, where a mould is produced as a negative of the component geometry from a wax-like polymer with inkjet-like print heads. This printed 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. Each additively manufactured layer is checked by an inspection unit, where defects can be detected instantly, mechanically removed and the layer remanufactured, if necessary. Data on the manufacture can be collected for continuous development of the technology.

"We were fascinated by the idea Tritone innovated by using the well-known MIM powders in an industrial 'powder-free' AM process. For our customers it will be a big advantage handling only a clean and safe metal paste to receive strong dense green parts," stated Michael Junghanss, Managing Partner at Alphacam.

The Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Dresden was the first European user of this system, installed at ICAM®, the Innovation Center Additive Manufacturing.

www.alphacam.de
www.tritoneam.com

Index acquires majority interest in One Click Metal

The Boldseries metal AM solution consists of the MPRINT+ machine, the MPURE unpacking station, which includes a sieving unit, and the MPREP data preparation software (Courtesy One Click Metal GmbH)

The Index Group, Esslingen, Germany, has acquired a majority interest in Trumpf's One Click Metal GmbH, based in Tamm, Germany. The deal will provide One Click Metal with additional knowledge and capital to continue its growth trajectory in the market of entry-level Additive Manufacturing machines. Trumpf will remain involved as an active and strategic partner, supporting the company's future development in collaboration with Index.

Trumpf founded One Click Metal in April 2019 within the scope of the 'Trumpf Internehmertum' (or, Trumpf Internship) initiative. Today, with a workforce of about twenty employees, One Click Metal develops comprehensive solutions in the field of metal AM for small and medium-sized components. From programming to manufacturing, to unpacking and the powder cycle, all process steps are said to be geared towards the simplest, most convenient use.

One Click Metal's customers include businesses from the mechanical engineering, tool manufacturing and automotive industries, as well as training centres. The systems are used not only for product development and prototyping, but also for the production of individual parts and small production runs.

www.trumpf.com
www.oneclickmetal.com
www.index-werke.de

FIT AG and pro-beam Group cooperate for electron beam AM process development

The pro-beam Group, a provider of electron beam and laser technology, headquartered in Gilching, Germany, and Additive Manufacturing specialist FIT AG, Lupburg, Germany, have announced they will collaborate to develop Additive Manufacturing processes using electron beam technology.

Under a framework agreement, the two companies have expressed their intention to combine their knowledge and create new technological opportunities through the resulting synergies. The cooperation will cover the areas of process development, material development, and equipment development for electron beam AM.

FIT AG has over twenty-five years of experience in AM, especially in data preparation and process technology. pro-beam has more than four decades of expertise in electron beam technology, making the company particularly suitable for the development of further electron beam uses within AM.

"The respective expertise of the two companies FIT and pro-beam holds enormous potential to achieve a significant expansion of Additive Manufacturing applications using the electron beam," stated Dr Thorsten Löwer, CTO at pro-beam.

Carl Fruth, founder and CEO of FIT AG, commented, "I am convinced that this technology cooperation will produce important results. We have some very specific ideas in mind that we can now tackle with pro-beam to achieve a market-ready technology solution."

www.fit.technology
www.pro-beam.com

Online manufacturing platform 3D Hubs changes name to Hubs

3D Hubs, Amsterdam, the Netherlands, has changed its name to Hubs, in order to reposition the company as one offering a wide range of manufacturing services. The rebrand, which follows the company's acquisition by Protolabs in January, also aims to strengthen its position as a leader in global outsourcing for custom part manufacturing.

Founded in 2013, the company originally established itself by connecting the world's largest network of Additive Manufacturing services. Starting in 2018, at the request of its customers, the company expanded its manufacturing services to include CNC machining, sheet metal fabrication and injection moulding.

Existing users will not be affected by the rebranding. In the future, Hubs aims to expand its global network of manufacturing partners, complementing its service offering to that of Protolabs' in-house facilities.

"COVID-19 and the resulting supply chain disruptions have accelerated the manufacturing market's need to embrace supply chain resilience and efficiency," stated Bram de Zwart, CEO and co-founder at Hubs. "Hubs has been at the forefront of this movement from the beginning, by creating pricing transparency, a globally distributed manufacturing partner network and smart routing of customer orders within this network. Together with Protolabs, we are now more ready than ever to drive the industry forward and make custom part manufacturing accessible to engineers worldwide."

www.hubs.com
www.protolabs.com

Launcher acquires AMCM's M 4K machine for rocket production

Launcher, a space technology company headquartered in Hawthorne, California, USA, has acquired the M 4K Additive Manufacturing machine from AMCM GmbH, an EOS Group company, based in Starnberg, Germany, to advance its high-performance orbital launch vehicle strategy. The M 4K will reportedly enable Launcher to produce the world's largest single-part additively manufactured copper alloy combustor, used in the E-2 rocket engine to deliver small satellites to low Earth orbit.

Since 2017, Launcher has been an AMCM partner and the collaboration has resulted in the development of the M 4K, which has a part construction volume of 450 x 450 x 1000 mm and supports copper alloy, ideal for liquid rocket engine combustion chamber production.

Often, companies building AM liquid rocket engines have been forced to design smaller engines or produce multi-part combustion chambers to fit within the limited construction volume constraints of commercial AM machines. With Launcher's commitment to the industry's highest propulsion performance benchmarks, it needed to additively manufacture its E-2 engine combustion chamber as a single part, enabling optimal cooling channel design, fewer parts, simpler processes, and lower overall production costs.

In addition, while most companies developing an additively manufactured liquid rocket engine rely on Inconel alloy as their combustion chamber material, copper alloy is said to be the best material for liquid rocket engine combustion chambers due to its optimal thermal conductivity properties, which enable more effective regenerative cooling. Informed by NASA research on additively manufactured copper, Launcher requested copper alloy support in 2017 for the M 4K machine from AMCM and EOS.

Max Haot, founder and CEO of Launcher, commented, "AMCM's flexibility and openness to customer requirements, both in machine building and process implementation, is remarkable. We look forward to continuing our partnership with AMCM as Launcher advances its mission to build and operate the market's most efficient rockets delivering satellites to orbit."

As part of the collaboration between the companies, Launcher's first rocket engines were built on-site at AMCM in Starnberg, Germany, in October 2019. Following Launcher's test-fire in October 2020 at NASA's Stennis Space Center, Launcher purchased an AMCM M 4K as part of the company's expansion in Hawthorne.

www.launcherspace.com
www.amcm.com

Launcher has acquired the M 4K Additive Manufacturing machine from AMCM as part of the companies ongoing partnership (Courtesy AMCM GmbH)

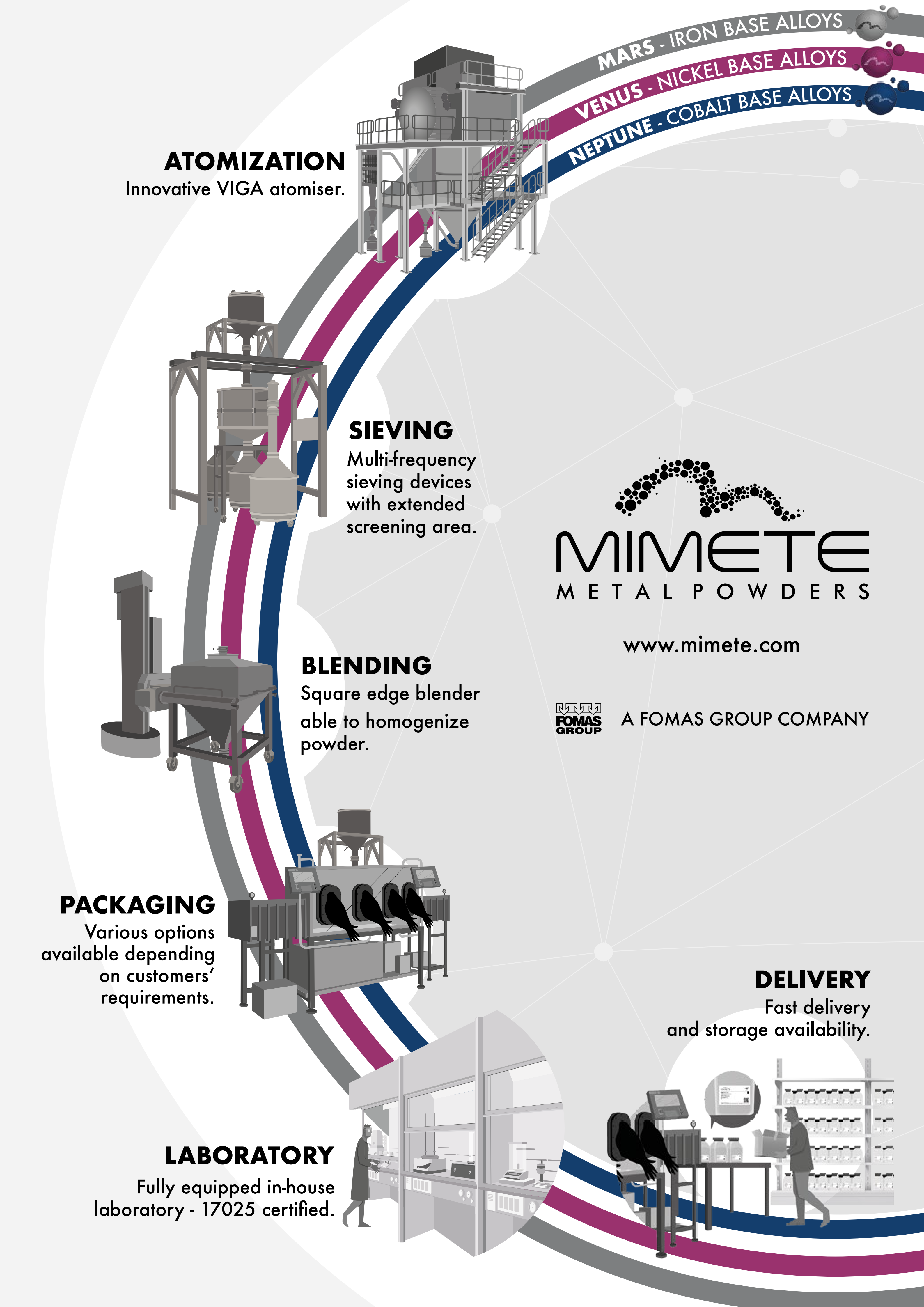
Fraunhofer IFAM to host second sinter-based AM workshop in September

The Fraunhofer Institute for Manufacturing Technologies and Advanced Manufacturing (IFAM), Bremen, Germany, is hosting a second workshop on sinter-based Additive Manufacturing, September 15–16, 2021.

The workshop will provide insights into Binder Jetting and other sinter-based technologies from the user's point of view. Participants can choose to attend the event either live or virtually. Prior to the workshop, an additional tutorial (live attendance only) is available for interested participants, in which the fundamentals of sinter-based AM technologies will be explained in-depth. The presenters will discuss experiences and applications for metal Binder Jetting, introduce new sinter-based technologies and include a session on enabling technologies such as depowdering and simulation, as well as an expert panel discussion on the challenges and future perspectives of sinter-based Additive Manufacturing.

Further information on the workshop and registration details are available via Fraunhofer IFAM.

www.ifam.fraunhofer.de



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Rodin Cars and 3D Systems produce titanium AM gearbox for the new Rodin FZero hypercar

3D Systems, Rock Hill, South Carolina, USA, has collaborated with Rodin Cars, a manufacturer of track cars headquartered in New Zealand, to produce metal additively manufactured parts for its soon-to-be-released hypercar, the Rodin FZero.

Rodin Cars designs and builds bespoke single-seat, open-wheel high-performance vehicles that are designed to be faster than contemporary Formula 1 cars. Among the hundreds of metal AM parts Rodin Cars is producing for the Rodin FZero, there is a first-of-its-kind 8-speed sequential gearbox with a hydraulically controlled differential. This completely custom component can only be produced using Additive Manufacturing and was made possible through the collaboration of the two companies.

A gearbox created using traditional manufacturing methods would be cast out of magnesium or machined from billet material. The resulting component would not only be slow to produce, but heavier, and would not withstand the rigours presented by the track. Rodin Cars explains that it wanted to flip this design into a true innovation – the ultimate component produced from additively manufactured titanium that would be compact, light, strong, and durable.

Rodin Cars released its first high-performance track car – the Rodin FZed – in 2019 with a gearbox designed by Ricardo, a UK-based engineering firm. For the new Rodin FZero, the company envisioned a brand new gearbox with specific gear ratios and differential produced from titanium to enhance the reputation of this new high-performance vehicle.

The eighteen-month design process – a collaboration between Rodin Cars for the casings and Ricardo for the internals – resulted in a gearbox with a hydraulically controlled differential that can only be produced using AM due to its ability to directly additively manufacture the necessary internal galleries and thin-wall bearing and mount structures. Rodin Cars' engineers worked alongside members of 3D Systems' Application Innovation Group (AIG) in Littleton, Colorado, and Leuven, Belgium to bring this unique design to life.

The 8 speed sequential gearbox weighs 68 kg and is additively manufactured from grade 23 titanium (Courtesy Rodin Cars)

The application engineers' knowledge combined with 3D Systems' Laser Beam Powder Bed Fusion (PBF-LB) solution, which the company refers to as direct metal printing (DMP) technology, helped facilitate the production of the new gearbox that includes 2 mm thick walls and a total weight of 68 kg. The application engineers in Littleton optimised the gearbox design details for AM at the large scale achievable on the DMP Factory 500 machine and produced the first part in Leuven.

The AM machine, which features a vacuum chamber to ensure the lowest O_2 content, enables the production of large parts as big as 500 x 500 x 500 mm. This results in high-surface quality for metal AM parts with excellent material properties. 3D Systems' AIG has successfully completed the technology transfer to Rodin Cars for full production with the company recently installing a DMP Factory 500 on-site at its newly expanded facility. Rodin Cars will produce the gearbox, as well as hundreds of other bespoke parts, for the Rodin FZero.

"Additive Manufacturing is enabling industry leaders to defy limitations and stand apart," stated Kevin Baughey, segment leader, transportation & motorsports, 3D Systems. "As a high-technology, high-performance car constructor, Rodin Cars delivers unparalleled vehicles to their customers. This is a shining example of how Additive Manufacturing not only enables parts to be produced that couldn't be created through conventional methods, it is also delivering a lighter, more durable, beautiful vehicle. It's the blending of the art of design with the science of hyper-performance cars and motorsports."

www.3dsystems.com

www.rodin-cars.com

Marotta Controls brings AM to high-performance manifold valves

Marotta Controls, a rapidly growing aerospace and defence supplier based in New Jersey, USA, has announced the successful integration of Additive Manufacturing into its portfolio of services. The company has used a novel Laser Beam Powder Bed Fusion (PBF-LB) process to create internal features of an advanced manifold valve. The now-patented process was used to generate radial passages in various geometries which were impossible to achieve via traditional machine boring methods. With these new geometries, the manifold valve delivered increased velocity pressure control.

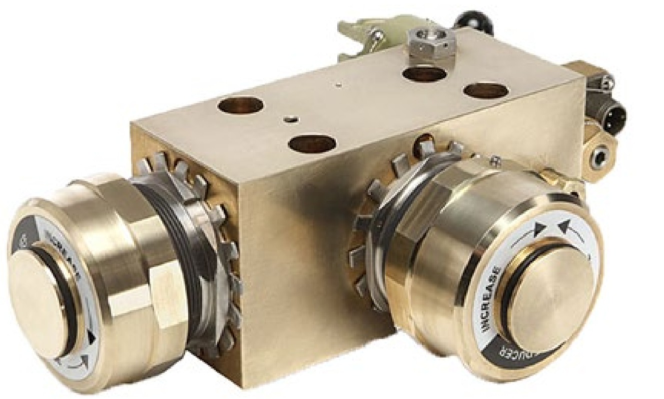
"We have a near eighty-year culture of creative thinking, of challenging the status quo," stated Brian Fly, vice president Marine Systems, Marotta Controls. "And we're proud to confirm that that mindset resulted in a remarkable evolution to a tried and true part used for generations. Additive Manufacturing offers some very interesting opportunities that we've inherently designed to embrace on behalf of our customers. We anticipate more unique, disruptive innovations to come out of this capability as we continue to apply it."

Marotta Controls was established through its work troubleshooting valve designs that, despite being accepted as proven parts, continued to leak in end applications. The company fixed this issue and others, becoming a go-to engineering shop capable of solving difficult problems. This, the company stated, is why it took on the challenge of improving the manifold's performance in high-pressure applications – a problem that required re-evaluating how and where best to apply Bernoulli's equation within the system's design.

Valves and manifolds are historically produced via subtractive machining, with boring tools removing unwanted material to construct their radial passages within a single metal block. The radial passages are typically cylindrical or slightly frustoconical in nature. This design approach allows for passages that expand in two dimensions. By introducing a third dimension through AM, however, Marotta has improved those passage features to achieve desired performance.

Marotta has evaluated its AM valve concept in more than a dozen design configurations, with the passage structures varying. Velocity improvements are said to be notable, as is the part's impact on the overall manifold's production and performance.

www.marotta.com



Marotta is using a patented AM method to produce manifold valves (Courtesy Marotta Controls)

Tekna titanium powder to be qualified for aerospace material standards

Tekna Holding AS, Sherbrooke, Québec, Canada, has accepted an invitation from the National Center for Advanced Materials Performance (NCAMP) to participate in a major aerospace qualification programme. Parts produced with Tekna's powder material, qualified under the programme, will automatically pass the initial design phase and analysis by the FAA, US Department of Defense (DoD), and NASA.

The qualification data generated will be posted in The Metallic Materials Properties Development and Standardization (MMPDS) Handbook, an accepted source for metallic material, recognised by the aforementioned entities. Tekna titanium (Ti64) powder will be included in reports hosted by the NCAMP and America Makes.

Jerome Pollak, Sales and Business Development Director for Americas, has also illustrated a benefit for the company's customers: "Let's say that a company wants to use Tekna material for building an aircraft part and they approach the FAA. As part of their plan, they will have to tell the FAA what material and process they intend to use and what material database they are using. If they can tell the FAA that they are using a database hosted by NCAMP or MMPDS and that the data was certified through those approved processes, then they get to move on to the next phase of the programme. If they can't say that, then the FAA will require them to go through a costly, time-consuming qualification process of at least one year. By qualifying Tekna powder upfront, we give our customers a significant head start."

www.tekna.com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Penn State University research lab acquires SPEE3D metal AM machine

The Applied Research Laboratory of Penn State University, Pennsylvania, USA, a US Department of Defense-designated University Research Centre, has acquired a LightSPEE3D Cold Spray metal Additive Manufacturing machine from SPEE3D, Melbourne, Australia, which will allow the institution to advance its AM capability.

SPEE3D machines use Cold Spray Additive Manufacturing, working on a cold fusion principle where compressed air is used to fuse powders, meaning no volatile gases or heat sources are required to bond layers together. In recent Australian Army field trials, the company's LightSPEE3D and WarpSPEE3D machines have proven robust enough for harsh environments such as the field of combat, making them an ideal expeditionary solution for building components on demand at the point of need.

"Our collaboration with SPEE3D is an excellent addition to our current capabilities in Metal Additive Manufacturing and Cold Spray," stated Tim Eden, PhD, Head of the Material Science Division at The Applied Research Laboratory at Penn State University and Professor of Engineering Science and Mechanics. "We are looking forward to developing and applying SPEE3D technology to meet the materials and manufacturing challenges of the US Navy, DoD and the industrial base."

Eden, alongside Janice Bryant, Expeditionary and Sustainment Technology Manager of the Naval Sea Systems Command (NAVSEA) Technology Office, will use the metal Additive Manufacturing technology to conduct research into the advancement and development of AM equipment within the US.

Bryant commented, "NAVSEA is excited about the potential of SPEE3D technology to bridge the gap between Cold Spray and metal Additive Manufacturing."

Byron Kennedy, CEO of SPEE3D, added, "Having our LightSPEE3D metal 3D printer at Penn State University's Applied Research Laboratory is quite exciting for SPEE3D. This partnership will no doubt allow the institution to develop leading research within the field, enabling them to work at the forefront of the industry."

www.spee3d.com

Seurat Technologies raises $41M in funding round to advance its novel metal AM technology

Additive Manufacturing systems developer Seurat Technologies, Wilmington, Massachusetts, USA, has closed a $41 million Series B funding round led by Capricorn's Technology Impact Fund. The company will use the funds to accelerate the development and commercialisation of its metal AM technology, Area Printing™.

Seurat's Area Printing technology is a metal powder-based AM process that is differentiated from existing technology in that it focuses over two million points of laser light on a bed of metal powder – each point fully controllable in power and duration – to create production-grade, fully functional components. Area Printing is said to be capable of delivering resolution and quality at the scale needed for mass production of metal components across all industries.

"Seurat is bringing to market a completely revolutionary technology," stated James DeMuth, CEO and co-founder of Seurat Technologies. "Think evolving from writing a letter to the advent of the printing press, but with lasers printing metal parts. Bringing on new financial and strategic investors at the calibre of Capricorn will greatly aid Seurat in taking the big next step forward towards commercialisation."

According to Seurat, its Area Printing technology shatters the existing barrier of cost per part. The first system generation will, the company claims, offer a cost reduction of 50% compared to today's Additive Manufacturing technologies. The unique process, however, reportedly has the potential to decrease cost much further, and future Seurat AM Area Printers will target manufacturing costs below conventional die casting processes by the year 2030.

Ion Yadigaroglu, Partner of the Technology Impact Fund and Capricorn Investment Group, commented, "Capricorn invests in fast-growing companies with superior management teams that are fundamentally transforming industries. Seurat is clearly a disruptor in the Additive Manufacturing space, offering a powerful Area Printing technology platform that creates significant value to the entire Manufacturing Sector."

In addition to Capricorn's investment, Seurat's Series B round is also supported by a new investment from leading mobility supplier DENSO, as well as continued support from True Ventures, GM Ventures, Porsche Automobil Holding SE, Siemens Energy, and Maniv Mobility.

www.seuratech.com

Cummins finalises first metal AM production part using Binder Jetting

Cummins Inc., Columbus, Indiana, USA, reports it is finalising its first production part made using metal Binder Jetting Additive Manufacturing (BJT) technology, marking a significant milestone in the company's AM and Industry 4.0 journey.

The component, a Cummins Emission Solutions (CES) lance tip adapter used in high horsepower engines, is now moving through Cummins' production part approval process (PPAP) for formal approval. The lance tip adapter, a critical emissions component in Cummins engines, atomises and injects diesel exhaust fluid into the engine exhaust stream to reduce the amount of nitrogen oxides (NOx) emitted from Cummins' engine systems.

"This is incredibly exciting, as it signifies yet another significant milestone in our 3D and Additive Manufacturing roadmap," stated Tim Millwood, vice president of Global Manufacturing. "We're on the cusp of being able to leverage a broad range of additive technologies to print the parts we need, using the right technology and at lower costs and increased speeds."

The company explains that producing this part through AM provides several additional benefits, including a lighter-weight design, improved geometry for fluid and air flow, and the elimination of the added complexity of cross-drillings. It hopes to have final approval of the part and to start official production later this year.

Cummins announced its investment in Binder Jetting in April 2019 when the company implemented GE Additive's high-precision binder jet technology. Cummins and GE Additive are actively partnering to develop third-generation binder jet technology, which will support an industrialised solution with even higher throughput, improved quality and lower cost.

In 2020, Cummins established an Additive Manufacturing Lab within the company's Manufacturing Engineering Development Center (MEDC) in Columbus. The purpose of the lab is to develop and validate the industrialised BJT AM process. Cummins' Engineering teams are taking this opportunity to gain experience and skillset in designing for Additive Manufacturing as the technology advances.

Currently, the Cummins Additive Manufacturing and Engineering teams are working on designing and manufacturing several additional concept parts, with the aim of finalising more parts yet this year. Cummins currently has two second-generation binder jet machines, one at its Additive Manufacturing Lab in Columbus and one at GE Additive's Disruptive Innovation Lab near Cincinnati, Ohio.

"This is the first of many milestones. The focus of our partnership is to productionise applications at cost, quality and needed scale. We are proud to work with Cummins to develop additive technology and provide meaningful return on investment throughout its supply chains," commented Jacob Brunsberg, Binder Jet product line leader, GE Additive.

Cummins Engineering and Manufacturing teams have additively manufactured using polymer for years and are continuing to make progress in low-volume metal Additive Manufacturing. These technologies include three GE Additive Concept Laser M2 DMLM machines – one is installed at the Cummins Technical Center in Columbus, and the other two are installed at the large Cummins Research and Development Center in San Luis Potosi (SLP), Mexico. Cummins also leverages sand AM technologies at its centre in SLP to make moulds for components.

The cost and cycle times of these machines make them well-suited for producing parts for Cummins' aftermarket customers and those needed in low volumes. Since selling the first metal additively manufactured part in 2019, Cummins has approved twenty part numbers and shipped nearly 350 parts using its suite of AM technologies.

Over the next several years, Cummins stated that, alongside GE Additive as its strategic partner, it will continue to improve its capabilities, speed-to-market and productivity of its AM processes.

www.cummins.com
www.ge.com/additive

The Cummins Emission Solutions (CES) lance tip adapter is moving through the company's production part approval process (PPAP) for formal approval (Courtesy Cummins Inc)

Innovation by Matsuura

Hybrid Additive Manufacturing

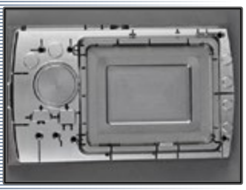
Seamless Metal Laser Sintering & Milling Process

LUMEX Avance-25

Build Volume:

(D)250mm x (W)250mm x (H)185m
(D)250mm x (W)250mm x (H)300m *

(* Option)



HOLLOW — **COMPLEX GEOMETRY**
3D Cooling Channels
Internal Features

POROUS — **VARIABLE DENSITY**
Gas Venting
Gas Assist

NO EDM — **LAYER MACHINING**
High Aspect Features
Reduced EDM Processing

MILLING — **PROFILE MACHINING**
High Accuracy
Precision Finished Parts

TIME — **TIME SAVING**
One Process Manufacture
Reduced Lead Times

The ***Matsuura LUMEX Avance-25*** is the world's first hybrid powder bed fusion machine. The combination of additive technology and ***Matsuura's*** 80 years of subtractive high speed milling technology into one seamless process, enables the production of complex, high accuracy molds and parts in a method that has never been possible, nor imagined. Further adding to ***Matsuura's*** expertise in the Hybrid metal AM field, this technology is now available on the new ***Matsuura LUMEX Avance-60*** possessing the largest powder bed platform available on the market.

LUMEX Avance-60

Build Volume:

(D)600mm x (W)600mm x (H)500m

The Matsuura Avance-60 the largest hybrid powder bed platform on the market.

More information at www.lumex-matsuura.com

Matsuura

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Liberty Powder Metals gains key quality certifications

Liberty Powder Metals' Technical Manager James Ashby at the company's laboratory (Courtesy Liberty Powder Metals)

Liberty Powder Metals, part of GFG Alliance's Liberty Steel Group, has been awarded EN 9100 and ISO 9001 quality certifications. EN 9100 is an internationally-recognised Quality Management System for the aerospace industry, with ISO 9001 being the equivalent system for general industry.

The certifications, which were awarded after extensive and rigorous audits of Liberty Powder Metals' quality management system and internal operations, covers the manufacture, processing and testing of metallic alloy powders for near-net shape Powder Metallurgy and Additive Manufacturing applications.

"Achieving these certifications for our Quality Management System highlights Liberty Powder Metals' commitment, dedication and systematic approach to delivering best-in-class metal powders to support our advanced manufacturing customers," stated Dr Simon Pike, General Manager.

The quality certifications will enable the business to expand its reach in AM, allowing it to sell to customers across the aerospace, automotive, industrial and engineering sectors.

The company's vacuum induction argon gas atomiser, which opened last December at the Materials Processing Institute on Teesside, North Yorkshire, UK, produces a range of stainless steel and nickel superalloy powders. To increase productivity, the atomiser possesses a unique anti-satellite facility.

Dermot Desmond, Commercial and Business Development Manager, added, "These certifications confirm the quality of our world-class manufacturing processes and demonstrate our commitment to high-quality working practices. Achieving this against the backdrop of the COVID-19 pandemic is testament to the dedication of all our staff and partners, enabling the business to push forward and start operating at full capacity."

In addition to producing steel and nickel superalloys, Liberty Powder Metals is now using its sieving, blending and optimisation facilities to process and supply aluminium and titanium powders.

www.libertysteelgroup.com

Alfa Romeo Racing Orlen adds three depowdering systems from AM Solutions

Alfa Romeo Racing Orlen has announced a partnership with AM Solutions, a German brand of the Rösler Group. As part of the agreement to bolster the team's post-processing of additively manufactured parts, Alfa Romeo Racing Orlen will acquire three of the company's S1 machines.

With AM having an increasingly profound effect on every aspect of industrial manufacturing, including that of a Formula 1 team, AM Solutions provides access to industrial solutions for partially- to fully-automated post-processing of polymer and metal parts for all AM technologies.

Over 300 AM parts feature on the Alfa Romeo Racing Orlen C41 race car, competing in the 2021 Formula 1 world championship, and the ability to have more precisely made items created in an efficient and cost-effective way will provide benefits to the team. The team's S1 system will be used for the automatic depowdering and cleaning of small to midsize volumes of AM parts and offers the team new technical features – such as a basket design for optimal distribution and circulation of the parts, a specially-developed wear protection lining made of non-staining anti-static polyurethane, ATEX conformity, and safe & ergonomic machine handling.

"We are delighted to partner with Alfa Romeo Racing ORLEN in the field of post-processing of additive manufactured parts. As an early adopter of 3D printing, Sauber has recognised the importance of post-processing in terms of automation, cost effectiveness and repeatability in the AM production chain," stated Stephan Rösler, president & CEO of the Rösler Group.

"Their deep knowledge and experience will help us to further improve our solutions and to increase the awareness of our still-young AM Solutions brand. We will bring our decades of know-how in surface finishing combined with our tailor made solutions for the needs and challenges of AM to the track. By this partnership, we create a perfect win-win situation for two highly innovative companies, that always strive for the max," continued Rösler.

Frédéric Vasseur, Team Principal, Alfa Romeo Racing Orlen and CEO of Sauber Motorsport AG, added, "Additive Manufacturing is playing an ever-increasing role in Formula 1 and every new iteration of our race cars feature more 3D printed parts – in addition to those used in other operations of the company, from the wind tunnel models to experimental parts. The innovations brought by AM Solutions help us create parts quickly, more efficiently and with less waste, meaning we gain on time and money, two resources available in very finite amounts in our sport, while, at the same time, improving the sustainability of our operations. It's all part of the marginal gains we make across every aspect of our operations as we move towards the front of the grid."

Christoph Hansen, Director of Technology & Innovation of Sauber Engineering, with Stephan Rösler, president & CEO of Rösler Oberflächentechnik GmbH (Courtesy AM Solutions)

www.solutions-for-am.com
www.sauber-group.com/motorsport/formula-1

Hyde Aero Products expands into metal Additive Manufacturing

Hyde Aero Products (HAP), Dukinfield, UK, part of the Hyde Group of companies, has established a new Additive Manufacturing subsidiary, Hyde Additive Technologies. Recognising that AM will play an increasingly important role in future aerospace components, the company has begun investing in the technology to promote cost-saving solutions.

Components developed so far include checking fixtures for small detailed parts and masking aids for HAP's treatment facility. The company has also used this rapid prototyping technology to produce, to scale, complex parts at RFQ stage, thus gaining a better understanding of machining strategies. While to date this work has been with polymers, HAP now wishes to move into metal AM.

Supported by customer Leonardo Helicopters, two Class III helicopter parts were identified as test cases for metal AM as part of a weight-reduction initiative: forward and aft service handles. HAP hoped to answer whether metal AM presents a viable, cost-effective solution and, if so, how does the company develop a business case for the adoption of metal AM in the future?

Following a meeting with the company, a process development support package was agreed to be delivered jointly by the National Centre for Additive Manufacturing (NCAM) and Renishaw engineers. A process design and topology optimisation study was first undertaken, beginning with a baseline stress analysis for a current machined-from-solid AlSi10Mg aluminium alloy handle. This was used to evaluate different AM handle designs featuring a variety of internal lattice structures, as well as a hollow handle, indicating weight savings between 20% and 45% were possible.

The first build of test cases for HAP, showing forward and aft service handles (Courtesy HAP)

Renishaw conducted a first build on a Laser Beam Powder Bed Fusion (PBF-LB) AM 500Q machine comprising a selection of vertically manufactured forward and aft service handles with the aforementioned hollow and latticed internal stuctures. In order to obtain an indication of the likely manufacturing cost, this was followed by a second build containing sixteen forward service handles with hollow internals.

NCAM engineers worked with HAP to develop a business case model for these handles, which could also be used for other metal AM parts in support of the company's planned expansion.

Paul Mellor, Technical Director, stated, "The work on the helicopter door handles gave us a great insight into the AM design for manufacture process, and will inform our future discussions with Leonardo."

www.hydegroup.com

Höganäs announces Magnus Hall as chairman as it appoints new board members

Sweden's Höganäs AB has announced the appointment of Magnus Hall as its new chairman, along with new board members Charlotte Strömberg and Anna Månsson. Hall, previously CEO of Vattenfall and Holmen, replaces Kurt Jofs, who served eight years on the board, the final two of which were as chairman.

The changes are seen as a natural part of the rotation that takes place on all boards, with the timing being ideal as Höganäs embarks on a journey to further reduce its climate footprint.

Charlotte Strömberg, previously Head of Investment Banking at Carnegie and CEO Nordics for the real estate advisory firm JLL, will replace Kerstin Konradsson. Anna Månsson will assume the position previously held by Joanna Rosén. Månsson has extensive automotive industry experience and currently works as a management consultant and partner with Bain & Co.

"I want to welcome Magnus as the new chairman of the board and I think he will add new perspectives on both the change journey the company is in, as well as our transition to a climate-neutral company," commented Fredrik Emilson, CEO. "I also would like to welcome Lotta [Strömberg] and Anna, and I think their experience of both change management and the car industry will benefit the company's further journey."

www.hoganas.com

Zenith Tecnica celebrates fifth year supplying titanium AM parts to leading satellite manufacturer

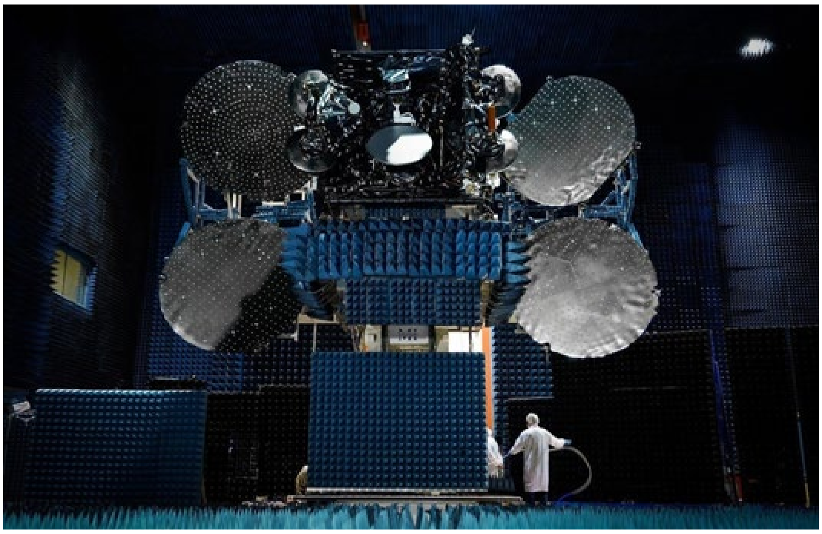
Zenith Tecnica, a contract manufacturer specialising in titanium Additive Manufacturing, headquartered in Auckland, New Zealand, recently celebrated its fifth year of partnering with leading satellite manufacturer Maxar Technologies, Westminster, Colorado, USA, to supply structural spacecraft flight hardware.

Since 2016, Maxar has built and launched five spacecraft with 260 titanium components produced by Zenith Tecnica using AM processes. More than 270 additional parts are reported to be currently in production and assembly on a further eight satellites.

"Maxar is committed to Additive Manufacturing and is a fantastic customer," stated Peter Sefont, Technical Director, Zenith Tecnica. "Its team is pragmatic and collaborates with suppliers to successfully leverage all the benefits that Additive Manufacturing has to offer. We are incredibly proud to be playing a part in the manufacturing of their spacecraft."

Zenith Tecnica manufactures titanium hardware for spacecraft structures. The company is able to optimise hardware geometry and thermal characteristics for specific satellite features and payloads by leveraging AM to best suit the needs of its customers. The result of this optimisation is reduced mass, fewer pieces of hardware and improved life on-orbit.

Since the introduction of AM into the production of spacecraft components, Maxar has achieved many reported benefits, including improved schedule agility, reduced manufacturing costs and increased performance of its satellites.



The Maxar-built, all-electric EUTELSAT 7C satellite uses nearly 1000 additively manufactured components (Courtesy Zenith Tecnica)

"The team at Zenith Tecnica operates as an extension of Maxar's team, and they always go the extra mile to ensure parts are delivered to a high standard of quality," added Gina Ghiglieri, Additive Manufacturing Technology Manager, Maxar. "Zenith Tecnica has been with us since the first metal Additive Manufacturing programmes at Maxar and has performed a critical role in helping define and qualify these production processes."

Maxar was a relatively early adopter of AM technologies, establishing its Additive Center of Excellence in 2012. As a result, Electron Beam Powder Bed Fusion (PBF-EB) titanium was qualified for flight, and, by 2016, the first components were on-orbit.

Zenith Tecnica undertook a validation and qualification process in order to gain confidence in the Additive Manufacturing processes and material. The AM titanium parts are built using GE Additive Arcam EBM machines. The parts are then heat treated before critical assembly features are machined. Zenith Tecnica performs 3D scanning inspections to ensure all parts conform to specifications.

In addition, Zenith Tecnica has a rigorous training system for all team members. The company's senior engineers and technicians have some of the highest levels of OEM training in PBF-EB provided by GE Additive. They are also required to have first-hand experience with every process in their facility to provide well-rounded expertise to customers. Guided by an AS9100 quality management system, Zenith Tecnica is able to offer agile manufacturing with accuracy and reliability.

www.maxar.com
www.zenithtecnica.com

GE successfully tests AM heat exchanger at temps 200°C higher than standard

GE Research's interdisciplinary team, led by Lana Osusky, working with top experts from the University of Maryland and Oak Ridge National Laboratory (ORNL), USA, have successfully built and tested a subscale additively manufactured heat exchanger at temperatures of 900°C and close to half of the 250 bar (3626 psi) pressure set as a goal for the testing. This is said to far exceed many of today's state-of-the-art devices by more than 200°C.

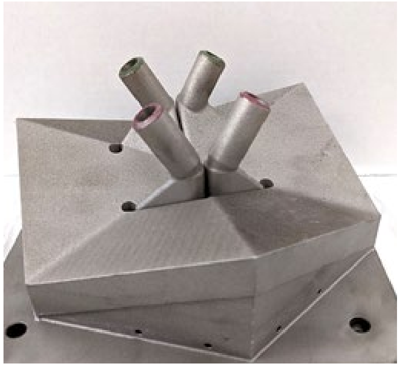
Beginning in early 2019, GE Research has been leading a $3.1 million project through the Advanced Research Projects Agency's (ARPA-E) High Intensity Thermal Exchange through Materials and Manufacturing Processes program (HITEMMP) to develop a high temperature, high pressure and super-compact heat exchanger that would enable cleaner, more efficient power generation. The recent breakthrough in the project was reportedly enabled by Additive Manufacturing.

"The design freedom afforded by 3D printing processes and design tools is allowing us to more rapidly develop, build and test new heat exchanger designs that were previously not possible," commented Lana Osusky, a Lead Engineer at GE Research.

After designing, simulating, building and testing a series of subscale prototypes, the team found success with a unique design of thin-walled unit cells resembling grapes, which was able to handle the higher temperatures and pressure. They observed that a composition of a collection of thin-walled unit cells – as shown in the video – resembled the fruit.

"We may not want to eat these grapes, but we still tasted victory when we completed this key milestone," she added.

Osusky stated that the GE-led team is on track to build and test its final prototype at both full temperature and pressure by the close of the project in Q1 2022.



The additively manufactured heat exchanger prototype was successfully tested as close to 200°C higher than traditional devices (Courtesy GE Research)

www.ge.com/research/
www.umd.edu
www.ornl.gov

Alloyed purchases Arcast arc melter to expand in-house capabilities

Alloyed, Oxford, UK, has acquired an Arc 200 melting furnace from Arcast Inc., Oxford, Maine, USA, and has installed it alongside the range of technologies already available within its Rapid Alloy Research Centre. This follows on from the company's investment in an Electro-Thermal Mechanical Testing machine in 2020.

"Alloyed is an expert in the development, licensing, and manufacture of proprietary alloys, alloy powders, and alloy components for a growing number of industry sectors," stated Gael Guetard, the director of Rapid Alloy Research Centre Director. "The acquisition of the Arc 200 from Arcast means that Alloyed is one of the only private commercial companies to have this technology in-house. It has been purchased to complement our two induction melters installed in 2020, these two melters having been key assets for our Cu, Ni, Pt, Fe, and Al alloy development projects."

"The induction melters use a ceramic crucible which reacts with some alloys and are limited to 2000°C, whereas the Arc 200 has a copper crucible that accommodates higher melting point alloys and means we can now produce alloys with high levels of Ti, Zr, Nb, Ta, Mo, W, etc. This significantly widens the markets and customers we can reach, particularly in the medical, space, and nuclear sectors," Guetard continued.

The Arc 200 uses a tungsten electrode to generate an arc in an argon atmosphere and melts the feedstock materials in a water-cooled copper crucible. The specific machine purchased by Alloyed also has the following options: high vacuum (10^{-5} mbar) and getter, allowing a clean melt; electromagnetic stirring/pulsing and button flipping, enabling the chemical homogeneity of the melt; high power (up to 800 A) to melt any metal; and tilt-casting into a mould, controlling the solidification structure and shape of the ingot.

"Before we purchased the Arc 200, we would outsource the melting of high temperature and reactive alloys, and this had the knock-on effect of increasing cost and lead times of our projects," Guetard explained. "In addition, it meant that we had little control over quality. Bringing this capability in-house means that we can significantly increase the pace of our alloy development projects and gain more control over the quality of the alloys, which is fundamental to customer satisfaction."

"We are currently in the commissioning phase, but we already have several exciting new alloys lined up: Ti-based alloys for medical applications, bulk metallic glasses for jewellery, high-entropy alloys for gas turbines, refractory-based alloys for space, and more," Guetard concluded.

www.arcastinc.com
www.alloyed.com

Launcher's Orbiter with multiple metal AM components set for SpaceX rideshare

Space technology company Launcher, headquartered in Hawthorne, California, USA, reports that Orbiter, its universal orbital transfer vehicle and satellite platform – which features an additively manufactured propellant tank, combustion chamber, and injector as part of the chemical propulsion module – is contracted with SpaceX to fly via Falcon 9 to Sun-Synchronous Orbit (SSO) in October 2022.

Designed to be compatible with both Launcher Light and SpaceX Falcon 9 rideshare flights, Orbiter is interoperable with either launch vehicle via a common ESPA Grande adapter ring. It is capable of carrying up to 150 kg of customer satellite payload in a modular stack of CubeSat deployers.

The Orbiter can also be configured to accommodate small satellite payloads directly on an integration surface compatible with small satellite separation systems. It is equipped with Launcher's signature combination of high-performance, low-cost, high-thrust chemical propulsion that allows customers to customise their payload orbit according to their mission needs.

An illustration of the Launcher Orbiter with the propulsion module ignited (Courtesy Launcher)

Launcher states that Orbiter allows small satellite constellation developers to take advantage of the price point of the SpaceX rideshare programme to build their constellation at optimum cost and timing. To complete their constellation with additional orbits and schedules, customers can purchase a launch service using Orbiter for a dedicated ride to orbit on Launcher Light, Launcher's own small orbital launch vehicle, slated for its first flight in 2024.

"Orbiter delivers the best of both worlds: the ability to maximise and tailor launch opportunities for your constellation using SpaceX's rideshare program, as well as the option to design additional complementary missions on a small, dedicated Launcher rocket when orbit requirements or schedules dictate," commented Max Haot, Launcher founder and CEO. "Customers benefit from working with the same partner, mission team, contract, qualification and regulatory processes, satellite interface, and orbital transfer vehicle hardware and software platform."

www.launcherspace.com

www.spacex.com

Sakuu Corp awarded three patents to support novel battery applications

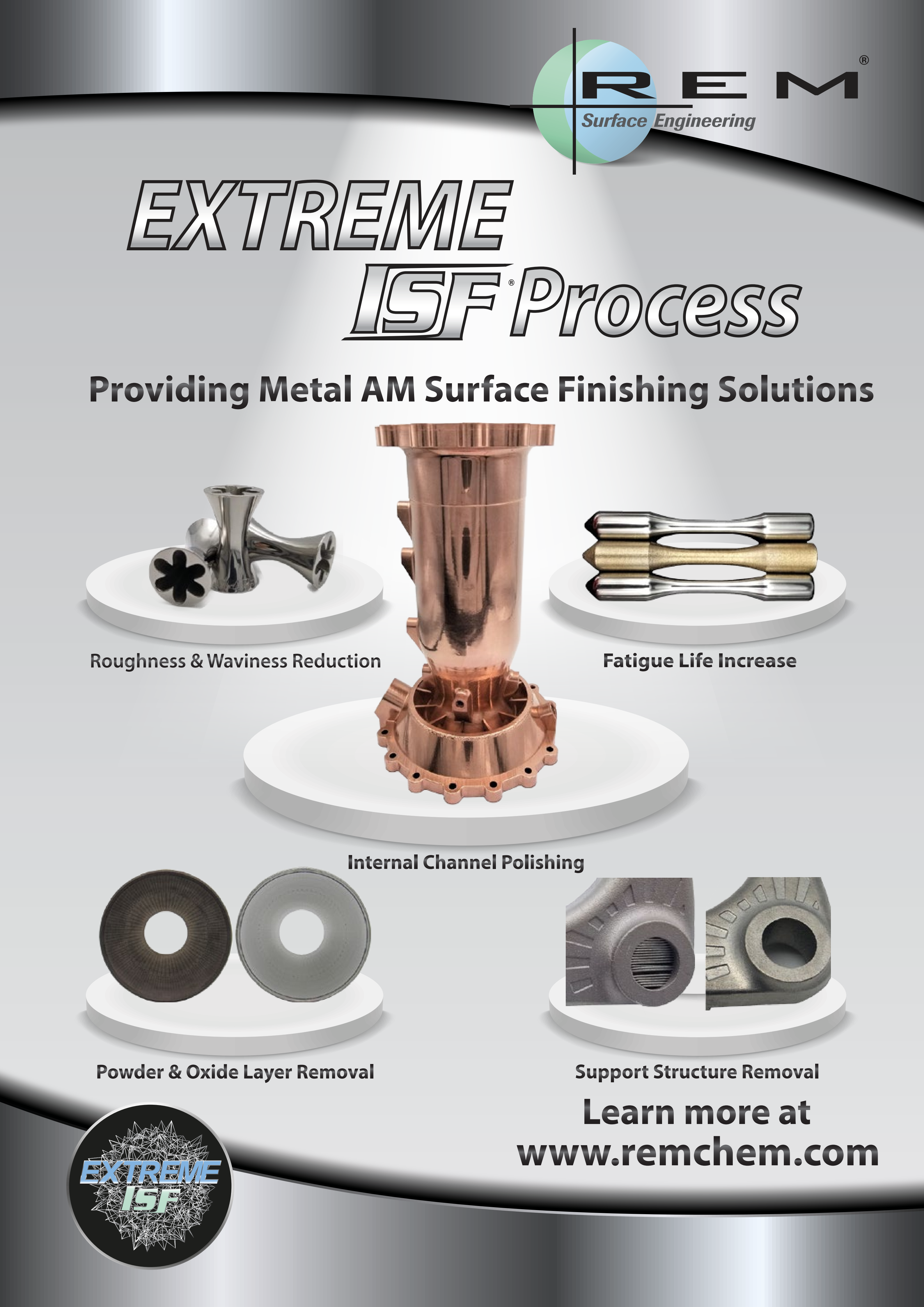
Sakuu Corporation, San Jose, California, USA, has received approval for three new patents: a hybrid solid-state cell with a sealed anode structure, an Additive Manufacturing system with the ability to create an active device such as a micro-reactor or solid-state battery and an electrophotographic multi-material AM machine, capable of using materials previously unsuited to electrophotography (namely ceramic, metal and polymer).

Sakuu has been working on creating the optimal solid-state battery via AM, for use in e-mobility and other applications. This latest patent is for a monolithic ceramic electrochemical cell housing an anode and cathode receptive space, alongside a separator between the two – allowing for higher charging rates without the risk to safety posed by lithium-ion batteries. This follows on from two previous battery patents – integrated cell stack battery and monolithic solid-state battery – which were granted back in 2020. Collectively, these structures enable increased energy density for solid-state batteries, without compromising stability and lifespan.

The second patent for a three-dimensional AM system, allows for patterned single layers to be easily assembled into a three-dimensional active device onto an assembly plate. AM has the potential to produce three-dimensional devices with more efficient use of materials and reduced weight on the finished device. This patent includes a carrier substrate which allows for single layers to be built separately and then dispensed on a stack on the assembly plate.

The final patent, an electrophotographic three-dimensional AM system, can be used to create a part derived from a composite toner material. Electrophotography is known for being capable of rapidly producing large areas of thin layers with very high precision – ideal for applications including solid state batteries and other active devices.

www.sakuu.com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ExOne and Abbott utilise continuous furnaces for the sintering of aluminium binder jet parts

The ExOne Company, North Huntingdon, Pennsylvania, USA, and Abbott Furnace Company, St Marys, Pennsylvania, USA, have announced that they are collaborating on the use of continuous furnaces for the sintering of aluminium in high-volume binder jet applications. While most Binder Jetting (BJT) Additive Manufacturing systems sold today are paired with a batch sintering furnace, ExOne found, with Abbott's assistance, that Al 6061 preferred a continuous furnace – the very type that would be advantageous in high-volume production.

Sintering bound-powder aluminium parts to high densities has been a well-known challenge for decades. While bound aluminium parts can be sintered to lower densities, Stephen Feldbauer, PhD, Director, R&D at Abbott, explained that the metal powder market has been trying to develop a method to successfully deliver high densities and strengths.

When Feldbauer looked at a micrograph of ExOne's recent work on the Additive Manufacturing and sintering of Al 6061 with other furnace approaches, he saw enough progress had been made by ExOne to deliver what others had struggled to for so many years. Feldbauer, who also teaches Powder Metallurgy processing at Penn State University, could tell exactly what challenges were occurring and had a good idea of how to fix them. "I teach sintering in applied materials. I teach powder metal processing," he explained. "I was able to draw on my experience."

Abbott's continuous furnaces, such as the Vulcan Delube System, specialises in removing binders or lubricants from powder metal and binder jet parts efficiently and 'cleaning' the parts through several chambers of tightly controlled atmospheres and thermal profiles. "Aluminium wants to oxidise so easily," added Feldbauer. "We're printing and sintering it and controlling that. That ability to control atmosphere in sintering is really what sets Abbott apart worldwide. To process continuously and to have very tight control of the atmosphere."

ExOne and Abbott can now deliver high density repeatable results in Al 6061. Feldbauer added that this achievement will transform manufacturing in important ways, delivering more lightweight geometries in aluminium that are important to the automotive, aerospace and other industries. "Now, we're actually offering a competitive process to high-volume production of high-quality parts," he concluded.

www.exone.com
www.abbottfurnace.com

Abbott's continuous furnaces, such as the Vulcan Delube System, specialises in removing binders or lubricants from powder metal and binder jet parts (Courtesy Abbott Furnace Company)

Matexcel expands to provide product analysis services

Materials service provider Matexcel, Bohemia, New York, USA, reports that it now provides professional analysing, testing and certification services in order to support quality, performance, regulatory compliance, safety, and other requirements for different products, components and raw materials.

Analysis of physical and chemical properties is an essential tool for product development, as it can help elucidate how products work with regards to price, competition and environment. Product analysis services include contamination, failure, corrosion, comparative, electromagnetic performance, film, formula, structural and metallographic analyses, as well as fire & flammability, non-destructive testing, package, ageing performance, biodegradation and hazardous substance testing services.

Matexcel's service also provides compositional analysis and material identification service to help determine the unknown components of a material, confirm the identity of a suspect material and identify differences between similar materials.

"Our on-site and in-house laboratory testing services provide the data you need to optimise the production process and quickly, responsibly and economically bring the product to market," stated a Matexcel spokesperson.

www.matexcel.com


AlphaSTAR
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www.alphastarcorp.com

AML3D to produce tooling component for Boeing, unveils new WAM Technology Centre

AML3D Limited has unveiled a new multimillion dollar Technology Centre at its base in Edinburgh, South Australia, enabling the company to showcase its recently patented Wire Additive Manufacturing (WAM®) process, a wire-based form of Directed Energy Deposition (DED).

"The opening of this incredible facility has been a long-time dream of AML3D and marks yet another significant milestone for our company and our journey alongside the recent granting of our patent. Our new premises will enable AML3D to keep up with accelerating demand in 3D printing, while continuing to push boundaries in technological research and development," stated Andrew Sales, Managing Director.

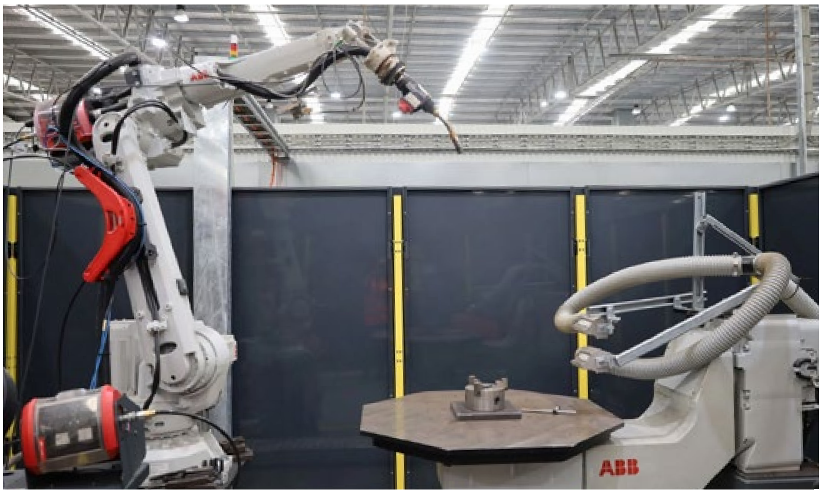
In an earlier statement, the company also announced it had receieved a purchase contract from Boeing to produce an additively manufactured tooling component.

AML3D stated it will supply an Invar-36 'mandrel tool artefact' weighing approximately 150 kg to the aerospace company.

The tooling component will be tested for its mechanical properties, internal soundness and vacuum integrity. It will also be used to assess AML3D's ability to produce parts to Boeing specifications.

"AML3D is very excited to begin working with Boeing, one of the world's largest aerospace companies," added Sales. "This purchase contract will provide the company with a key opportunity to showcase its ability to produce parts on time and to specification with a high-quality customer as the world adapts to 3D printed solutions in addition to traditional manufacturing."

www.aml3d.com



AML3D's Wire Additive Manufacturing (WAM®) process, seen here in an ARCEMY Production Cell (Courtesy AML3D Limited)

Tangible Solutions expands post-processing capability for orthopaedic AM implants

Tangible Solutions, located in Fairborn, Ohio, USA, a manufacturer of additively manufactured titanium orthopaedic implants, has announced the expansion of its post-processing business with the addition of additional staff, thus providing greater capacity in the post-processing side of the business.

The company handles all phases of orthopaedic implant creation, offering design support, prototyping, 510(k) clearance support, Additive Manufacturing, post-processing and testing throughout and after production at its Fairborn facility.

"The cost in time and dollars involved in post-processing steps can vary widely and, if these processes are outsourced for a manufacturing project, the costs can be even higher," stated Adam Clark, Tangible's Chief Executive Officer. "A contract manufacturer that manages an Additive Manufacturing project from beginning to end within their facility can save a customer important time and costs when introducing an implant to the market."

According to Tangible Solutions, it is capable of delivering all post-processing steps required in the Additive Manufacturing of titanium orthopaedic medical devices, of which two of the processes are laser marking and passivation. Marking is required by the medical device industry as it must survive the various environments that an implantable device will encounter throughout its lifecycle. Laser marking and passivation are often used in tandem to support ASTM F86 requirements.

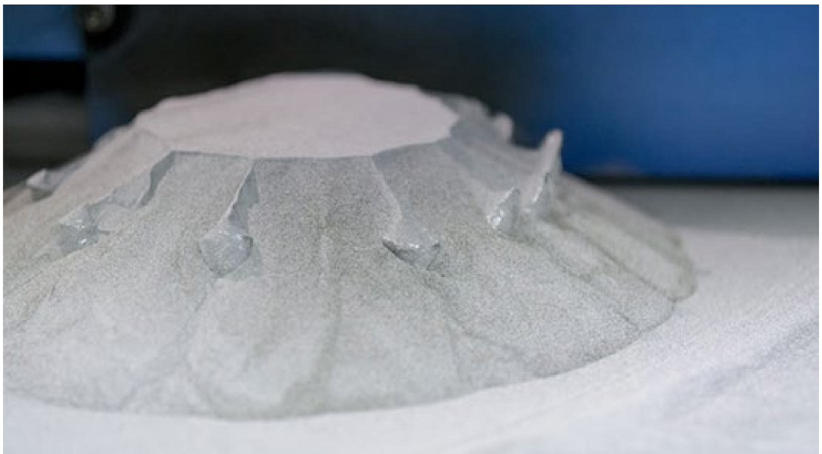
"The addition of laser marking and passivation to Tangible's list of services almost completes our journey to becoming a full end-to-end contract manufacturer of 3D printed titanium orthopaedic implants," stated Chris Collins, Tangible COO. "We continue to strive toward zero outside services at a rapid rate."

www.tangiblesolutions3d.com

Velo3D highlights advantages of F357 aluminium powder for AM

When weight reduction is the primary goal, aluminium alloys are a frequent choice for aerospace and high-performance motorsports applications, explains Velo3D's Zach Murphree, in this exclusive report for *Metal AM* magazine. Aluminium is much lighter than nickel alloy and has been particularly popular for Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing because it's good for prototyping and easy to post-process.

There are, indeed, lightweight metal alloys with higher specific strengths (a better ratio of strength to density) than aluminium, such as the titanium grades. In the case of thermal management, there are certainly materials with better heat-transfer coefficients, such as copper alloys. For the lowest density or a higher galvanic potential, magnesium alloys are also a great choice. Despite this, aluminium alloys have persisted, because, when it comes to the trade-off between cost, performance, and manufacturability, they remain among one of the best materials to optimise all three, continues Murphree.



Aluminium powder is particularly popular for PBF-LB Additive Manufacturing (Courtesy Velo3D)

KW Micro Power designs and manufactures compact turbogenerators for high power density energy generation. The company redesigned its aerospace-grade auxiliary power unit (APU) model for metal AM, using aluminium F357, and built the component on a Velo3D machine, reducing weight by 44% (Courtesy Velo3D)

These same trade-offs drove much of the early development in aluminium when it came to metal Additive Manufacturing, especially PBF-LB. Aluminium alloys are generally grouped as either casting alloys or wrought alloys, and much of the original success in AM aluminium was with casting alloys. Wrought alloys can be desirable for demanding applications – particularly in aerospace where alloys such as 2024, 6061, or 7075 see a lot of use – but these higher-strength alloys suffer from poor weldability. Even 6061, which is considered to be a weldable aerospace-grade alloy, isn't well-suited for PBF-LB. Since PBF-LB is, at its most basic level, a welding process, how can this be the case? It turns out that 'weldability' is not the primary criterion here, but, rather, 'autogenous weldability.'

Autogenous weldability means that an alloy is weldable without a filler material, adds Murphree. This isn't as much of a problem in a normal welding application, but the powder bed in a PBF-LB machine is a single material, meaning that there isn't a great way to get a filler into the process. Because of this, alloys that aren't autogenously weldable can present a problem – many of these cases have a tendency to crack in the build process.

As such, casting alloys took the lead in the development of aluminium for Additive Manufacturing. Some of the original success in AM aluminium came with AlSi12, an alloy that is 12% silicon. This is a fairly significant amount of Si for an aluminium alloy, but the Si serves to increase the flowability of the meltpool, and also to decrease the amount of contraction as the meltpool solidifies – in this regard, the more silicon, the better! But in the sense of mechanical properties, a high silicon content is not a good thing.

The next step was a logical one: reduce the proportion of silicon in the alloy from 12% to 10% and

Two views of additively manufactured Aluminium F357 heat exchangers. Note the ultra-thin features in the core (cross-section image at left). The AM process for using Aluminium F357 in Velo3D's Sapphire AM machine was developed jointly with PWR, a global supplier of advanced cooling solutions to Formula 1, NASCAR, other motor racing series, and the automotive, military and aerospace industries (Courtesy Velo3D)

add magnesium to increase the strength. The result was AlSi10Mg, affectionately known by insiders as 'alsitenmag.'

Even with the additional magnesium, however, AlSi10Mg wasn't an ideal stopping point; parts built with it still didn't meet many of the mechanical requirements of the final applications. This AM alloy tends to have low elongation, which is pretty significant: the higher the elongation, the tougher the material. Even with this deficiency, many people stopped here and settled for 'alsitenmag' as acceptable, even though it wasn't what they were really looking for.

The safety factor

A large proportion of the applications that were good candidates for AM were originally castings in A356, one of the most widely used cast-aluminium alloys, Murphree continues. It is lightweight and extremely corrosion resistant. To push the mechanical properties a bit further one can add more magnesium – this leads to A357, a stronger alloy that can be heat treated to better properties, but is a bit harder to cast. This could be an ideal candidate for PBF-LB, but there's a catch: A357 also contains 0.04 to 0.07% beryllium – and beryllium is one of the most toxic metals to humans there is. Especially if it is inhaled, which can happen during powder handling and post-processing. Not an ideal fit for AM.

Fortunately, the beryllium can be eliminated from the alloy, with the result being F357 ('F' for 'Free of beryllium'). F357 is lightweight, offers great weldability, can be anodised, has high corrosion-resistance and is tolerant of a wide range of temperatures. It's an excellent candidate for those AM parts with thin-walled, complex structures that you see in a number of aerospace and high-end motorsports applications.

While a number of leading AM equipment makers are exploring F357 now, if you have a need for this aluminium alloy, there are several things to consider as you decide on which PBF-LB AM machine to use to deliver your parts at the highest levels of quality.

Making aluminium F357 work for you

<u>Surface finish</u>

Surface finish is important, especially at those increasingly low angles that AM machines can build at these days, sometimes completely support-free. Not to mention those complex interior geometries where post-processing a surface is limited, if not impossible. Many of the applications where you see F357 being used are in high-stress environments — and a superior surface finish right out of the AM machine provides better corrosion resistance and fatigue life.

<u>Hot tearing defects</u>

Hot tearing defects can occur with F357, because its reduced silicon content can lead to cracks as it cools. The most advanced AM machines have defined parameter sets and high-fidelity laser controls that are specifically tuned to address this potential problem.

<u>Humidity</u>

Humidity can be another issue when you're using aluminium. The powder is often 'stickier' and tends to clump, especially with 'snowplow' recoater systems. Aluminium powder is an excellent desiccant, and moisture will adsorb onto the surface of the particles immediately. When the humidity inside the build chamber creeps up, aluminium powder can be difficult to spread, and can often lead to build-killing powder-bed defects. A non-contact recoater completely avoids such problems. Also look for the tightest build chamber that can maintain extremely low oxygen and humidity levels, with active control of both at all times throughout the build.

The combination of F357 with the advanced metal AM capabilities now available provides significant advantages over AlSi10Mg and legacy metal AM systems, adds Murphree. It enables the elimination of engineering compromises that, in the past, could not be avoided, freeing the design engineer to achieve that desirable mix of geometric complexity and high performance at the lightest weights possible.

Contact

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www.velo3d.com
www.kwmicro.com
www.pwr.com.au

ASTM signs MoU with NSERC HI-AM Network to advance AM standards

Representatives from global standards organisation ASTM International and Canada's NSERC Network for Holistic Innovation in Additive Manufacturing (HI-AM) have signed a Memorandum of Understanding (MoU) that will support close cooperation in the development of Additive Manufacturing standards.

The NSERC HI-AM Network works to address the challenges that prevent the industrial adoption of metal Additive Manufacturing and to equip Canada for the era of Industry 4.0. It brings together nineteen leading AM experts from seven Canadian universities and is hosted by the University of Waterloo.

"One of our core values has been identifying partnerships with organisations that can support the acceleration of standards development," stated Brian Meincke, ASTM International vice president of global business development and innovation strategy. "We are excited to work closely with the HI-AM Network and hope this partnership will advance and facilitate innovative global Additive Manufacturing standardisations."

The MoU will allow for greater collaboration on activities, promote information exchange on topics of interest, and encourage greater industry participation from Canada in the standard development process, impacting the global industrialisation of AM technologies.

ASTM International contributes to the development of AM standards through the work of the Additive Manufacturing technologies committee (F42) with the support of the Additive Manufacturing Center of Excellence (AM CoE).

Dr Mohsen Seifi, ASTM International director of global Additive Manufacturing programs, said, "Advancement of AM technologies requires robust research and development programs, and HI-AM Network has demonstrated invaluable contributions to support filling standards development gaps in this field. We are thrilled to partner with world-class universities in the HI-AM Network to focus on key industry challenges and have already registered two standard work items as a result of this collaboration."

One work item (WK76983) focuses on best practices for in-situ defect detection, while the other (WK77008) addresses benchmarking of powder bed density measurement.

www.astm.org/GLOBAL/mou.html
www.nserc-hi-am.ca

Rio Tinto develops new water atomised steel powder

Rio Tinto reports it has developed a new water atomised steel powder designed specifically for Additive Manufacturing applications at its Rio Tinto Fer et Titane (RTFT) metallurgical complex in Sorel-Tracy, Québec, Canada. The new powder is reported to deliver mechanical properties superior to conventional metal manufacturing techniques.

The water atomised powder is part of RTFT's ongoing development project aimed at producing a range of additional powder grades with advanced properties for AM.

Rio Tinto's Critical Minerals and Technology Centre at Sorel-Tracy partnered with Germany's KSB SE & Co. KGaA, one of the leading manufacturers of pumps and valves and a pioneer in industrial AM, to develop and test the performance of the new powder in AM applications. Full-scale industrial parts have already been produced and tested, including parts for liquid iron casting equipment at Rio Tinto's Sorel-Tracy site, said to be an industry first.

Stéphane Leblanc, Rio Tinto Iron and Titanium Managing Director, stated, "This is a new generation of steel powders designed for 3D printing at RTFT's metallurgical complex, where we have over fifty years of experience in making steel and iron powders. Our new Additive Manufacturing steel powder grade, produced with the largest water atomiser in North America, brings a very competitive raw material addition to the growing 3D market."

www.ksb.com
www.riotinto.com

UC Rusal announces plans to demerge high-carbon assets and rebrand as AL+

UC Rusal, a leading aluminium producer headquartered in Moscow, Russia, has announced a proposal to demerge its high-carbon assets and change the company name to AL+.

UC Rusal, acting as AL+, will retain the majority of production assets and will have a focus on sustainability, further developing its inert anode technology in pursuit of carbon-free aluminium production. A newly-created company, consisting of UC Rusal's higher-carbon assets, including alumina refineries and smelters throughout Russia, will undertake a long-term modernisation programme to reduce emissions via technologies such as carbon capture.

"This announcement is another major step in our journey to lead the global aluminium industry into the low-carbon economy," stated Lord Gregory Barker, executive chairman of the En+ Group. "AL+ will be a market leader in green aluminium production as measured by carbon footprint and other environmental credentials. However, this demerger additionally secures the future of important assets in Russia that also have a future in a low-carbon world, but which require a fundamentally different approach to technology and a different investment path to our major international businesses."

This proposed demerger remains subject to approval by regulatory bodies and consultations with key stakeholders. Further details of the demerger plan will be forthcoming.

www.rusal.ru
www.enplusgroup.com

David Graf named vice and group president of Carpenter Technology's Specialty Alloys Operations

Carpenter Technology Corporation, Philadelphia, Pennsylvania, USA, has appointed Dr David Graf to lead Carpenter Technology's Specialty Alloys Operations (SAO) business segment as vice president and group president. Since joining the company in 2018 as Chief Technology Officer, Dr Graf is said to have been instrumental in driving improvements in multiple disciplines. In 2020, he assumed leadership of the Carpenter Additive business where he led activities to restructure, reorganise and streamline the business activities.

"David's demonstrated leadership, strong business acumen and deep technical knowledge will play a pivotal role in ensuring SAO and Carpenter Technology continually deliver as the preferred solutions provider to our customers," stated Tony R Thene, president and CEO.

Prior to joining Carpenter Technology, Graf worked for WR Grace for eight years, where he served as Global R&D Director; as well as General Manager Americas and vice president of Marketing for the Specialty Catalysts division. Prior to that, he worked for The Dow Chemical Company for over a decade in a variety of R&D leadership roles.

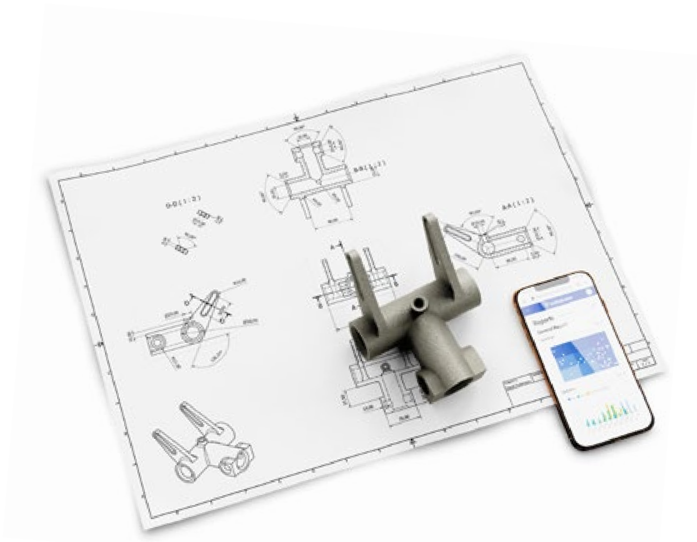
Dr Graf holds a Bachelor of Science degree in Chemistry from Michigan State University; his PhD is from the University of Minnesota. He also worked as a Postdoctoral Associate at the Massachusetts Institute of Technology.

www.carpentertechnology.com

3YOURMIND software adopted to increase combat readiness for US Department of Defence

As part of the Phillips Corporation's redefinition of the US Department of Defense's logistics strategy with the use of Additive Manufacturing, 3YOURMIND's suite of software solutions has been selected to enhance AM part identification. The two US-based companies have collaborated on analysing the feasibility of AM to increase combat readiness since November 2019.

"We are thrilled to announce this partnership with 3YOURMIND," stated Tim McClanahan, Business Development Manager. "Our AM Innovation Center includes the most advanced hardware, software and services on the market. Adding 3YOURMIND software enables us to provide many more proactive solutions to our military partners for leveraging the full potential of their Additive Manufacturing assets."



The adoption of 3YOURMIND's PLM software comes just months after the US Department of Defense released its AM Strategy Report (Courtesy 3YOURMIND)

Time is critical for troops in the field who face emergency situations daily and require immediate answers to complex issues. Utilising 3YOURMIND software enables digitisation of the warehouse, as well as the identification of AM-ready spare parts and their manufacture on-demand at global forward operating bases.

3YOURMIND's software platform analyses Computer Aided Design (CAD) data and develops a library of files categorised by technical and economic metrics. These metrics are used to determine if a part is suitable for AM and what type of time or cost advantages can be applied. Through a consultative approach (the PREP process), 3YOURMIND will provide training and support for Phillips Corporation in order to support the US DoD's goal of modernisation.

"3YOURMIND and Phillips Corporation share a similar vision to reimagine the supply chain," commented William Cuervo, Senior Business Development Manager USA at 3YOURMIND. "Our Agile PLM software, equipped with a sophisticated part identifier tool, is a secure program that provides data transparency and streamlined communications that enable defence organisations to take decisive actions."

www.3yourmind.com
www.phillipscorp.com

ASM and JIM collaborate to benefit the materials science community

ASM International, Materials Park, Ohio, USA, has announced a collaboration with the Japanese Institute of Metals and Materials (JIM) in order to encourage the international exchange of knowledge and ideas regarding the materials science community. This initiative also provides opportunities for each organisation to expand both their respective networks and resources.

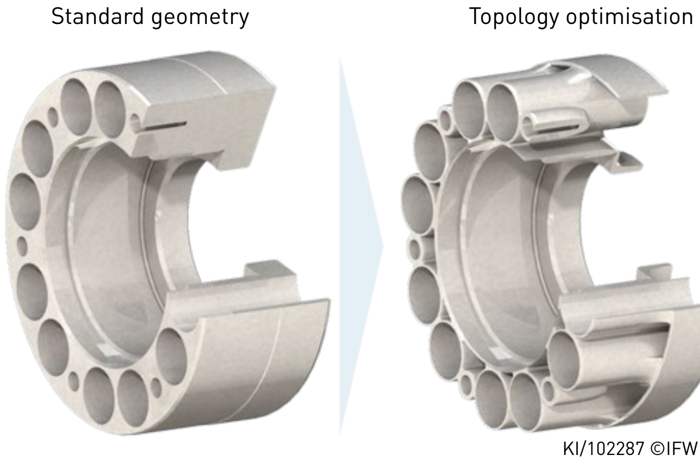
JIM is an academic society that promotes the advancement of theory, science, and industrial processes as it relates to metals and other materials. ASM International is said to be the world's largest association of materials-centric engineers and scientists dedicated to informing, educating, and connecting the materials community to solve problems and stimulate innovation around the world. As part of this collaboration between the two organisations, JIM membership will be provided with various benefits of ASM membership.

Student initiatives are said to be a cornerstone of this collaboration, encouraging both ASM and JIM students and young researchers in attending each society's respective annual events which include ASM's International Materials Applications and Technologies (IMAT) Fall Meeting and the JIM Annual Spring Meeting. Mutually beneficial to both organisations, this allows for students to attend materials science conferences and engage in the exchange of both technical and cultural information.

JIM is the first partner to join ASM International in this collaboration to expand value within the materials community at large.

www.jim.or.jp/en/
www.asminternational.org

Project explores AM of highly-stressed components in hardened martensitic stainless steel



The spring disk component in original condition (left) and after topology optimisation (right) (Courtesy IFW)

The Institute of Production Engineering and Machine Tools (IFW), part of Hannover University's engineering centre (PZH) in Garbsen, Germany, and the Fraunhofer Institute for Additive Manufacturing Technologies (IAPT), part of the Fraunhofer-Gesellschaft research organisation, Hamburg, have collaborated on a new Additive Manufacturing research project, AddSpin.

For AddSpin, the two institutes investigated to what extent Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing is suitable for tightly toleranced, highly stressed machine components, with the goal of reducing machining and non-productive times of machine tools by reducing mass and, thus, the moment of inertia.

The potential was demonstrated using the clamping system of the sliding headstock automatic lathe from INDEX-Werke GMBH & CO KG Hahn & Tessky, Esslingen. For this purpose, four components of the installed clamping system – spring housing (AlZn5,5MgCu), the movable spring disk (16MnCr5), cover and spring cover (both CF53) – from Hydronic-hiestand Hydraulik & Elektronik GmbH, Pfullendorf, were selected, which offer high potential for the reduction of the moment of inertia.

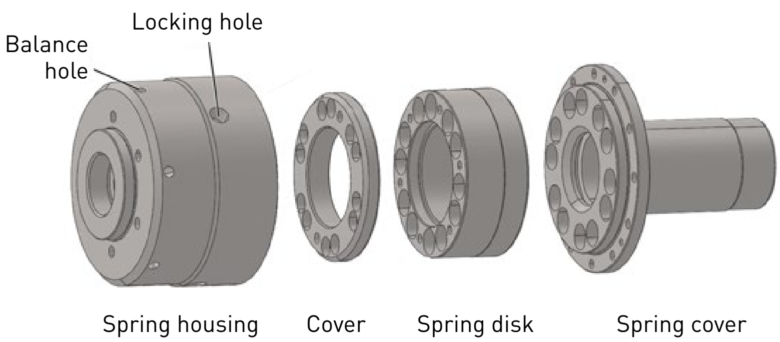
One aim of the project was the selection and qualification of a material that is suitable for both the application and the AM process: X5CrNiCuNb16-4, a precipitation-hardened martensitic stainless steel, was chosen for this study.

At the beginning of this qualification process, suitable parameters were determined. Based on parameters of already-known steel materials, test specimens were produced by varying process speed, laser power and layer thickness in the AM process; these were then analysed for their density. The combination of parameters which allowed both high density and build-up rate was selected for the production of further test parts and components.

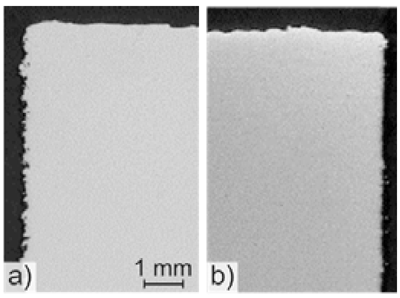
In the next step, the surfaces of the components were optimised by adjusting the process parameters for the component contour, reducing the roughness of the lateral surfaces to below 6 µm.

The mechanical properties were then characterised under different heat treatment conditions. In addition, extruded reference samples were produced. For all eight sample types, the moduli of elasticity, tensile strength, yield strength, hardness and wear rates were determined experimentally. The samples showed tensile strengths of more than 1000 MPa without heat treatment, with possible tensile strengths of up to 1200 MPa achieved through targeted post-treatment.

Using the determined values, a topological optimisation was



The four clamping system components to be optimised (Courtesy IFW)

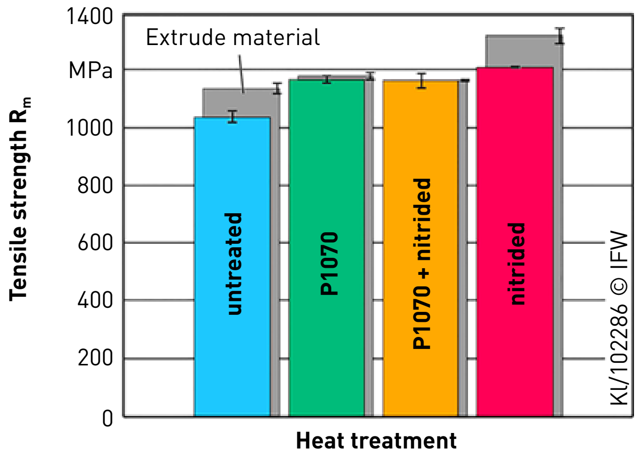


Sectional view of the specimens to evaluate the density: without surface optimisation (left) and with an optimised surface (right) (Courtesy APT)

subsequently performed using ANSYS simulation software. A minimisation of the mass was determined and it was shown that the component masses can be reduced by up to 67%.

In relation to the entire rotary system, the optimisation of these four components already results in a 19% reduction of the moment of inertia. For the process step of taper turning at constant cutting speed, for example, results show a theoretical reduction of 19% in machining time.

The verification of the theoretical productivity increase will be conducted in future by practical tests under real operating conditions. For this purpose, the AM components will be installed in the automatic lathe and machining tests will be carried out. The knowledge gained will be summarised in the form of a final guideline for the production-oriented design of highly stressed components.



Tensile strengths of 1.4542 in different treatment states (Courtesy IFW)

The IGF project 20276 N of the Research Association VDW Werkzeugmaschinen e.V. was funded via the AiF as part of the programme for the promotion of joint industrial research (IGF) by the Federal Ministry of Economics and Energy based on a resolution of the German Bundestag.

www.ifw.uni-hannover.de/en/institute

www.iapt.fraunhofer.de/en.html

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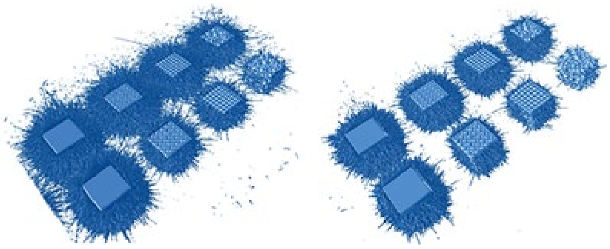
Linde and 3D Medlab test optimal atmospheric solutions for AM



Spatter formation using argon gas only (left image) versus spatter formation using novel argon-helium gas mixture (right image) (Courtesy Linde)

Global industrial gas specialist Linde, Guildford, Surrey, UK, has announced the results from testing its new process gas developed for the optimisation of the Additive Manufacturing of medical components. The introduction of the novel gas mixture follows on from the promising results of a joint development programme between Linde and 3D Medlab, Marignane, France – now part of Marle Group.

Undertaken between January 2020 and March 2021, the study investigated the effect of the new process gas on spatter formation and process stability during Laser Beam Powder Bed Fusion (PBF-LB) of Ti64 lattice structures and their resulting properties. Process monitoring with optical tomography pictures showed that spatter emission was significantly reduced when working with argon-helium mixtures compared to argon alone. Research results have appeared to confirm that Linde's argon-helium gas mixture decreases spatter emissions by 35%, considerably reducing the risk of manufactured defective parts and improving overall surface quality.

"The ability to print reliably repeatable products is key to improving product qualification, which is crucial for the medical industry," stated Sophie Dubiez-Le Goff, Expert Powder Metallurgy for Additive Manufacturing, Linde. "Additionally, from a commercial perspective, printing time is the greatest single cost element in Additive Manufacturing, but this can be speeded up for thin parts by using just the right atmospheric gas mixture. Linde's novel argon-helium mix has been developed to do just that, and is a major step forward in the manufacture of titanium medical devices."

Levels of porosity and surface quality are fundamental factors in the quality of mechanical properties of highly intricate parts, by ensuring the finished product is as close to the original design specification as possible and also that fewer metal powder parts can potentially be released into the human body.

"Porosity is the first criteria we look at in terms of defining the quality of an additive manufactured medical device," added Gael Volpi, Head of Additive Manufacturing, Marle Group. "The results of our joint atmospheric gas study with Linde shows that the right balance of helium to argon in the process gas mixture – and ease of implementation – can make all the difference to both quality of output and productivity."

The inert gas within the build chamber is a critical element that can affect both part quality and overall production speed, so the study was primarily aimed at assessing the ideal gas mixture to optimise both outcomes. When using argon alone, it was observed during testing that there was a significant amount of spatter – or molten metal particles caused by the laser – splashing against adjacent parts being manufactured. Spatter on highly-intricate parts is undesirable, resulting in less fine quality of part threads. Additionally, the use of pure argon resulted in a level of porosity that Linde and 3D Medlab engineers believed could be significantly improved.

"Higher productivity was not reached at the expense of quality," continued Dubiez-Le Goff. "On the contrary, thanks to the new process gas mixture being so effective in reducing porosity content by 70% – according to micro-computed tomography analyses – compression properties remained comparable to parts processed with argon only."

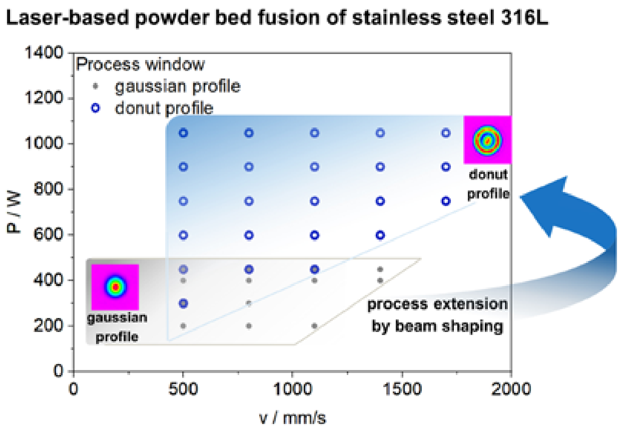
www.linde-am.com

www.3d-medlab.com

nLIGHT, Optoprim and TUM collaborate to push the limits of Powder Bed Fusion processes

nLIGHT, Inc., Vancouver, Washington, USA, launched the AFX-1000, a programmable high-power fibre laser, in November 2020. The laser has the ability to switch between a single-mode beam and other beam profiles without the use of free space optics, said to make the AFX-1000 an ideal beam source for applications in Additive Manufacturing processes.

In order to demonstrate the potential of the new beam profiles in powder bed fusion processes, nLIGHT and Optoprim collaborated with the Professorship of Laser-based Additive Manufacturing by Prof. Dr.-Ing. Katrin Wudy at Germany's Technical University of Munich (TUM).



nLIGHT AFX-1000 with switchable donut profiles offers potential for widening and smoothing the melt pool and expanding the process window (Courtesy nLIGHT/Optoprim/TUM)

Some of the fundamental research questions for investigations with the AFX-1000 targeted in the collaborative effort include identifing which beam profiles enable an increased melt pool size combined with a smooth melt pool. The team will look at how the spatial change of the beam profile influences the temperature gradients and microstructure.

The collaboration will also identify which processing strategies lead to process acceleration and simultaneous stabilisation.

To date, experiments with the nLIGHT beam source highlight the potential for widening and smoothing the melt pool, as well as increasing process speed with the donut profiles.

"This approach will change the way we use Additive Manufacturing with metals. It gives us the ability to tailor laser-based processing regarding faster and optimal processing conditions as well as the microstructure of parts e.g. through larger melt pools," stated Prof Wudy. "We are excited to push the barriers of Additive Manufacturing with our partners of nLIGHT and Optoprim in the years to come."

www.nlight.net
www.optoprim.de
www.mw.tum.de/lbam

Titomic appoints Herbert Koeck as its new CEO

Titomic Limited, Melbourne, Australia, has appointed Herbert Koeck as Chief Executive Officer. He succeeds Nobert Schulze, Interim CEO of Titomic, who will continue to support the company in a different role.

For the last five years, Koeck has been a member of the executive management team of 3D Systems Corporation, where he was accountable for the sales and global orders of the group. This included influencing product development to ensure customer success. The company's revenue for his final full year, 2020, was USD $557.2 million. Prior to this position, Koeck acted as the company's senior VP for Europe and India.

"Herbert is a proven leader with deep Additive Manufacturing experience, hardcore marketing skills, business vision and ability to bring people together," stated Dr Andreas Schwer, Titomic's chairman. "His experience in bringing advanced technologies to customers around the world is exactly what Titomic needs as the company enters its next chapter focusing on commercialising its Cold Spray Additive Manufacturing (CSAM) technology, centred on building partnerships as well as joint ventures with customers. During this exciting time of transformation, Herbert is the right leader at the right time for Titomic."

With this addition, Titomic's executive management team now consists of Jeff Lang as CTO; Chris Healy, Chief Legal Officer and Joanna Walker, CFO. The transformation of the management team comes alongside many recent changes to the Titomic board of directors, which now consists of chairman Dr Andreas Schwer former CEO of SAMI; Mira Ricardel principal Chertoff Group and former White House official; business executive Humphrey Nolan; Dag W R Stromme, former Morgan Stanley Managing Director and private equity executive; business executive Richard Willson; and Titomic's two co-founders, Richard Fox and Jeff Lang, the company's current CTO.

www.titomic.com

Pangea and Aenium collaborate on Additive Manufacturing of NASA-GRCop42-based rocket propulsion systems

The agreement seeks to provide a breakthrough in the engineering of complex combustion devices (Courtesy Pangea Aerospace/Aenium)

Pangea Aerospace, Barcelona, Spain, a developer of rocket engines for the space sector, and Aenium, Valladolid, Spain, a company focused on Additive Manufacturing technologies and material science, have partnered to develop and industrialise advanced combustion devices using innovative AM processes and materials. The agreement seeks to provide a breakthrough in the engineering of complex combustion devices and drive the analysis of different types of advanced superalloys for the most demanding applications within the space sector.

Pangea will assign the R&D, manufacturing and industrialisation of its new aerospike demonstrator to the consortium, with the goal of achieving a successful hot-fire test by the end of 2021. The aerospike engine can radically transform space propulsion thanks to its higher efficiency (up to 15% more efficient than currently used rocket engines), reusability capabilities and low cost.

The company is currently manufacturing its DemoP, a liquid oxygen and methane aerospike engine demonstrator designed to characterise and validate several key enabling technologies for future aerospike developments. These will include the use of methane as a fuel and, together with Aenium, the development of a reusable dual regenerative cooling system exploiting both propellants.

In addition, the partnership will bring to the European market GRCop-42, a high-conductivity, high-strength dispersion-strengthened copper-alloy, developed by NASA for use in high heat flux applications, such as liquid rocket engine combustion devices. This copper-chrome-niobium alloy is suitable for harsh environments specific to regeneratively cooled combustion chambers and nozzles, providing good oxidation resistance.

"The agreement with Aenium goes beyond shared exclusive capabilities on GRCop42 in Europe, a copper material specifically developed for rocket engines. Aenium also brings unmatched expertise and R&D capability in processes and materials," stated Adrià Argemi, CEO of Pangea Aerospace.

Historically, several aerospike engines have been developed, including the J-2T, XRS-2200 and RS-2200, but none have ever flown. This is due to the engineering difficulties linked with aerospike nozzles: cooling and manufacturing. This is where Additive Manufacturing techniques and new materials such as GrCop42 are enhancing the possibility to build a functional and economically viable aerospike engine at a fraction of the cost and time.

"GRCop42-based alloys are one of the key solutions that allow us to solve the thermal challenges of aerospike nozzle rocket engines. We are now ready to offer this unique capability to all the European aerospace sector," added Argemi.

Pangea Aerospace has already started the preliminary design of its larger, commercially ready aerospike engine and its subsystems. "This alliance will propel the next generation of reusable rocket engines, also bringing the opportunity to the EU market to improve their combustion devices with the most innovative material science and qualified industrial Additive Manufacturing," stated Miguel Ampudia, CIO of Aenium.

www.pangeaaerospace.com
www.aenium.es

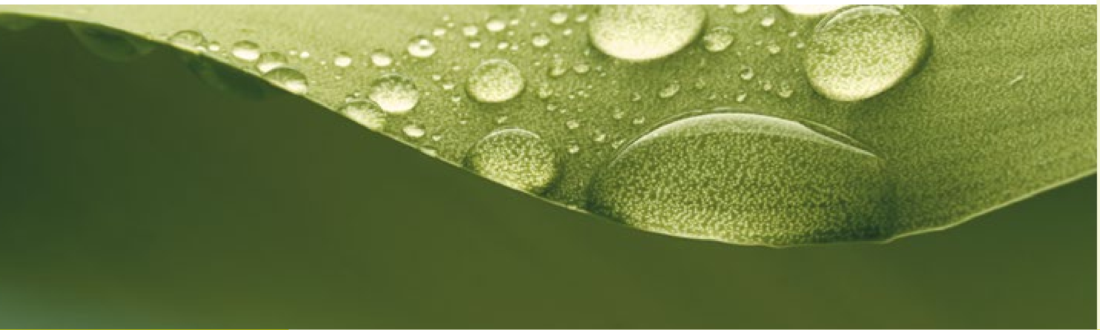
Signing of the agreement between Pangea Aerospace and Aenium (Courtesy Pangea Aerospace/Aenium)

LÖMI

Solvent Debinding Systems for AM

3 in 1:

- ➔ Debinding
- ➔ Drying of parts
- ➔ Solvent recovery



- ➔ Wide range of feedstock processible
- ➔ All organic solvents and water
- ➔ Advanced clean technology, closed systems
- ➔ Ergonomic front-end loaders
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www.loemi.com

Airbus opens new £40M aerospace research centre in UK

Airbus' Aerospace Integrated Research and Test Centre (AIRTeC) in Filton, Bristol (Courtesy Airbus)

Airbus reports that Kwasi Kwarteng, UK Secretary of State for Business, Energy and Industrial Strategy, has officially opened Airbus' Aerospace Integrated Research and Test Centre (AIRTeC) located in Filton, Bristol. The new centre features an Additive Manufacturing suite and digital manufacturing laboratory.

AIRTeC is a £40 million, state-of-the-art research and testing facility jointly funded by the UK government's Aerospace Technology Insitute (ATI) programme and Airbus. The facility is designed to undertake structural testing of large-scale aircraft assemblies, from full-size wings down to the individual components and materials used in aircraft design. It is said to provide the most advanced working environment and tools for Airbus, alongside external suppliers, partners, and academia, to deliver the next generation of aircraft wing, landing-gear systems and fuel system designs.

The facility is also said to be a key asset in helping industry accelerate the design, manufacture, testing, certification, infrastructure, and commercial operation of zero-emission aircraft through sustained investment in R&T and R&D and fostering greater collaboration across sectors.

Companies in other sectors, such as maritime and nuclear, along with universities, will be able to utilise AIRTeC's innovative and adaptable environment, which includes a state-of-the-art specialist test space, a 40 m-long strong floor, and a 14 x 10 m strong wall capable of testing full-size wings – with a force equivalent to the weight of 240 cars – using a 25 MN high-capacity loading test machine.

AIRTeC also includes labs, collaborative office space, and reconfigurable testing areas and will enable Airbus and its partners to develop cutting-edge designs. The facility is said to be central to Airbus' Wing of Tomorrow programme, which is exploring the best materials, manufacturing, and assembly techniques to help deliver more fuel efficient, cleaner aircraft. In addition to the AM suite and digital manufacturing laboratory, the new facility also features the Airbus low-speed wind tunnel.

"The launch of this fantastic new centre comes as Airbus prepares to ramp up production of its most popular aircraft towards the end of the year – a clear vote of confidence in Britain as we build back better from the pandemic," stated Kwarteng. "These top-class research and testing facilities will be used to continue the spirit of innovation for which we are world renowned and will produce the cleaner, more efficient flights of tomorrow."

He added, "This is great news, not just for Filton but for the rest of the UK which will benefit from jobs in the supply chain. I am proud of the government's support for the centre's construction, showing we are leaving no stone unturned in our drive to make the aviation industry cleaner in the fight against climate change."

John Harrison, General Counsel and UK Chairman of Airbus, commented, "Airbus makes a significant contribution to the UK aerospace industry and we are delighted to welcome the Secretary of State to help us showcase our fantastic facility. AIRTeC will take our research and testing capabilities at Filton to the next level and will make us even more competitive for the future."

www.airbus.com

Matsuura Machinery USA launches metal AM production services

Matsuura Machinery USA, Inc., the US subsidiary of Matsuura Machinery Corporation, based in St. Paul, Minnesota, reports that it now offers quick-turn prototyping, producing a wide range of metal additively manufactured parts, including unique functional prototypes and low to mid-volume production runs.

"Due to unprecedented customer interest and demand, Matsuura's Metal Additive Manufacturing Service Bureau is now providing the production of 3D Metal printed and machined parts," stated Tom Houle, Director, LUMEX, NA.

The company explains that with its LUMEX Avance-25 and Avance-60 metal AM machines, the production of high-volume mould components with conformal cooling and integrated porous venting will minimise the need for traditional EDM processes and provide significant savings to the production of moulded plastic components. Customers can lower their capital equipment investments for tooling and moulding machines while reducing mould cavitation requirements and accelerating Return on Investment (ROI).

"Products and shapes previously impossible to manufacture (including ultra-deep ribs, 3D mesh, hollows, free-form surfaces, and porous structures) can now be produced using the LUMEX Technology," Houle added.

Matsuura USA established its Additive Manufacturing Center to promote the use of metal AM parts as a solution to continuing supply chain challenges and delays.

Houle continued, "The LUMEX team in our Additive Manufacturing Center, along with our collaboration with the Customer Solutions team and machine designers in Japan and Germany, will help customers quickly realise the benefits of Additive Manufacturing. Our team's insight into the process and the technology, will assist in modification of your traditional designs into suitable 3D Metal Printing."

Matsuura customers are reported to be seeing the value that comes with implementing AM technology, with multiple customer case studies showing 25% to 45% reductions in cycle time.

"Metal 3D printing can benefit tooling, injection moulding, CNC machining, and die casting processes and operations. We will work with you throughout the entire 3D printing process, including through the design to enable our customers to fully realise the benefits throughout the life of their products," Houle concluded.

www.matsuurausa.com

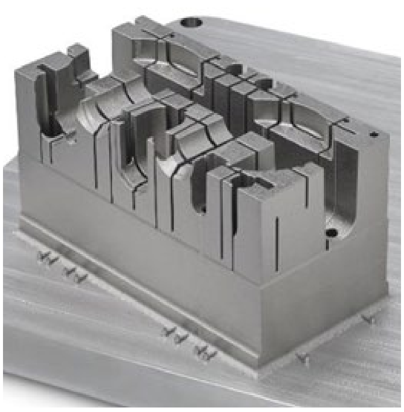
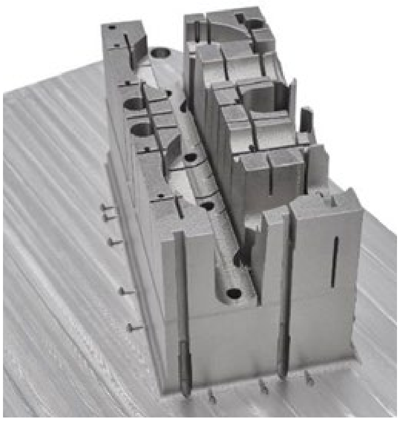
Erofio Group produces first AM part in trial of GE Additive's Concept Laser M Line

Industrial moulding company Erofio Group, Batalha, Portugal, has successfully additively manufactured its first part using GE Additive's Concept Laser M Line, having been chosen to test the machine ahead of its wider commercial launch planned for later this year.

The company's AM leader Luis Santos and his team opted for a parameter previously used on the Concept Laser M2 Series 5, making only minimal changes to adapt it for the new M Line system. Following remote optimisation support from the GE Additive team in Lichtenfels, the part was successfully manufactured on its first attempt, over a six-day period in May 2021.

"We fully expected the first part to be printed on the M Line to go well," stated Jan Siebert, General Manager, laser technologies, GE Additive. "And when it did there was a rush of excitement felt across the entire team here in Lichtenfels. Work continues here in Germany on the M Line, ahead of the launch, and we will factor in additional feedback from the team at Erofio."

The AM part, a mould core, was manufactured using M300 hot work tool steel, often used for the production of injection moulding and die-casting tool inserts with conformal cooling, as well as functional components. The core contains more than eight independent, internal conformal cooling channels, stretching over 8 m in length and between 5 mm to 8 mm in diameter. The ability to manufacture this part using AM has enabled a more efficient heat exchange, which, in turn, increases process productivity as well as the productivity of the initial production; the company stated that the time to manufacture the core was reduced by 30%. This method of manufacture has also reduced the company's finishing requirements by 90%.

Erofio Group's mould core, which represents the first part manufactured in the company's trialling of the Concept Laser M Line (Courtesy Erofio Group)

"We are honoured to be part of GE Additive's thorough commercial readiness process," stated Santos. "We're learning a lot from them and I think it's safe to say they are learning a lot from us and our first impressions working with the M Line. Having the first part come off our system is a great milestone and we're looking forward to supporting the wider team as the solution comes to market and beyond."

"We have a solid working relationship with the team at Erofio that goes back well over a decade. As we near a critical phase in commercialising the M Line system, we specifically sought out a trusted partner to gain early installation experience, data and honest customer feedback," added Wolfgang Lauer, Concept Laser M Line Product Manager, GE Additive.

Siebert concluded, "It is critically important that when GE Additive brings new solutions to market, it can tangibly and immediately demonstrate business impact. Our M Line system operates at higher levels of reliability and repeatability, meeting customers' needs from day one. This is not a science experiment and we are not developing laboratory equipment. Overly ambitious claims and incomplete specifications in other vendors' product launch announcements only serve to undermine the trust that our wider industry has collectively built in metal additive technology in recent years."

www.erofio.pt
www.ge.com/additive

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FORWARD

GE gains US Air Force approval for first critical additively manufactured jet engine component

GE Aviation has received Engineering Change Proposal (ECP) approval from the US Air Force (USAF) for an additively manufactured sump cover used in the company's F110 jet engine. The component is said to be the first engine part designed for and produced by metal Additive Manufacturing to be qualified by any US Department of Defense entity. The full approval process was concluded in under a year and represents the latest milestone in the USAF and GE's pathfinder Pacer Edge programme.

"Much like the GE90 T25 sensor that was an FAA certification pathfinder for metal Additive Manufacturing for GE Aviation in commercial aerospace, the F110 sump cover sets a solid foundation for many more additively manufactured component qualifications with GE's military customers," stated Matt Szolwinski, Chief Engineer and leader of GE's Large Military Engineering team.

The airworthiness qualification of the sump cover brings Pacer Edge Phase 1a of the pathfinder to its conclusion, with GE citing the key to the accelerated qualification being its decade of metal Additive Manufacturing and engineering expertise. The team's in-depth knowledge of commercial aerospace engine airworthiness for flightworthy metal AM parts is seen as being instrumental in helping USAF establish its own robust process validation and certification processes for military airworthiness.

Close collaboration and knowledge sharing have reportedly enhanced USAF's spiral development approach of continuously identifying, reverse engineering and developing technical data packages (TDPs) for increasingly complex and larger parts suitable for metal Additive Manufacturing.

"USAF's strong vision for additive as part of its wider sustainment and readiness strategy has allowed our combined team to progress at speed. We continue to share our learnings and have developed an efficient, structured way of working – especially for developing qualification processes and expediting design iterations. This lean, operational efficiency is already driving results and now sets us up for the next phases of the programme, including looking at complex and large format, load-carrying structures," added Szolwinski.

Phase 1b is already underway and focuses on an out-of-production sump cover housing on the TF34 engine, which has been in service for over forty years.

A digital thread also runs through the pathfinder. GE experts focused on digital twinning, maintenance-based predictive analytics and part lifecycle management expertise have been able to complement the USAF's digital engineering strategy and in-house knowledge.

Recently, the Air Force's Propulsion Directorate and RSO invested $10 million to fund additional phases of the Pacer Edge program, leveraging the Defense Logistics Agency's (DLA) Captains of Industry contract vehicle. This funding will accelerate the development of the USAF's organic AM capability and capacity to design and print flightworthy hardware for military engines, aircraft and support equipment. The Pacer Edge team is utilising this capability to alleviate hard-to-source and obsolete spare parts constraints for legacy systems.

"The F110 sump cover was a terrific pathfinder, allowing us to exercise the USAF's airworthiness process. There are numerous parts in queue that are ideal candidates for metal 3D printing. Next, we are focused on refining the airworthiness process, so it is as responsive as the technology," concluded Melanie Jonason, Chief Engineer for the USAF's Propulsion Sustainment Division.

www.afrso.com
www.ge.com/additive
www.geaviation.com

Additively manufactured, cobalt-chrome sump cover for F110 engine. Produced on a GE Additive Concept Laser M2 machine at the GE Additive Technology Center in Cincinnati, as part of collaboration with the US Air Force's Rapid Sustainment Office (Courtesy GE Additive)

First Titanium Powder Metallurgy Technology and Application Summit Forum in China reports success

The first Titanium Powder Metallurgy Technology and Application Summit Forum took place in Taizhou City, Jiangsu Province, China, on June 18, 2021. The successful conference, which was jointly held by the China Powder Metallurgy Alliance (CPMA), Jiangsu Jinwu New Materials Co., Ltd. (JSJW), and Uniris Exhibition Shanghai Co., Ltd., welcomed nearly 300 attendees representing 153 organisations from across China.

Reporting for *Metal AM* magazine, Dr Chiou Yau Hung (Dr Q) stated that the conference focused on the topics of Metal Injection Moulding (MIM), metal powder, mixing, feedstock, debinding, sintering and application in high-efficiency titanium alloy, as well as Additive Manufacturing and traditional processing.

After the conference presentations and round-table Q&A sessions, the common consensus was that the accelerated development of automobile manufacturing, consumer electronics (3C products), 5G communication, aerospace, biomedical and other industries, was resulting in demand for advanced materials and innovative forming technologies such as Powder Metallurgy, MIM, and AM is expanding.

Thanks to the sponsorship of JSJW, guests were able to participate in all activities free of charge. Professor Guo Zhimeng of the University of Science and Technology Beijing, and JSJW founder, stated, "Jinwu assistance is only a small force in promoting the application of titanium and titanium alloy products. We hope that more end customers can accept and use more titanium and titanium alloy designs, and lead the whole industry further."

Conference attendees were also given the opportunity to visit the production plant of JSJW, to learn about the manufacturing process of spherical titanium powder and the equipment specially designed to verify the performance of the powder.

JSJW was also reported to have joined the powder technology R&D share platform (RDSP) established by the CPMA. This project is aimed at opening the research resources of equipment and raw material suppliers to their customers, allowing the exchange of information through the platform to solve problems in product manufacturing.

Nearly 300 guests attended the first Titanium Powder Metallurgy Technology and Application Summit Forum (Courtesy Dr Q/Uniris Exhibition Shanghai Co., Ltd)

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www.jsjinwu.com
https://en.uniris.cn

'Innovation in progress' announced as theme of purmundus challenge 2021

'Innovation in progress' has been announced as the theme of this year's purmundus challenge, an international competition for design in Additive Manufacturing. The finalists and winners will be presented at Formnext 2021, scheduled to take place in Frankfurt, Germany, from November 16–19.

The international judging panel will select the winners of the purmundus challenge and present them with their awards at the trade fair on November 18. In addition, a prize for the 'public's choice', will be voted for over the duration of the event by attendees.

As part of the competition, participants tackle the challenge of identifying useful, end-to-end solutions for Additive Manufacturing. In addition to a hybrid production functionality, the aim is also to create a guiding idea for the AM and production of tomorrow.

The organisers once again encourage entrants to consider methods and materials that have not yet become established, are still the subject of research or are yet to be invented. The deadline for submissions is September 22, 2021.

www.purmundus-challenge.com

Turkish dental laboratory adds HBD metal AM machine

Dental laboratory Özel Epitel Sabit Dis Protez Lab, Istanbul, Turkey, has recently seen the installation of a HBD-150D Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing machine from Chinese company HBD, customised for titanium partial dentures.

In the field of dentistry, laboratories have been moving towards partial digitalisation for some time as a way to increase efficiency. HBD's industry-bespoke Additive Manufacturing machines are said to aid in this transition, producing hundreds of customised metal crowns within several hours without the need for waxing or casting, thus reducing both environmental impact and man hours.

HBD offers a range of AM machines, with build chambers ranging from 100 mm to 600 mm. The company also launched its new HBD-150D Dual Laser AM machine during Dental South China 2021, a global dentistry event.

en.hb3dp.com

Multistation enters agreement to distribute Meltio metal AM machines in France

Multistation SAS, Paris, France, has entered a distribution agreement with Meltio, Linares, Spain, to offer Meltio's metal AM technology solutions on the French market.

Meltio's AM process is based on what it refers to as 'wire-powder laser metal deposition', a Directed Energy Deposition (DED) technology that enables the production of parts using either metal wire or metal powder independently or simultaneously. As well as a standalone metal AM machine, the company's Meltio Engine solution can be integrated into a robot, a machine tool or a 3-axis machine system.

Multistation states that it will focus on building an ecosystem in France around Meltio AM technology by establishing partnerships and development opportunities with research centres, universities, robotic integrators, manufacturers & distributors of machine tools and industrial users of this technology.

www.multistation.com
www.meltio3d.com

The Meltio system can be integrated into a robotic arm as a cost-effective solution for large metal part manufacturing (Courtesy Meltio)

Metal AM winners in MPIF Powder Metallurgy Design Excellence Awards

This year, the winners in the 2021 Powder Metallurgy Design Excellence Awards competition included three components made using metal Additive Manufacturing. Organised by the Metal Powder Industries Federation (MPIF), the awards were announced during the International Conference on Powder Metallurgy and Particulate Materials (PowderMet2021), an event co-located with the Additive Manufacturing with Powder Metallurgy (AMPM2021) and Tungsten2021 conferences, held in Orlando, Florida, USA, from June 20–23, 2021. In the design competition, a total of six Grand Prizes and sixteen Awards of Distinction are presented across the manufacturing categories of conventional Powder Metallurgy (PM), Metal Injection Moulding (MIM) and metal Additive Manufacturing.

A Grand Prize was awarded to Parmatech for a 316L stainless steel putter head and hosel, made for Cobra Puma Golf (Courtesy MPIF)

3DEO Inc. received an Award of Distinction for this casing extractor for Glock pistols (left) and a further Award of Distinction for the open comb base plate used in a double-edge safety razor (right) (Courtesy MPIF)

Grand Prizes

A Grand Prize was awarded to Parmatech Corporation, California, USA, in the Hand Tools/Recreation Category for Metal AM components for a 316L stainless steel putter head and hosel, made for Cobra Puma Golf, and used in the King Supersport-35 golf putter. The MPIF explained that the use of Additive Manufacturing technology has allowed designers to place or remove material strategically, ensuring the optimal mass distribution and stiffness. This flexibility also allowed the production of both right and left-hand versions of the putter head and hosel without the need for tooling changes. The development of unique lattice structures also eliminated the need for supports during the sintering process.

Awards of Distinction

In the Aerospace/Military/Firearms Category for Metal AM components, 3DEO Inc., California, USA, received an Award of Distinction for a 17-4 PH stainless steel casing extractor for Glock pistols. A hybrid AM approach was used to make the part, offering the robustness and accuracy of CNC machining and the scalability of MIM, while overcoming the drawbacks of each process. The part has a complex geometry with several small, critical features.

3DEO Inc. received a further Award of Distinction in the Hand Tools/Recreation Category for an open comb base plate used in a double-edge safety razor for their customer Blackland Razors. A hybrid AM approach was also used to make the parts, offering tight dimensional tolerances that set the blade gap for this shaving razor.

www.mpif.org

Desktop Metal acquires multi-material solutions provider Aerosint

Desktop Metal, Inc, Burlington, Massachussets, USA, has acquired Belgium-based Aerosint, a developer of multi-material deposition systems for powder-based Additive Manufacturing.

"This transaction advances our strategy to own differentiated print technologies that enable an expanding set of AM 2.0 applications at scale," stated Ric Fulop, co-founder and CEO of Desktop Metal. "Multi-material printing is the next frontier in AM. Today people print parts, but in the future, people will look to print full products, which may be composed of multiple materials. Industrialising Aerosint's core technology and related powder processing systems will provide many benefits to the broad adoption of AM solutions."

Fulop continued, "We look forward to partnering with our new colleagues at Aerosint to mature this unique technology and integrate it into upcoming Desktop Metal products over the next several years. We are also excited for Aerosint to independently continue its growth trajectory by offering selective powder deposition solutions and services to third-party manufacturers and customers of powder-based AM systems."

Founded in 2016, Aerosint utilises a powder deposition system based on a proprietary digital process that selectively deposits two or more powders to form a single, thin powder layer containing multiple materials. The company's patented selective powder deposition technology enables three-dimensional control of material placement during manufacturing and can be integrated into any powder bed AM process, such as Laser Beam Powder Bed Fusion (PBF-LB) or Binder Jetting (BJT). This multi-material approach to powder deposition is designed to support the high-speed Additive Manufacturing of a broad range of metals, ceramics and polymers.

Reported to be the only high-throughput, multi-material powder recoating system in the market, Aerosint's selective powder deposition enables a range of new applications for AM. In addition to reducing powder waste, material cost, and post-processing time associated with single-material, commercially available powder bed AM processes, multi-material powder deposition has the potential to realise further benefits at scale, such as localised optimisation of mechanical properties (wear resistance or vibration dampening) and improved chemical and physical properties (thermal and electrical conductivity, corrosion resistance, or aesthetics).

"At Aerosint, we believe the future of AM is going to be multi-material," added Edouard Moens de Hase, co-founder and Managing Director of Aerosint. "We are thrilled to partner with Desktop Metal to accelerate the execution of this vision, now with access to its scale, distribution network, and industry-leading AM 2.0 technology portfolio. We look forward to beginning a close collaboration with Desktop Metal while strengthening our ongoing efforts with our existing partners to transform the AM industry and capture new market opportunities."

Aerosint will operate as a wholly owned subsidiary of Desktop Metal and continue to be led by founders Moens de Hase and Matthias Hick, Innovation Director. Aerosint multi-material products and services will continue to be available to the AM industry with integration into Desktop Metal platforms targeted within the next two years.

www.aerosint.com

www.desktopmetal.com

A multi-metal heat exchanger manufactured with Aerosint's multi-material deposition system (Courtesy Aerosint)

Tsunami Medical launches AM interbody lumbar implant

Tsunami Medical, Modena, Italy, a manufacturing company focusing on technological innovation for spinal surgery and diagnostic invasive procedures, has launched Ustica, an additively manufactured titanium transforaminal lumbar interbody fusion (TLIF) cage. This solution has evolved after years of research from the clinically-proven First Generation TLIF cage.

"This new solution meets with the standards of successfully proven Bone InGrowth Technology®," stated Stefano Caselli, CEO, Tsunami Medical. "Ustica has a unique multi-direction extension mechanism, which allows cranial-caudal height extension in combination with amendment to the required lordosis angle by individual extension in anterior and posterior direction."

The Ustica was developed after years of research, evolving from Tsunami Medical's first generation TLIF cages (Courtesy Tsunami Medical)

Founded in 1997, Tsunami Medical manufactured invasive diagnostic devices as a subcontractor of large manufacturing companies. In 2010, the company started designing and producing devices using Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing technology, resulting in its currently available implant product portfolio.

Peter Witke, CCO, Tsunami Medical, commented, "Solutions with the expansion feature show excellent stability characteristics and the cages are printed in one step. Extension of height, plus the amendment to lordosis angle, are performed with the same introduction instrument."

Caselli concluded, "We consider these meaningful extensions of our TLIF cage family, meeting with international market needs and tender requirements."

www.tsunamimedical.com

QuesTek wins 2021 ASM International award for its Ferrium C64 steel

QuesTek Innovations LLC, Evanston, Illinois, USA, has received the 2021 ASM International Engineering Materials Achievement Award for the design and commercialisation of Ferrium® C64®, a novel high-performance carburisable steel enabling more durable, lighter weight transmission gears with increased power density. QuesTek will officially accept the award in 2022 at ASM's IMAT annual meeting in New Orleans, Louisiana.

"This puts us in the rarified company of previous award winners like the US Army Research Laboratory, NASA Glenn Research Center, IBM Systems and Technology Group, GE Aviation, and Northrop Grumman Corporation, among others," stated Jason Sebastian, president of QuesTek. "We're grateful for the recognition by ASM."

Ferrium C64 began in 2005 as a response to a problem that the US Navy couldn't solve: how to enhance the performance and safety of its helicopters. QuesTek's answer, Ferrium C64, provided gearbox longevity, increased power-to-weight ratio, and reduced costs for production, operation and support. The metal's unique properties – high surface hardness, quench hardenability, high strength and toughness, long fatigue life, and high-temperature resistance –next attracted the attention of the US Army.

Through the Army's Future Advanced Rotorcraft Drive System (FARDS) programme, the company was awarded a subcontract from Bell Helicopter to jointly evaluate the applications of C64 in an effort to improve the performance and affordability of current aircraft drive systems. QuesTek has also demonstrated C64 in Powder Bed Fusion (PBF) Additive Manufacturing technology, where initial results show similar properties to forged bar.

"As a leading provider of aerospace and defence gear material solutions, Carpenter Technology has seen significant interest and adoption of Ferrium C64," stated Marshall Akins, Carpenter's vice president of Aerospace and Defense. "Due to its excellent core and fatigue strength, as well as its high case hardness and temperature resistance, C64 is a cutting-edge solution enabling step-changes in the performance of key applications. We expect Ferrium C64 to play a major role in our specialty steel portfolio for decades to come."

The award was given to the cross-functional team at QuesTek for their direct contributions to the design, qualification and commercialisation of C64 steel: Jason Sebastian, Chris Kern, Jeff Grabowski, Kerem Taskin, Tom Kozmel and Greg Olson.

www.questek.com

PM China expo celebrates a successful 14th show, attracts 31,000 visitors

The 2021 China International Exhibition for Powder Metallurgy, Cemented Carbides and Advanced Ceramics (PM China 2021), which changed its name from Shanghai International Exhibition for Powder Metallurgy, Cemented Carbides and Advanced Ceramics upon the approval of the Ministry of Culture, took place at the Shanghai World Expo Exhibition Center from May 23–25.

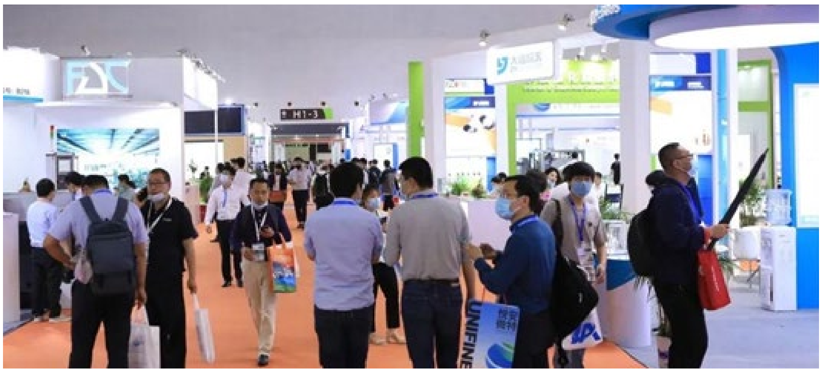
Celebrating its fourteenth edition, the event organiser Uniris Exhibition Shanghai Co., Ltd. welcomed over 31,000 visitors and featured 506 exhibitors across the 30,000 m^2 of show space. Showcased were a range of products, services, and solutions in the fields of Powder Metallurgy, cemented carbides, advanced ceramics, Metal Injection Moulding, metal AM and magnetic materials including materials, applications and production equipment.

This year saw the exhibition adopt a 'Cloud Exhibition' service which enabled 'face-to-face' interviews with exhibitors via camera. The webcasts were shown live on social media and other online platforms. In addition to the exhibition, the event also hosted a number of high-quality academic forums and technical seminars, with over sixty speakers including leading experts, scholars, scientific research talents and corporate executives. The forums and seminars included:

- 3rd Shanghai International Summit on Advanced Ceramic Technology and Industry Development
- 10th Shanghai International Powder Metallurgy & Injection Molding Forum
- 2nd Shanghai Tungsten Industry Summit & International Cemented Carbides Seminars
- Joint Council & Academic Forum Powered by the Powder Metallurgy Professional Committee of Shanghai Mechanical Engineering Society & Powder Metallurgy Branch of Shanghai New Materials Association

The 15th China International Exhibition for Powder Metallurgy, Cemented Carbides and Advanced Ceramics (PM China 2022) is scheduled to take place at the Shanghai World Expo Exhibition Center on May 23–25, 2022.

www.pmexchina.com



Attendees during the 14th China International Exhibition for Powder Metallurgy, Cemented Carbides and Advanced Ceramics (Courtesy PM China 2021)

ExOne's Adoption Center has delivered two million metal AM parts

The ExOne Company, North Huntingdon, Pennsylvania, USA, has reported the company's metal Additive Manufacturing Adoption Center has delivered over two million metal parts to its global customers and has added two X1 25Pro metal AM machines for the dedicated production of stainless steel parts.

Located outside of Pittsburgh, ExOne's newly-renovated Adoption Center produces parts on more than two dozen metal AM machines for industrial customers and on-demand manufacturing service bureaus such as Shapeways, Sculpteo, Xometry, and more. The centre's mission is to allow customers to try metal Binder Jetting (BJT) Additive Manufacturing for their designs before making a machine purchase.

ExOne has qualified more than twenty metal, ceramic, and composite materials for its Binder Jetting process. More than half of those materials are single-alloy metals, such as 17-4PH, 316L, 304L, M2 tool steel, Inconel 718, and more. Most recently, ExOne announced that 6061 aluminium is now a customer-qualified material, and titanium is now fast-tracked for qualification in partnership with a global medical device firm.

The company's most popular material continues to be X1 Metal 420i – a metal matrix composite made up of 60% 420 stainless steel that is 40% infiltrated with bronze, said to be one of the earliest metals ever processed on ExOne machines. This material is durable and corrosion resistant, suitable for industrial and tooling applications, as well as being a material option for consumer goods, such as jewellery.

Two new X1 25Pro machines have been installed in the centre; these are designed for high-volume production and have build areas of 400 x 250 x 250 mm, enabling it to additively manufacture a wide range of part sizes. Currently, the X1 25Pros are being used for the dedicated production of 316L and 17-4PH stainless steel parts.

www.exone.com

Advanced Innovative Engineering uses Additive Manufacturing to re-engineer rotary engines

Advanced Innovative Engineering (AIE), a manufacturer of rotary engines based in Lichfield, Staffordshire, UK, has turned to Additive Manufacturing to improve the performance of its engines. The goal for the company, located at the heart of the UK's aerospace engineering and manufacturing industries, was to investigate the suitability of AM to reduce weight, cut product development and manufacturing lead times and lower production costs.

Through the DRAMA (Digital Reconfigurable AM facilities for Aerospace) project, led by the UK's Manufacturing Technology Centre (MTC), engineers from the National Centre of Additive Manufacturing (NCAM) based at the MTC visited AIE to gain an understanding of the products currently manufactured and the processes involved. NCAM then split the project into three distinct activities:

AIE rotary housing – conceptual fin designs: Fin designs were to be constrained, thereby maximising heat dissipation within the motor housing, whilst remaining within the original engine geometry bounds and minimising weight. A variety of fin geometries fell into approximate categories: honeycomb lattice, TPMS Gyroid lattice and algorithmic tree. Each were developed within the constraints allowed before being additively manufactured. This allowed AIE to assess as-built surface roughness and the potential for manufacturing and functionality issues.

Thermal/structural FEA simulation: the two preferred fin designs and primary engine components (engine housing and front & rear end plates) underwent structural simulations to assess areas of critical concern for stress values below yield point criteria for aluminium under the scenarios modelled.

AM process selection: Laser Beam Powder Bed Fusion (PBF-LB) was selected as the most appropriate AM process. A build layout was created and demonstrator parts were additively manufactured using a Renishaw 500Q AM machine.

NCAM engineers, with this testing criteria, have succeeded in helping AIE to reduce the engine mass from 6 kg to 4 kg, reduce component count significantly and, therefore, manufacturing costs, while maintaining the engine's operational capability.

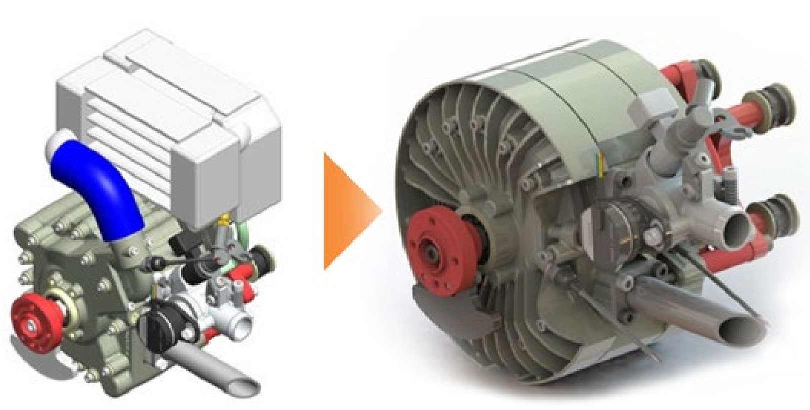
Various fin geometries tested against AIE's operational requirements (Courtesy DRAMA/AIE)

Encouraged by these results, AIE expects to pursue this with a follow-on project to further explore the thermal sensitivity of the assumed input parameters, as well as considering convective and radiative heat transfer interactions between surface. Further CFD studies of the fluid flow over the engine will also be undertaken to more accurately assess flow characteristics through the fin designs and better inform design for a full production version.

"Accessing the expertise of NCAM through the DRAMA programme has been instrumental in enabling AIE to develop an understanding of metal Additive Manufacturing, its potential applicability to its engine designs and the solutions it can provide over and above traditional manufacturing processes. DRAMA really has been a game-changer for AIE, reshaping our approach to product design through seeing what is possible using AM," stated Nathan Bailey, Managing Director, AIE.

DRAMA project partners include MTC, ATS, Autodesk, Granta Design, MAA, NPL, Renishaw and the University of Birmingham.

www.aieuk.com
ncam.the-mtc.org



Original rotary engine (left) post-project engine (right) (Courtesy DRAMA/AIE)

Neutrons used to detect internal stress in AM parts

A team of researchers gathered from the Federal Office for Materials Research and Testing (BAM) and Siemens Energy GmbH, both based in Berlin, Germany; the Heinz Maier-Leibnitz Center, Garching; and the University of Potsdam, Institute of Physics and Astronomy have succeeded in using neutrons from the Technical University of Munich research neutron source reactor for non-destructive detection of internal stress within additively manufactured turbine buckets.

Gas turbine buckets have to withstand extreme conditions whilst exposed to tremendous centrifugal forces at high temperatures and under high pressure. In order to further maximise energy yields, the buckets have to hold up to temperatures which are higher than the melting point of the material. This is made possible by manufacturing hollow turbine buckets which are air-cooled from the inside.

These turbine buckets can be made using Laser Beam Powder Bed Fusion (PBF-LB), producing intricate lattice structures inside the hollow turbine buckets that provide the part with the necessary stability.

"Complex components with such intricate structures would be impossible to make using conventional manufacturing methods like casting or milling," stated Dr Tobias Fritsch of the BAM.

But the laser's highly-localised heat input and the rapid cooling of the melt pool lead to residual stress in the material. Unfortunately, these stresses can damage the components as early as during the production process, and up until the necessary post-processing takes place.

Fritsch, with previously-gained experience in neutron measurements in mind, investigated a gas turbine component for internal stress using neutrons from the Research Neutron Source Heinz Maier-Leibnitz (FRM II). The component was made using Additive Manufacturing processes by gas turbine manufacturer Siemens Energy, which additively manufactured a lattice structure only a few millimetres in size using a nickel-chrome alloy typical of those used for gas turbine components. The usual heat-treatment after production was intentionally omitted.

"We wanted to see whether or not we could use neutrons to detect internal stresses in this complex component," explained Fritsch. "We're very glad to be able to make measurements in the Heinz Maier-Leibnitz Zentrum in Garching; with the equipment provided by STRESS-SPEC we were even able to resolve internal stress in lattice structures as intricate and complex as these."

Now that the team has succeeded in detecting the internal stress within the component, the next step is to reduce this destructive stress.

"We know that we have to modify the production process parameters and, thus, the way in which the component is built up during printing," added Fritsch. "The more localised the heat application is during the melting process, the more internal stress results."

For as long as the AM machine's laser is aimed at a given point, the heat of the point rises relative to adjacent areas. This results in temperature gradients that lead to irregularities in the atomic lattice, meaning heat should be as evenly distributed as possible through the manufacturing process. In the future, the group will research the situation with new components and modified manufacturing parameters. The team is already working together with Siemens to plan new measurements with the TUM neutron source in Garching.

Further details are available via the original research paper, published in the *Journal of Applied Crystallography*.

www.bam.de
www.siemens-energy.com
www.mlz-garching.de
www.physik.uni-potsdam.de
www.tum.de

Using the remote control Dr Tobias Fritsch brings the lattice structure into the correct measuring position in the residual stress diffractometer STRESS-SPEC at the research neutron source (Courtesy Dr Michael Hofmann / TUM)

Optimised thermal management in semiconductor fabrication using AI-enabled generative design and Additive Manufacturing

An unexpected consequence of the COVID-19 pandemic has been its impact on the multibillion dollar semiconductor microchip market: at the very same moment as demand for consumer electronics skyrocketed due to global lockdowns, the supply of semiconductors was bottlenecked by production disruptions. Now, supply chain shortages threaten the production volume of the industries dependent on these parts. Scott Green and Niels Holmstock, 3D Systems, and Lieven Vervecken and Gert-Jan Paulus, Diabatix, explore how metal AM can be used to increase efficiency in semiconductor fabrication and boost the speed at which these vital components can be produced.

Metal Additive Manufacturing is easily connected with market segments such as aerospace, automotive, and healthcare, but the value AM provides is unique, and can be applied to any market segments wherein the performance and function of a system can benefit from function-first component design methodologies.

In 2021, it has never been more critical for semiconductor fabrication equipment to have the highest possible productivity, reliability, and technical capability to help alleviate the burden of global chip shortages. Sometimes, nothing major changes, and new endeavours are not attempted, until there is a deadline, pressure, or an emergency – and the race is on. Now, novel AI-enabled generative design software, plus production-quality metal AM, are working together to solve major performance and supply chain challenges in the semiconductor capital equipment industry. Fig. 1 shows a metal AM wafer table with a sophisticated cooling structure, key to increasing the efficiency of semiconductor manufacture.

Microchip fabrication and supply chain shortages

Microchip fabrication is considered state-of-the-art in advanced manufacturing. This industry is driven by the pursuit of faster, more efficient processors and higher capacity memory chips where we see racing vectors driving ultra-high levels of detail fidelity, resolution, and precision, all wrapped within massive investments in advanced tooling systems and infrastructure. Multibillion dollar production lines depreciated over billion-unit production runs present staggering metrics, as well as massive continuous optimisation initiatives. When it comes to optimising the hardware

Fig. 1 Metal AM makes it possible to produce wafer tables with sophisticated integrated cooling structures, greatly improving efficiency in semiconductor manufacturing (Courtesy 3D Systems)

Fig. 2 An additively manufactured hydraulic manifold produced on 3D Systems' DMP 350 platform (Courtesy 3D Systems)

and tools that exist within these production lines, the emergence of industrial Additive Manufacturing solutions has started to present a significant opportunity to engineers and designers at the very front line of problem solving.

Now, more than a year into the pandemic, we're all too familiar with its impacts, not least of which is the blow dealt to supply chains. An unexpected side effect of the pandemic has been a global shortage of semiconductors, which is disrupting the production of all sorts of consumer products, from cars to electronics. In December 2020, Volkswagen said that bottlenecks in the supply of semiconductors meant it would produce 100,000 fewer cars in the first quarter of 2021, as its parts makers were unable to secure supplies. Nissan, Renault, Daimler, and General Motors are also struggling with the shortage, which may lead to production being reduced by as much as 20% per week.

On top of this, due to the pandemic requiring the vast majority of the population to work remotely and stay at home, demand for consumer electronics, such as laptops and entertainment devices, has skyrocketed. The manufacturers of these devices are competing for microchip supply with the automotive industry, as modern vehicles come with increasingly sophisticated technology and computing built into their designs.

If we need more chips, can't chip manufacturers just increase manufacturing capacity? In theory, it sounds easy enough, but production capacity and technology are proving to be hurdles in achieving these goals. For semiconductor fabrication plants to increase production, they need to install new manufacturing lines. These lines require new equipment, and capital equipment manufacturers are innovating to help fabricators meet the increased demand. However, these tools are complex and expensive, with a long product development cycle; in some cases, lead times are six to nine months. As such, it is difficult for capital equipment manufacturers to pivot production lines that rely on traditional manufacturing technologies in order to scale proportionately to unexpected demand growth like we're seeing today.

Additive Manufacturing to the rescue

Within silicon wafer tooling there are many complex phenomena with which to interact. Temperature, inertia, turbulence, resonance, vibrations, precision, wear-and-tear, and ultra-high level sanitation standards driven by a zero-tolerance policy for contamination, converge to present a significant challenge, while, at the same time, offering many opportunities for optimisation. This is where Additive Manufacturing comes in. AM allows for step changes in component performance and efficiency.

Following the traditional rules of design and manufacture as they apply to conventional parts, performance is always somewhat compromised, since the dawn of computer-aided design, or even before. By using Additive Manufacturing, and specifically by embracing design for Additive Manufacturing (DfAM) and the philosophy of 'design for function', companies at the frontline of problem-solving are able to innovate in ways previously considered impossible. AM's rapid adoption in semiconductor capital equipment (semicap) manufacturers is improving quality, production, technical capability, and reducing supply chain risks.

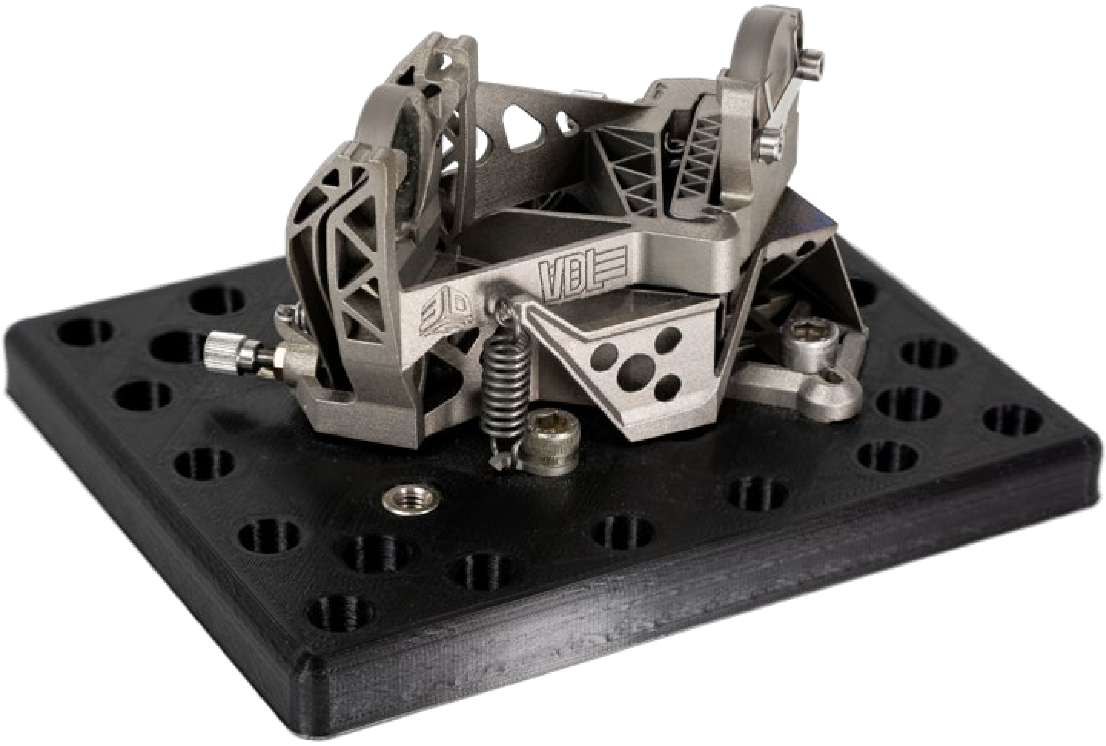


Fig. 3 An additively manufactured optical assembly produced as a single consolidated part on 3D Systems' DMP 350 platform (Courtesy VDL)

There are countless interesting challenges in semicap, but they can be boiled down to three key topics of function-first design:

- Fluid manifold flow optimisation
- Part count reduction and mass management
- Thermal management

Fluid manifold flow optimisation

Traditionally, these very complex components are time consuming and difficult to fabricate, requiring multiple manufacturing processes, from sheet metal folding to hydroforming and tube bending, all integrated with assembly steps. The net result never quite approaches the perfect solution, as the vast assembly processes and steps are full of potential points of failure. When AM is applied, designers can present the perfect tubular system, using advanced fluid flow computational fluid dynamics (CFD) to influence and, in some instances, automate the creation of forms, as well allowing the integration of sophisticated baffle strategies which allow for minimising turbulence while maximising flow efficiency. The benefit of such architectures is the minimisation of vibrations and resonance that correlates with net turbulence within systems, as shown in Fig. 2.

Turbulence and vibrations impact the precision of output, and, in a world where nanometres count, this presents significant capability. Using 3D systems' DMP 350 platform engineers were able to realise a 90% reduction in liquid-induced disturbance forces to reduce system vibration and realise 1–2 nm accuracy improvement.

Part count reduction and mass management

An added benefit of AM is its ability to grant designers access to significant levels of component consolidation, which ultimately drives the design efficiency principle of part count reduction, thus leading to the expression of complex manifolds as monolithic components with no assembly required. This simplifies not only supply chain lead time, but also makes the process of design easier. In some examples, we have seen lead times of months become hours, driven by the elimination of tooling, assembly, and the associated inspection process. A part count reduction of up to 50 x has been achieved through component consolidation in some of these complex systems. An example of a highly complex optical assembly produced in one part using metal AM is shown in Fig. 3.

Down selection of alloys to cheaper lower density materials is just one driver of weight reduction. DfAM generally presents significant opportunities for more efficient design through bulk material savings. Lighter weight assemblies in semicap have multiple benefits, including:

- Lower thermal mass, which results in faster thermal condition response
- Lower inertia results in opportunities for faster and higher precision conveyance, and more precise stop and start

Fig. 4 A silicon wafer table with integrated advanced cooling structures (cut-away section) produced using 3D Systems' DMP Factory 500 (Courtesy 3D Systems)

acceleration/deceleration profiles, while reducing wear and tear of mechanisms

- Reduced mass/inertia combined with DfAM-based improvements in the stiffness of subcomponents in high-velocity reciprocating mechanisms, which also reduces vibration generation within systems

At a silicon wafer tooling company, engineers were able to realise a 50% weight reduction for reduced inertia, with a boost in stiffness of 23%, resulting in a higher resonant frequency and reduced system vibration, all equalling improved speed and productivity.

Thermal management

Another application where we see AM presenting step changes in capability is in the production of highly efficient wafer tables (as shown in Fig. 4). These tables are used for handling and fixturing the silicon plates during the manufacturing process. Thermal variation causes minute changes in the expansion of materials. Over time, these thermal gradients and fluctuations can create scenarios where the position of structural elements being additively manufactured and accumulated on the surfaces of the silicon wafers can shift (commonly known as edge placement error, or EPE). To solve this, engineers are turning to AM to design, develop and manufacture next-generation silicon wafer table architectures.

One silicon wafer tooling company was able to realise a sixfold improvement in thermal performance and a fivefold stabilisation improvement. The thermal profile within the conditioning ring was able to see a ΔT improvement from 13.8 mK to 2.3 mK, with a thermal temperature gradient reduced from 22 mK to 3.7 mK, in a more responsive system presenting a time constant moving from 7 s to 1.5 s.

The efficiency, performance, and responsiveness of the AM architecture were so high that the engineers were able to look at actually regressing an alloy selection from expensive copper to cheaper and lighter aluminium – an unanticipated benefit of a DfAM design optimisation functionality offset. In the case study below, we will discuss a cutting edge approach to achieving optimal thermal performance.

We have previously discussed what technical values AM provides at a component or subsystem level, but it is also important to understand the pressures on semicap, which make applications such as the following wafer table function optimisation case study a perfect example of a confluence of values and benefits.

Yield

With semiconductor equipment typically being large and costly, customers are expecting significant yield from a single machine.

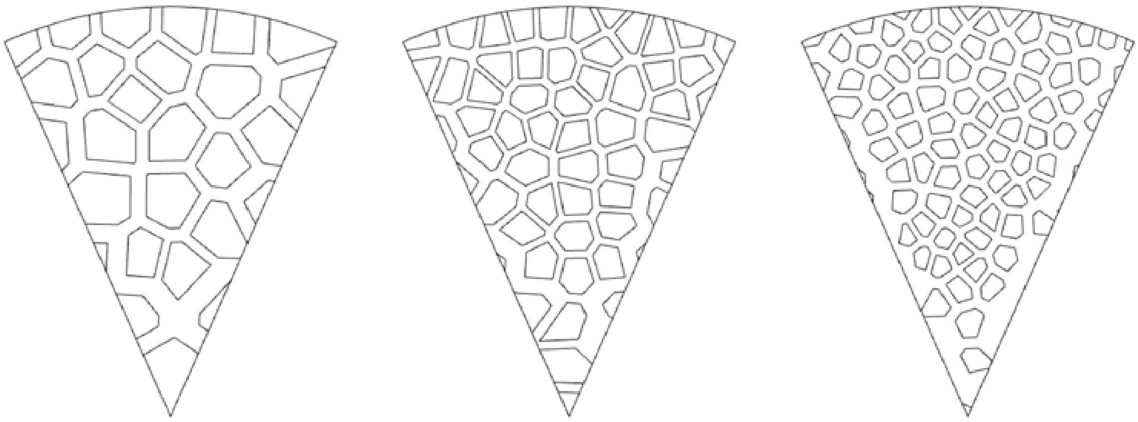


Fig. 5 Parametric line work model of a best first guess Voronoi structure and its limitations in parametric variations (Courtesy 3D Systems)

Reliability
The reliability of the semiconductor equipment is key with outages leading to significant losses in missed production time.

Precision
Moore's Law expects transistors to reduce in size every two years. To meet this expectation, transistor density is increasing, and phenomena such as EPE in semicap are becoming harder to overcome.

Wafer table case study

Although we see an increasing demand for AM components across the entire process chain of microchip production, lithography has been at the forefront of metal AM adoption. Lithography is a key step in the microchip production process and a significant contributor to transistor density on a die. As this is an early step in the production chain, having a high yield is vital. The wafer table is one of many key components in semicap, especially in lithography.

There is an ongoing transition away from human-made design towards computer-generated (i.e. generative design), and human-aided design (as opposed to computer-aided design).

Generative design and structural topology optimisation are relatively well understood as an approach in 2021, but there are many unique segments of topology optimisation. Uniquely, in this case, we will discuss topology optimisation as a product of automated, massive parallel iterative loops of computational fluid dynamics simulation and DfAM. Here, we detail the realisation of a semiconductor wafer cooling table demonstrator from design concept to Additive Manufacturing. As part of this exercise, we will compare traditional cooling design to generative cooling design and how it affects performance and design effort.

Traditional design workflow
As in many engineering disciplines, the traditional design workflow for cooling channel design is dominated by trial and error. A designer draws a cooling design, which can be tested against the specifications through either CFD simulation or prototype and practical testing. Benchtop tests can be simple and easy, and, depending on the application, full system integrated tests can be challenging, with schedule and cost being major factors.

When designing a cooling pattern, the first guess is typically based on rules of thumb and directly reused or rescaled designs of earlier work; with enough experience, you can apply heuristic design rules to get a good starting point. Rarely does this work out on the first try; after a failure, the designer must make continued iterations. This approach is only slightly better than blindly designing.

Traditional parametric CAD has the framework for generating many design options and can be partly automated. It takes a moderately experienced designer to invoke a design table of sorts, and define a set of parameters, such as channel width, number of turns, etc., with this structure allowing for rapid iteration on a complex design by parameter changes. However, it is important to understand that, with this design approach, the performance of the final design is directly correlated to the quality of the initial guess. As there is no guarantee that this initial guess is even sufficiently close to the desired result, there is no guarantee the desired result can be reached with even huge parameter changes.

To illustrate, if a designer starts with a design characterised by parallel cooling fins, they will never be able to generate anything other than derivations of that design strategy within some narrow variations (Fig. 5). This approach typically leads to multiple lengthy and costly iterations and introduces significant uncertainty on the design cycle time. There can also be major implications on the programme schedule if lengthy

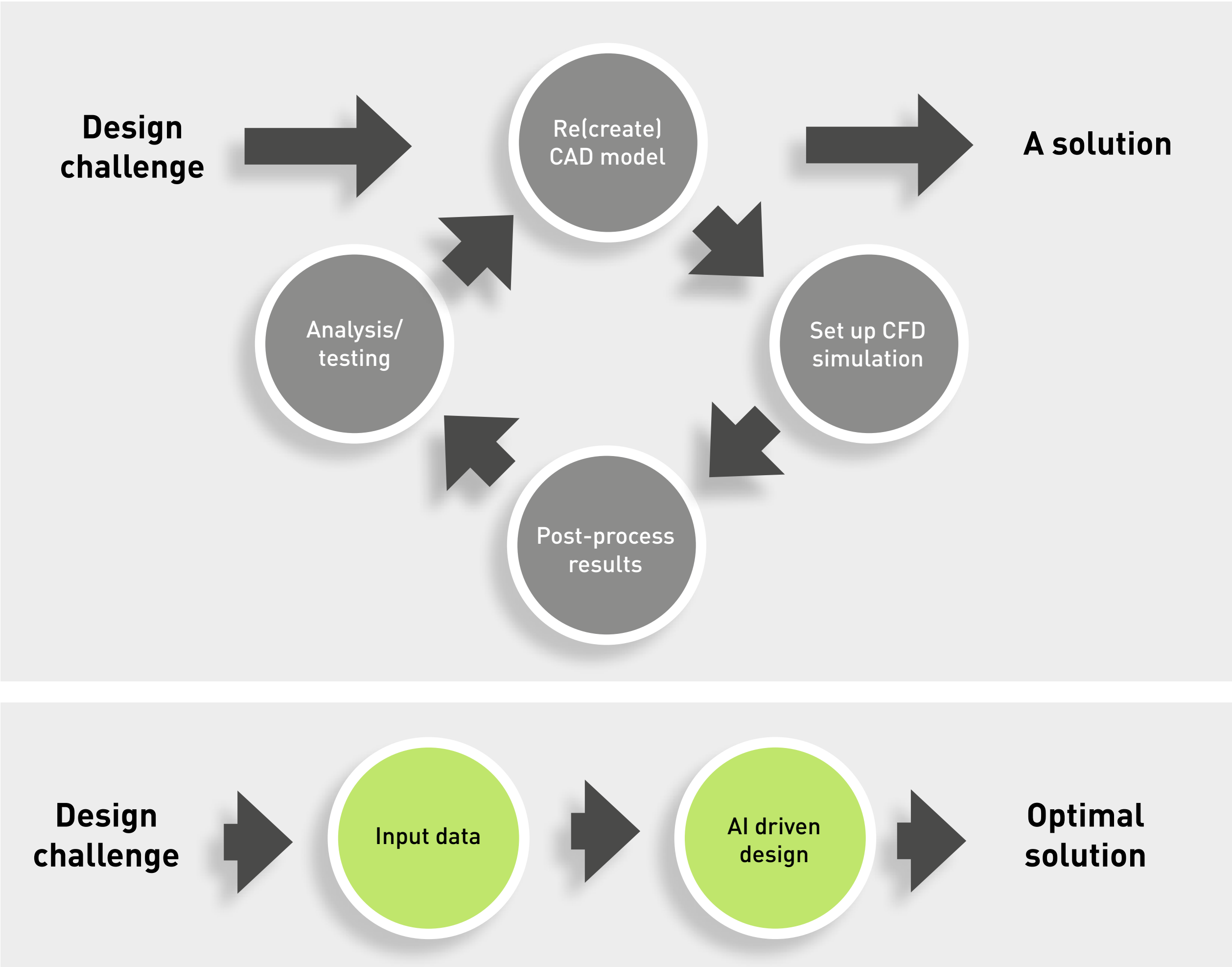


Fig. 6 Top; a conventional design cycle, from design challenge to solution, and bottom; the generative design cycle, from design challenge to optimal solution (Courtesy Diabatix)

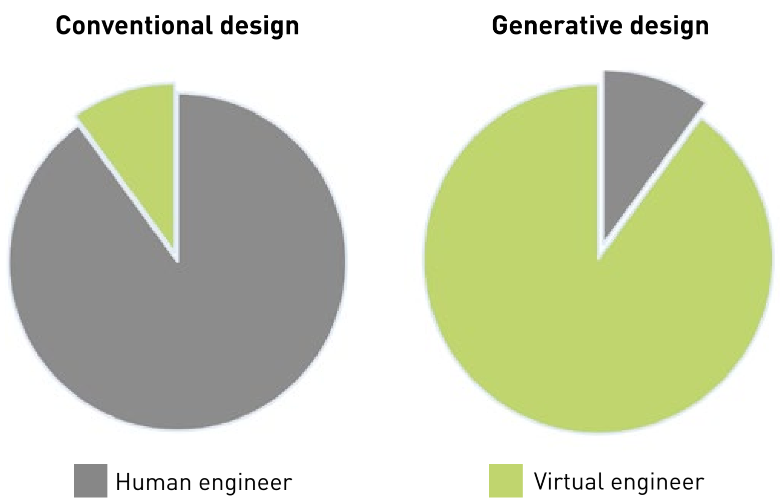


Fig. 7 Comparison between the involvement of a human engineer and virtual engineer in conventional and generative design (Courtesy Diabatix)

manufacturing processes are used for production; weeks and months can pass between iterations, knowledge and experience, allowing momentum to be lost. Furthermore, if the designer did not take manufacturing limitations into account and the analysis was done by simulation, there is a significant risk that the design will not even be manufacturable, despite all efforts. These issues, however, can be addressed with generative design and Additive Manufacturing.

Generative design – optimising for Additive Manufacturing

The American Psychological Association and National Institutes of Health indicate that humans are only able to manage simultaneous consideration of roughly three to four concepts.

This natural human limitation has been a driving force in mechanical design for as long as parts have been made. When designing high-tech components where function is critical, the overwhelming consideration of physical and functional constraints alongside manufacturability parameters become too much for one person, and whole teams of people and specialists must get involved, thereby increasing the overhead and lead time.

Generative design is an automated design process that requires minimal human input or interaction to achieve highly-optimised design files with ideal functional performance. By making use of physical modelling, massive computational resources, and state-of-the-art optimisation and artificial intelligence techniques, generative design can overcome the limitations of a traditional CAD design approach. The overwhelming and simultaneous consideration of parallel constraints is reduced to a few simple steps for setting constraints in a software program, and a generative design engine does the rest. The starting point for generative design is not a best guess, but simply a description of the design target, an indication of the available design space, and a set of design limitations such as manufacturing constraints. When using generative design software, engineers are no longer designers in a committee, but become managers of their own virtual design team. A comparison of the conventional and generative design cycles, and the degree of human involvement in each, is shown in Figs. 6 and 7.

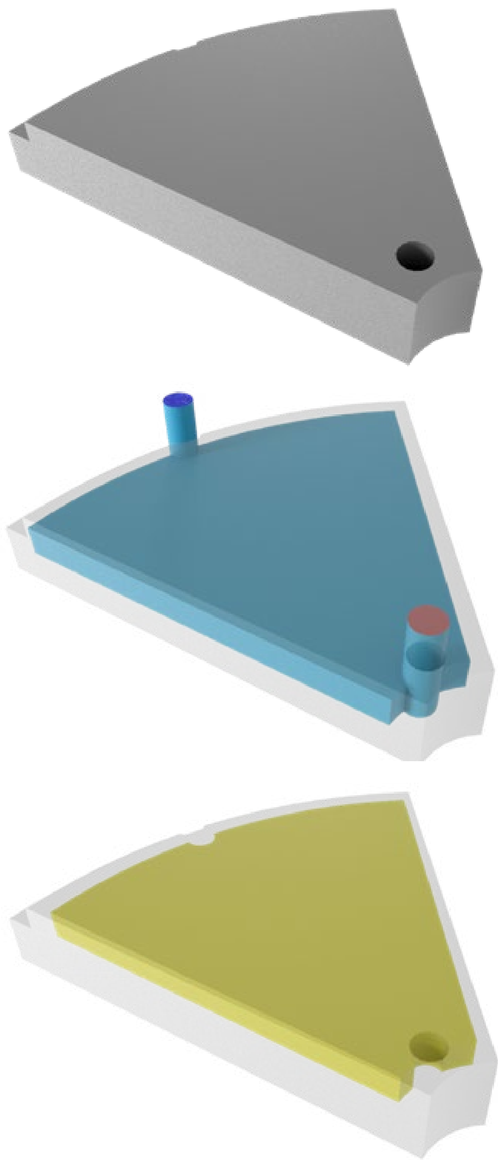


Fig. 8 Top: solid part; middle: fluid region; bottom: design region (Courtesy Diabatix)

Setting up the generative constraints

In the first step, the creation of the design setup, all information required to create the design is collected. The starting point is a set of CAD bodies that include the geometries of the main components, the domain in which the coolant can flow, and the domain that represents the design region (Fig. 8). Once the geometric information is available, the boundary conditions can be applied. Similar to a traditional CFD simulation, information such as material properties, coolant properties and pass/fail heat map tolerances are required.

Finally, the targets of the design need to be set. These targets contain information about the design objective, the system constraints, and the manufacturing limitations. Almost any design target can be chosen as long as a mathematical equivalent can be formulated – for example, cost or manufacturing time reductions can be achieved alongside more traditional requirements regarding temperature, weight and pressure.

The actual generative stage is an iterative process that does not require human interaction. The process collects data from thousands of sequentially executed advanced CFD simulations to make measured design changes in each step of the process. Besides the physical input from the CFD simulations, feedback on manufacturability is collected during each step of the process. Because of this computationally-heavy workload, the process is executed through commercial cloud services, using several hundreds of CPUs in parallel. During the process, the cooling

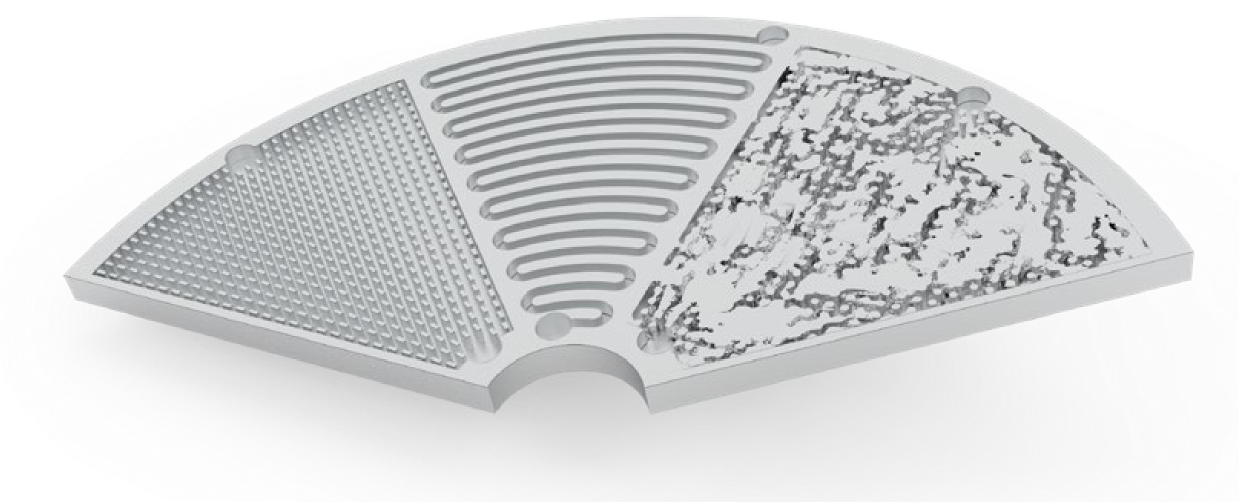


Fig. 9 Three possible cooling strategies presented as 45° sections of a design in order to compare performance (Courtesy 3D Systems)

structure is gradually built within the designated design space, considering the physical properties of the material and the coolant.

After completion of the design process, the generated design is converted into a common CAD file format and ready for use. Because simulation is an integral part of the generative design process, a performance analysis is immediately available, as well, which allows for the assessment of design quality and to unveil new opportunities, such as reducing the component envelope.

The main objective in this case study is to maximise the thermal uniformity of the wafer table, while not inducing fluid pressure drop in the system. A bonus benefit of an advanced cooling strategy would be a minimal time to stabilised operating temperature, resulting in an incremental production rate increase.

Physical constraints

Geometry
Disc-shaped thermal load with an internal diameter of 60 mm, an outer diameter of 300 mm and a thickness of 28 mm

Material choice

- Aluminium (AL6061-RAM2), due to its good thermal conductivity and moderate strength for this application
- Typically, a thermal table does not require a very high-strength material due to its limited physical load
- Ductile materials such as copper would not be appropriate. Though copper alloys provide significant thermal conductivity values, they are much too soft for loads and high accelerations
- Low cost, prolific, easy-to-additively-manufacture aluminium alloys containing silicon may appear to be the right fit for such applications based on datasheet values, but, from an application perspective, the silicon content is unacceptable for many applications, either due to dangerous fluid reactivity or concerns around silicon contamination of the wafer product

Operational constraints

- Distilled water is used as a coolant so there are minimal concerns for alkaline corrosion
- The heat source presents itself uniformly at roughly 10 Watt over the full surface
- At the inlet, the volumetric flow rate is fixed to 7.5 litres per minute at a temperature of 21°C

Result constraints

- The target is maximising the temperature uniformity over the surface while considering that it needs to be at least below 0.1°C
- The pressure loss between the inlet and outlet is set not to exceed 70 kPa
- To ensure that the design can be manufactured, the manufacturing guidelines of PBF-LB Additive Manufacturing on a DMP machine are selected: namely, a maximum overhang angle of 45° and a minimal wall thickness of 150 µm. We assume a flat build orientation, which is typically preferred in AM for large discs. This flat orientation has the added benefit of creating a flat control surface on the bottom during wire EDM plate removal

By making use of the periodicity in the design, we divide the disc into sections of 45° with different cooling channels and compare performance (Fig. 9). We assume one inlet and outlet per section. In this article, we limit our analysis to two conventional designs and one generative design. The state-of-the-art Diabatix ColdStream® platform is used for this case study. This platform is the first to offer generative design for flow and thermal components. All analyses and generative design are performed by Diabatix®.

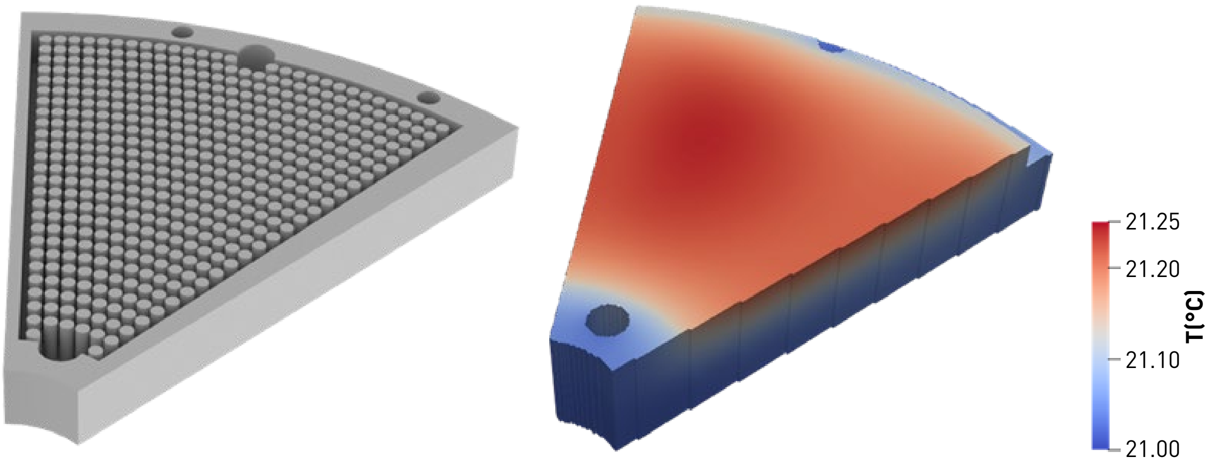


Fig. 10 Left; pin-fin design reference, right; heat map for pin-fin strategy (Courtesy Diabatix)

CONVENTIONAL DESIGN 1
Cooling fin array
One common design strategy for cooling is 'pin-fin', shown in Fig. 10. The pin-fin strategy is easy to design manually and creates a large heat exchange interface. Yet, from an AM point of view, this design has two disadvantages. First, gaps between fins cannot be more than 4–5 mm in metal AM, as they need to provide enough support for the closing surface over the cooling channel. Second, by not making use of the third dimension, there is room for improvement.

When analysing the performance of the fin array, we noted that the pressure drop of 22 kPa is below specification. The temperature peaks at 21.24°C and the temperature spread is not within the 0.1°C constraint. The coolant primarily follows the path of the lowest resistance, which is the direct connection between the inlet and outlet. As a result, local hotspots are difficult to avoid. Variations on this design can be imagined, which attempt to force fluid divergence at the inlet and convergence at the outlet. Changing the pin density can help reduce the occurrence of hotspots, but will strongly increase the pressure drop, as well. Summary of results:

- Max temperature (21.4°C)
- Temperature gradient (0.12°C) FAIL
- Pressure drop (22 kPa) PASS
- Time to stable temp (410 sec)

CONVENTIONAL DESIGN 2
Linear serpentine channel
Another, even more common design strategy often employed is the serpentine channel, shown in Fig. 11. Using this type of channel in AM components imposes a constraint on the channel's width. As with the previous pin-fin design, there are maximum bridging distance constraints. As a result,

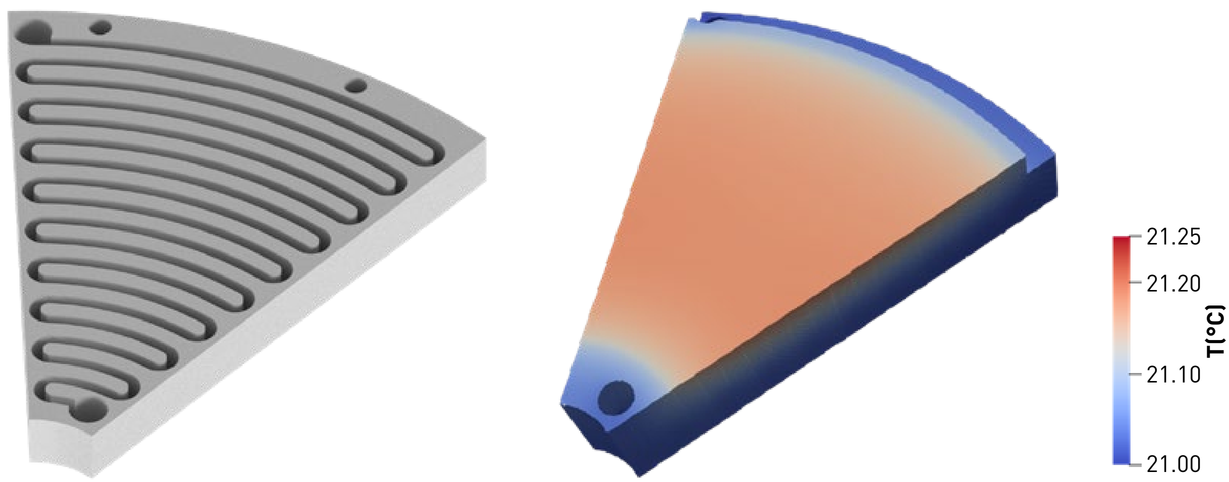


Fig. 11 Left; serpentine design reference, right; heat map for serpentine strategy (Courtesy Diabatix)

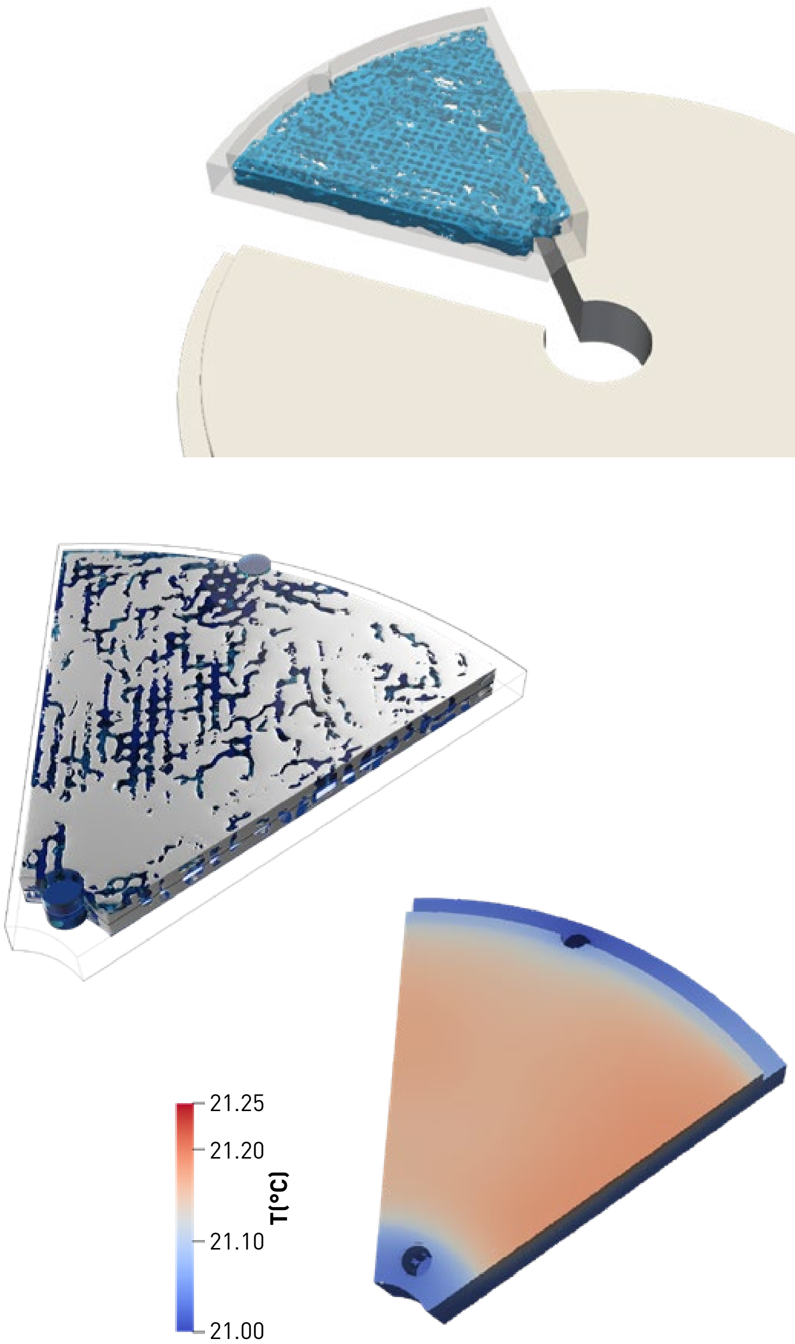


Fig. 12 Top: generative result reference; middle: close up of generative result; bottom; heat map for generative strategy (Courtesy Diabatix)

a fairly long channel is required to provide sufficient coverage of the surface. Furthermore, prior experience tells us sharp switch-back style interior channels can create challenges in maintaining ideal pressure in operation. Even more challenging are the powder removal implications for such a strategy.

When analysing the simulated performance of this traditional channel design, we remark that the maximum temperature is only 21.18°C and that the temperature spread of 0.09°C passes the bar, but, as expected, the pressure drop of 420 kPa is far beyond acceptable. This is a direct consequence of the length of the channel.

More complex derivations of the strategy which can help reduce the pressure drop and maintain a high-temperature spread are possible. One such example would be multiple parallel serpentine channels with individually shorter overall lengths and comparable, or longer, cumulative channel areas. This could be preferable, but would require a longer initial design time, and likely a long tail of iteration on proper Inlet channel divergence and outlet channel convergence strategies. Summary of results:

- Temperature gradient: (0.09°C) PASS
- Pressure drop: (420 kPa) FAIL
- Time to stable temp (409 sec)

GENERATIVE DESIGN
The best of all worlds

As previously described, the generative design (Fig. 12) delivers on the promise of highly optimised geometry with minimal input constraints, creating optimised and unique solutions to specific problems. It is possible, with enough generative design experience in a narrow range of problems with sufficiently wide parameters, that a designer could develop a heuristic approach to solve structural design problems on their own. But, in the use cases of thermal management with fluid flow and precision constraints, a new range of extremely complex solutions are being produced, which become nearly impossible to generalise with a human-created design strategy, while maintaining the significant technical merits the computer-generated solution provides.

By making active use of the third dimension, a complex network of channels is created that directs the flow to the regions of interest. By design, the structures are self-supporting and obey the required minimal and maximal feature sizes. These shapes are well beyond human engineering capabilities. In this practical example, we will explore the efficiency and details of this novel approach.

The performance of the Diabatix ColdStream results fall perfectly within acceptable end tolerance ranges for both pressure drop and temperature uniformity. The peak temperature is 21.18°C, an improvement of 25% compared to the fin array, and the lowest of the three designs. Also, the temperature spread is with 0.1°C on target. The temperature is very similar to the serpentine channel, but the 40 kPa pressure drop of this design is more than 10 times lower. This performance is achieved by alternately making use of smaller channels with high heat transfer rates and high-pressure drops, as well as larger channels with both lower heat transfer rates and low-pressure drops.

By using the Diabatix ColdStream platform, preparation of the design process and analysis of the results only requires a few hours of human engineering time. In return, a design is generated that easily outperforms conventional designs. Furthermore, manufacturability can be ensured.

The drawback of this is that the process is computationally expensive. At the time of writing this article, this problem can take several weeks to calculate completely even while using hundreds of CPUs in parallel. Yet, it does not require any human intervention, nor any additional design iterations afterward.

This makes it a very effective method for design cycle time reduction. Like the design process, the manufacturing process also runs without any human presence, allowing it to function overnight, during weekends and over holidays. Summary of results:

- Max temperature: 21.18°C
- Temperature gradient: (0.1°C) PASS
- Pressure drop: (40 kPa) PASS
- Time to stable temp (381 sec)

Comparative summary

In this study, three cooling strategies were investigated: a cooling fin array, a linear serpentine channel,

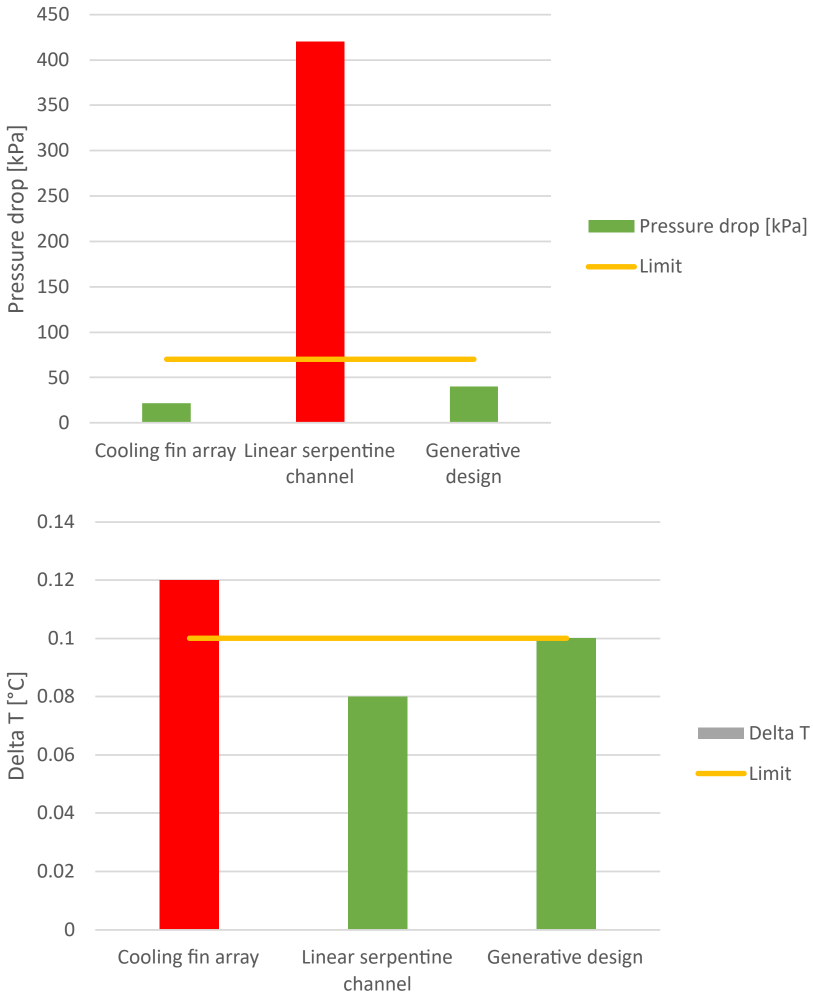


Fig. 13 Top; pressure drop performance comparison, bottom; temperature performance comparison (Courtesy Diabatix)

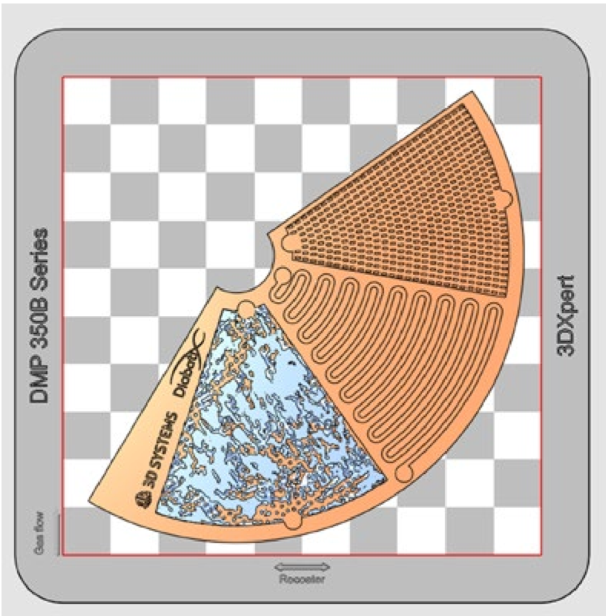


Fig. 14 Cooling strategy demonstrator prepared with 3DXpert (Courtesy 3D Systems)

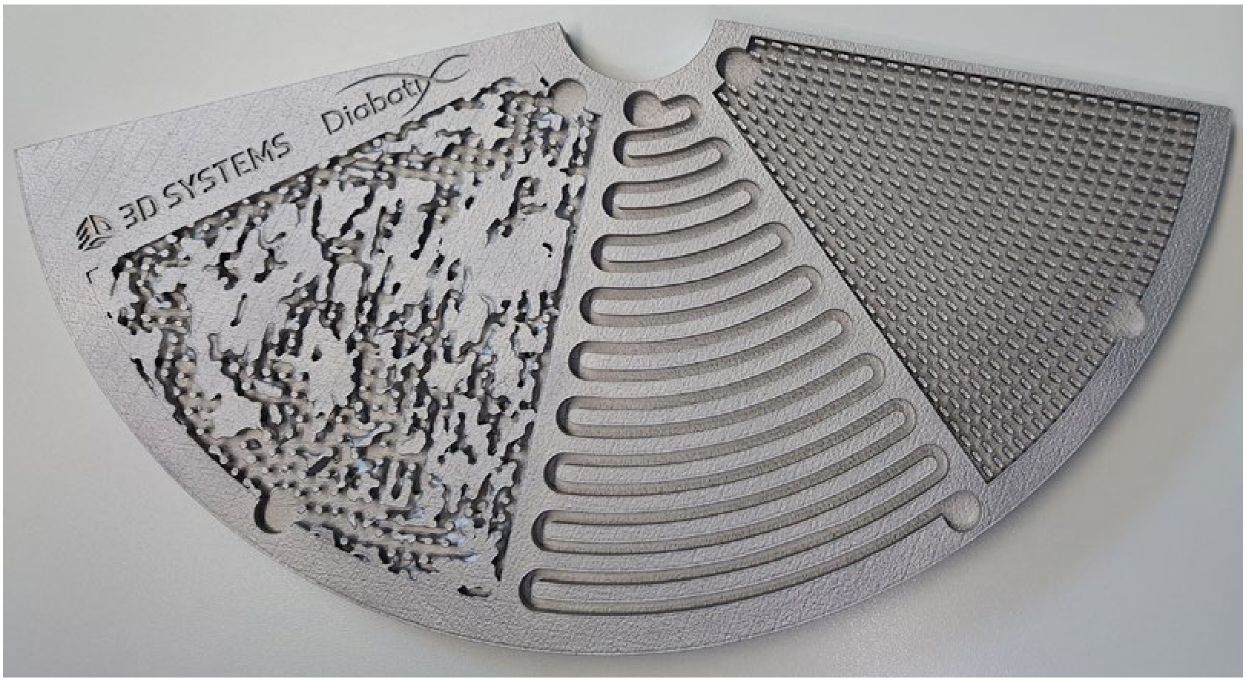


Fig. 15 The final metal additively manufactured cooling strategy demonstrator (Courtesy 3D Systems)

and a Diabatix generative design. The generative design approach produced an optimised 3D geometric solution, which satisfied the overall temperature gradient constraint, exceeded the pressure drop constraint and satisfies metal AM constraints. An unexpected benefit of the generatively-designed component was a 29 sec reduction in the time required for the component to get to stable temperature (Fig. 13). This ~7% reduction in wait time translates directly to increased productivity, thus more wafer product produced per day.

Metal AM workflow

In a typical AM workflow after the design phase, we enter the build file generation phase. Using 3D Systems' 3DXpert® comprehensive Additive Manufacturing software (Fig. 14), the following steps were performed.

1. Positioning and orientation of the 3D file for manufacture
2. Rescaling the 3D file to account for shrinkage that occurs during manufacture
3. Add material for post-processing where needed
4. Add manufacturing supports
5. Build simulation
6. Final slice & hatching
7. Export package for manufacture

No matter which AM tool is targeted, the general workflow is the same. However, there are some unique aspects of the implemented solution that require some illustration.

In 3DXpert, the combination of slicing and hatching is automated based on a selected technology profile. For standard users, a handful of default profiles are provided for each material, which will result in good mechanical properties. Expert users have the option to tweak and create their technology profile, leading to a high degree of optimisation, but this can also increase the risk of not getting validated results.

There is also valuable flexibility in user-defined build style zones. These zones can be defined around critical features (in full 3D) and can be assigned build style profiles. This novel build style assignment strategy allows the user to apply constraints to individual features on a part resulting in the best mix of speed, quality, and accuracy for any given project's unique requirements.

Additionally, full build simulation technology is quite accurate, and increasingly powerful computational simulation tools are available to simulate the result of the print process without having to print the part. This can greatly increase the chance of first-time-right manufacturing and reduce scrap costs. By making use of 3DXpert's integrated Additive Works Amphyon technology, significant reductions in cost and time spent during trial and error can be realised, allowing for faster time to successful manufacture.

Post-processing

In metal AM, the Laser Beam Powder Bed Fusion (PBF-LB) process is typically only the beginning of the production process, with parts undergoing multiple post-processing steps. Often seen treatments are:

Heat treatment

Relax any residual thermal stresses and/or optimise the material's microstructure for the relevant application

Base plate removal
Typical wire-EDM for accurate cuts or bandsaw for rough cuts

Support removal and shot peening
Often still a manual process, but automated processes are arising

Finishing
Chemical finishing and smoothing are common practices for high-requirement parts

Machining
CNC machining of high-precision interfaces is typically applied, but it is advantageous to apply proper DfAM consideration to reduce machining and associated tool costs

Cleaning
Finished part cleaning for application with high cleanliness requirements

Metal AM value driver

When quoting components for metal AM production, we notice that many companies still make their buying decisions solely on the purchasing cost of each component. Although the price for metal AM is steadily dropping, the price for metal printed components is still, to date, more expensive.

The true value of metal AM, however, lies in the total cost of ownership (TCO) of the solution; this includes many factors, and is especially true for semicap. By achieving higher performance through optimised components, we have seen many cases where, thanks to higher performing systems, the amount of required systems to meet a certain production goal is reduced, thereby significantly reducing the total cost of the solution.

Another example of improved TCO is the lifetime of the component. By integrating and optimising component designs, the lifetime of an additively manufactured component is often significantly increased over its traditionally made counterpart. We have seen examples where a metal AM optimised part had a 20% higher purchase price but the lifetime is trebled compared to its non-AM counterpart. This leads to a significant cost reduction over the lifetime of the solution but is often not taken into account when making the purchase decision.

Conclusion

In this article, we demonstrated the practical development of improved cooling strategies for wafer tooling. The novel generative design approach (using Diabatix's ColdStream platform) automatically generated optimal self-supporting cooling structures which reduced overall temperature gradients, maintained fluid pressure within system requirements, and presented an incremental reduction in time for an entire system to produce wafer product. Manufactured as a monolithic single part by 3D Systems' Application Innovation Group with 3D Systems' direct metal additive technology, the resulting part also presents a reduction in manufacturing time and increase in components reliability over traditional manufacturing methods.

As semiconductor capital equipment manufacturers race to meet the demand for new fab equipment, new opportunities for improved quality and performance, and supply chain optimisation arise through function-first design methodologies through related software tools. These are then able to be realised through direct metal Additive Manufacturing and the available materials on the market. Extensive practical experience can be applied through full solution providers, significantly reducing wasteful trial and error and speeding time to market during this critical time for the industry.

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Forging a process for mass customisation via metal Additive Manufacturing

Metal Additive Manufacturing technologies offer the potential for true mass customisation, but in order to leverage this opportunity, new, complex workflows and business models have to be implemented. In this article, Siemens Digital Industries Software's Ashley Eckhoff considers the challenges when addressing the topic, from the addition of further complexity, to an already challenging Additive Manufacturing workflow, to traceability and regulation. By adapting the AM process to meet these needs, companies can reap the benefits of new markets uniquely suited to this technology.

Customisation is touted as a major value proposition for adopting Additive Manufacturing, not least because AM does not suffer from the high first article cost common to most traditional manufacturing methods (Fig. 1). However, customisation requires a completely new business model, posing its own set of challenges to the development and delivery of metal AM products. Instead of manufacturing in bulk and sending pre-made products to a warehouse before a customer order is received, customised products can only be manufactured and fully processed after ordering. Depending on the production strategy, this can dramatically extend lead times for deliveries. Supporting a greater number of independent products in the manufacturing queue compounds the challenges in the manufacturing process: each order needs to be associated with a unique product and tracked throughout the entire process to ensure the right product gets to the right customer.

Adding to the complexity of the additive workflow, it is crucial to build every custom metal AM product right the first time. Mistakes in manufacturing and rework can be costly in terms of time, capital and reputation. The end-product needs to meet the performance requirements of the customer, whether that is the durability requirement of a medical implant, the total weight requirement of a performance bicycle, or the kinetic energy transfer required in a golf club. The customer expects a customised experience from your product, so getting it wrong is not an option.

These hurdles can be daunting, but with the right solutions for each major step in the process they can become a part of the normal

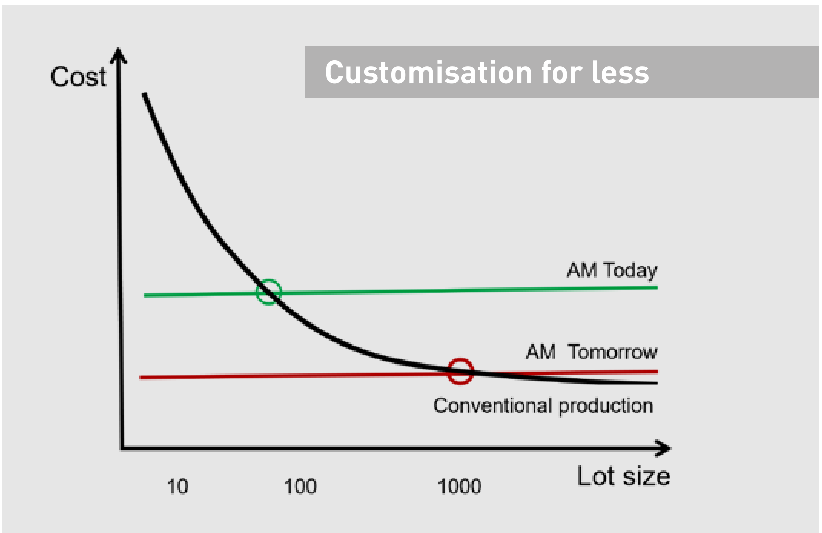

Fig. 1 Additive Manufacturing does not suffer from high first article cost like many traditional manufacturing methods do (Courtesy Siemens)

Fig. 2 A custom-shaped bicycle crank with internal lattice structures (Courtesy Siemens)

Fig. 3 Custom bicycle components are currently focused on racing, but the technology could also enable new adaptive designs for riders (Courtesy Siemens)

"Fully custom Additive Manufacturing leverages as many aspects of a simulation environment as possible to deliver the most value to the customer, but, when moving towards mass customisation, it is difficult to justify the time required to set up and run each of these simulations for every build."

Additive Manufacturing production process – and by approaching these challenges methodically and holistically from end-to-end, implementing customised product manufacturing can become a lucrative long-term business proposition.

Simulate every part (sometimes)

Simulation is a very important aspect of any Additive Manufacturing workflow; whether it takes the form of topology optimisation, stress testing or AM machine performance depends on the application. On its own, AM is an amazing process, combining centuries of metallurgical knowledge with state-of-the-art production capabilities to produce a part – but the biggest value is in the enablement of complex part geometries once thought impossible. Very few of those compound curves, internal channels and lattice structures could be manufactured with traditional CAM processes in any reasonable timescale. These structures are computer generated, using algorithms that create hundreds of possible approaches using generative design techniques that rely heavily on simulation. Advanced simulation enables the production of additive products optimised for specific fluid flow patterns, lighter products than ever before with custom lattices that enable a lightweighted part to retain its rigidity, and even provides insight into the impact of the building process itself on the structural integrity of the final part.

Fully custom Additive Manufacturing leverages as many aspects of a simulation environment as possible to deliver the most value to the customer, but, when moving towards mass customisation, it is difficult to justify the time required to set up and run each of these simulations for every build. Instead, a cost-benefit analysis may lead to a piecewise solution. For relatively similar custom parts, which share the majority of their respective geometries, performance simulations may only be run on a representative sample of parts within a target range. Then, any outliers can be simulated on a case-by-case basis, reducing the amount of simulation required to cover the entire range of customised parts. As an example, custom cranksets for bicycles (Fig. 2, 3) still need to adhere to the sizing standards of the industry, so the shaft connecting each crank arm will have the same external diameter and one of only a few lengths. By sharing this geometry and using consistent material composition across custom cranksets, simulation time can be optimised on a per-unit basis – this can be accomplished by first identifying a size range within which, say, 90% of cranks fall. A simulation can be run for each end of this range and with a few samples within the range to ensure that the product will meet specs throughout. Then, simulation need only be run on the individual parts that fall outside of this selected range to ensure that they also meet the product specifications.

So, when the standard deviation from the average part is low enough, separate simulations may not be needed. However, the design team must keep in mind that if they vary the part too much without simulating the effects, it can lead to a deformed part – even worse, it could also damage the AM machine if, for example, a deformation impacts the recoater. It takes experience and time to understand how much allowable change can be tolerated. Therefore, AM manufacturers should rely on increased use of simulation in early runs of the custom products until they gain enough experience to make confident decisions about when simulation is required and when it is not.

The promise of reduced simulation is not the same for every product, however. Articles like custom-built bicycle cranksets or built metal joints for carbon fibre frames will have a greater impact on the rider and will likely require more performance simulation on a per-unit basis than would a custom water bottle holder. Many of these adjustments will be accounted for in the design of the product for the customer, but, in the case of the carbon fibre frame, added insight may be needed as they reach manufacturing. When customising a bike frame, even the smallest tweaks to geometry matter. For example, a built bottom bracket joint connects to the seat post tube, two chain stays for the rear triangle and the down tube, for a total of four points of possible misalignment (Fig. 4). Complex parts such as these may require a larger sampling of simulation than less complex parts, so part complexity can also play a role in the need for simulation.

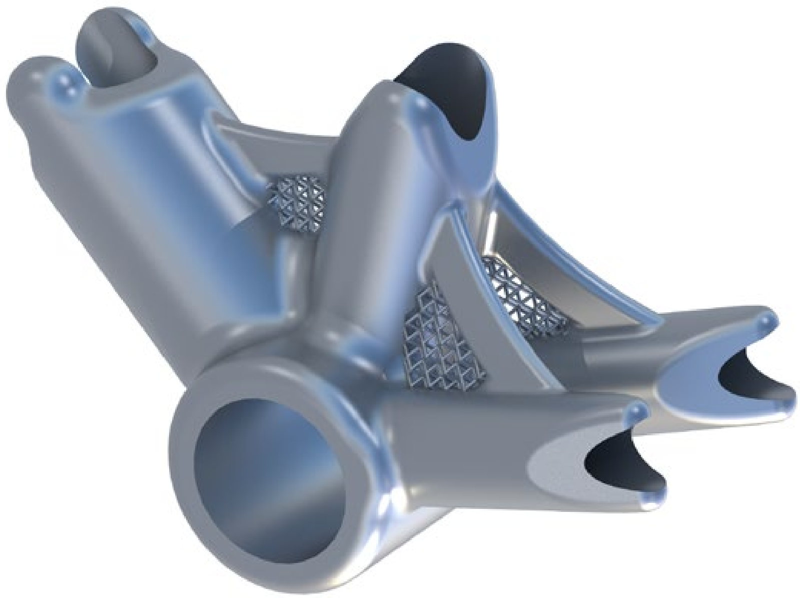

Fig. 4 An additively manufactured bike frame node connecting the seat tube, down tube, and two rear wheel tubes to the crank (Courtesy Siemens)

Overall, part simulation is an important element of a custom building workflow, but the cost of simulation must be considered when moving towards mass production of lot sizes of one. Depending on the breadth of customisation and the products being manufactured, a variety of techniques could be adopted to counteract the cost of the simulation process. The techniques discussed above are only a few options. Other simulation strategies could rely on trading simulation accuracy for speed to get a broad idea of how changes impact the product without incurring the cost of a more granular simulation. Regardless of the chosen solution, it is important to deploy part simulation strategically, understanding the costs and benefits of using such powerful capabilities.

When to simulate the process

After designing a custom product and then simulating and performing a multitude of engineering tasks to prepare it for production, it is time for manufacturing. This is where process simulation comes into play. As we have discussed, part customisation means that every part built is different than the last. This naturally leads to every build tray being different from the last, so techniques for mass production that generate efficiencies of scale will often not work in a customisation scenario. This means we need to think deeply about how to maximise our efficiency while generating consistently unique outputs.

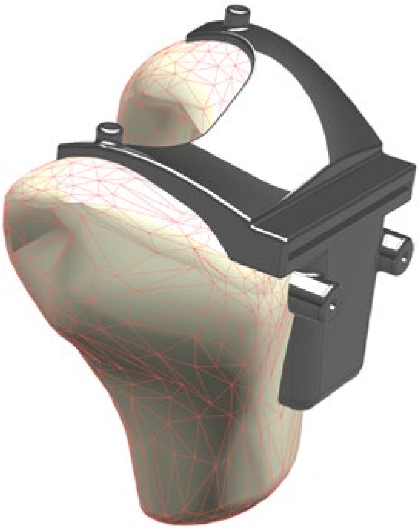

Fig. 5 Implants are not the only customised built parts associated with surgery. Custom surgical guides can also improve patient outcomes from invasive surgeries (Courtesy Siemens)

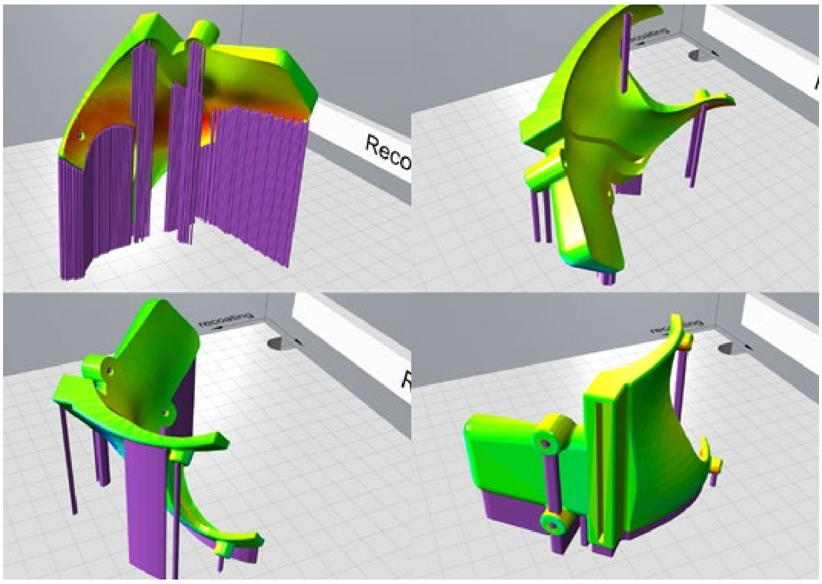

Fig. 6 Simulation-based orientation optimisation for easy support removal, minimum supports, minimum distortion, and minimum build time respectively (Courtesy Siemens)

Again, decisions about when to simulate the build process come down to an analysis of failure probabilities vs the cost of simulation and how to bring the average cost down. The uniqueness of each build tray containing customised builds means that those decisions must be made with care, and that additional techniques are required to maintain efficiency in the building process without greatly impacting first article quality. Simulation of the building process is becoming one of the recommended techniques for improving first article quality. However, as with part simulation, the simulation of the build process can be expensive with regards to time, so simulating every build tray would likely have a large impact on production performance. This means that strategies for when to simulate and when not to simulate the process must be designed.

One way to aid in this decision might be to define a change threshold beyond which simulation would enter the process. For example, if more than 50% of the parts in a build tray have surfaces that deviate from the nominal by more than 40%, then simulation of the build is performed. Just as with part simulation, the thresholds for making these decisions come from experience with the build process and an understanding of what changes and what magnitudes of change are acceptable without negatively impacting build quality.

If we look at the example of a custom surgical guide (Fig. 5), the only portions of the guide that are customised are the portions that interface with the patient's anatomy. In this case, the overall size of the guide is likely to remain static, so the deviance in part structure from the nominal guide shape is minimal. In such cases, it may be possible to simulate a representative build tray with a set number of parts in a desired orientation (Fig. 6). If the results of the simulation are positive, then you may be able to create future trays with the same number of parts in the same orientation and be successful without simulation of each future build tray being necessary – even though, technically, each future build tray would be unique. Looking at our custom bike crank example, however, the problem may be more complex. Custom crank arms will most likely have a much wider range of size variation than would be present with surgical guides, so different techniques might be required to minimise the need for simulation. One might embark on a policy of 'like part grouping', where an attempt is made to build crank arms whose sizes all fit within a given range as a single batch. If the size ranges for each batch are chosen carefully, it may be possible to simulate build trays of nominal parts within a given size range to identify areas of concern. Simulating these build groups as representative samples, one could theoretically reduce the overall number of build simulations required.

Just as with part simulation, the definition of the ranges, the overall deviance allowance, etc, are values that must be designed from build experience. Each AM machine, process and material will require a slightly different set of groupings, and what does and does not work can only be discovered through experimentation.

It is worth noting that, as new simulation techniques are developed; as existing techniques become more refined and efficient; and as computation becomes less expensive from a cost and time standpoint, the cost of simulation tends to decrease over time. We expect this same trend to apply to both part and process simulation in the Additive Manufacturing realm, as well. Simulation of the build process in particular is a relatively new process, so it can be assumed that there are efficiencies still to be resolved in that process as the tools mature and knowledge of the build process expands. One can imagine a future point where the cost of build simulation will be minimal, and a simulation of every build tray can be run before production. While, in most cases, this is not yet advisable, it certainly is possible if the cost/benefit ratio is favourable.

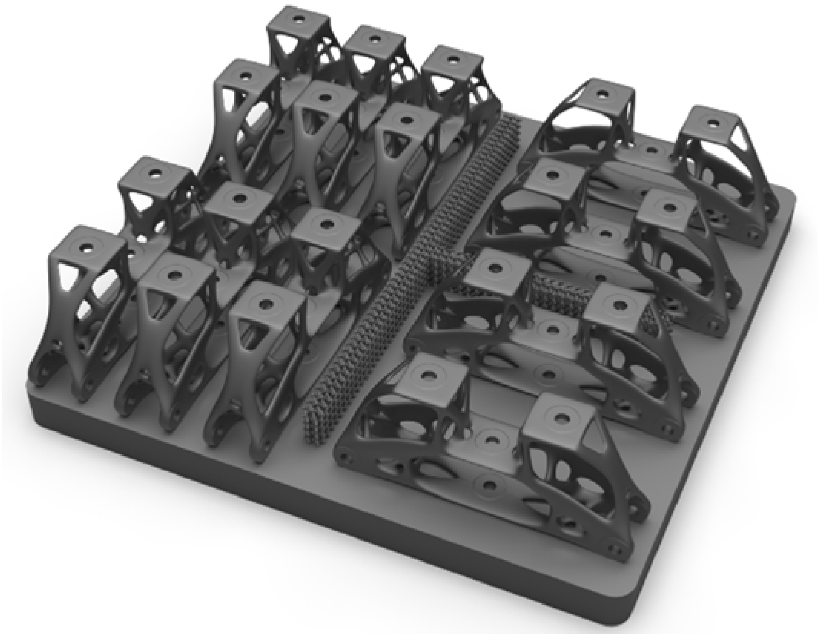

Fig. 7 A tray of parts with segmentation walls to separate parts that require different post processes (Courtesy Siemens)

"One can imagine a future point where the cost of build simulation will be minimal, and a simulation of every build tray can be run before production. While, in most cases, this is not yet advisable, it certainly is possible if the cost/benefit ratio is favourable."

Serialisation and traceability

Another aspect crucial to the success of creating custom metal products with AM is the implementation of a robust tracking system based on serialisation. There are two important reasons for serialisation in manufacturing custom metal products. The first is to ensure quality in the process, and we will refer to this as 'process traceability' for the purposes of this article (this is true for all product manufacturing, not just AM). The second is more relevant to customised product manufacturing: tracking an individual item from order to delivery, or 'product traceability'. Both are intertwined and extremely necessary to deliver the right product to the right customer.

Process traceability

Process traceability enables oversight to ensure that, during each step in the development process, the product receives the correct set of operations. Establishing process traceability means knowing exactly where the product is going; if it needs to be finished in a secondary process after building, that information is associated with the serial number.

To make the process as efficient as possible, a manufacturer needs to be able to segment large lots of products that all need to go through similar processes. This increases parallelisation, because it would be far too time consuming having a single component go into an electroplating bath at a time. Some of this organisation must be conducted through classic logistic operations.

An option specific to Additive Manufacturing is the use of sinter boxes or build tray segmentations (Fig. 7). Sinter boxes are normally used in polymer AM and are, put simply, cages that act as separators

Fig. 8 A custom built golf driver with exact internal weight positioning using a lattice structure (Courtesy Siemens)

"It is also easy to see that product traceability is of the utmost importance in the medical field where custom surgical guides, implants, and prosthetics are designed to exactly fit a specific patient's anatomy."

in a build bed containing a quantity of built parts that need to be physically grouped together so that they can move through post-processing steps as a single unit. Build tray segmentation is the use of small geometrical elements to define boundaries between groups of parts on the same build tray. The build tray segmentation technique integrates well with the benefits of metal AM when paired with post processing. The complex build patterns that many modern metal AM machines are capable of achieving enable entire lots of custom parts to be built simultaneously. Grouping of these parts by material and finishing process can be carried out manually, but, with a comprehensive design and manufacturing solution, the process can be automated. This saves engineering time that would otherwise be devoted to manually fitting together a three-dimensional jigsaw puzzle. From the AM machine, components can be separated from the build bed and sent along for depowdering, surface finishing, and, eventually, separation, if using a sinter box.

Product traceability

Product traceability relies on much of the information from process traceability, but the end goal here is to deliver the right product to the customer. For the most customised products, the personalised metal AM process may require an in-person fitment. That could be golf swing analysis for a custom golf club or a cycling pedal cadence tracking session for a custom bicycle part. It is also easy to see that product traceability is of the utmost importance in the medical field where custom surgical guides, implants, and prosthetics are designed to exactly fit a specific patient's anatomy. The ability to trace that part from the custom design stages, through manufacturing and finally delivery to the surgeon or patient is of paramount importance.

After the ordering process for a custom part is complete, all the geometric data specific to that part is attached to a serial number and imported into the process traceability environment, where it is used to ensure the right product is manufactured for the customer. From here, the individual product will follow the prescribed manufacturing process as discussed in process traceability. In the case of a custom-built golf club (Fig. 8), once the manufacturing process is complete, it is time for delivery. Organisation in this phase is crucial, because correctly matching order requests and finished products is essential to customer satisfaction, as well as to reducing rework and shipping corrections. Depending on the customisation of the golf club, it may not be apparent to the customer if they receive the wrong order. The club could be customised with internal structures to enhance their specific swing style, and getting the wrong club could lead to the assumption the technology does not work.

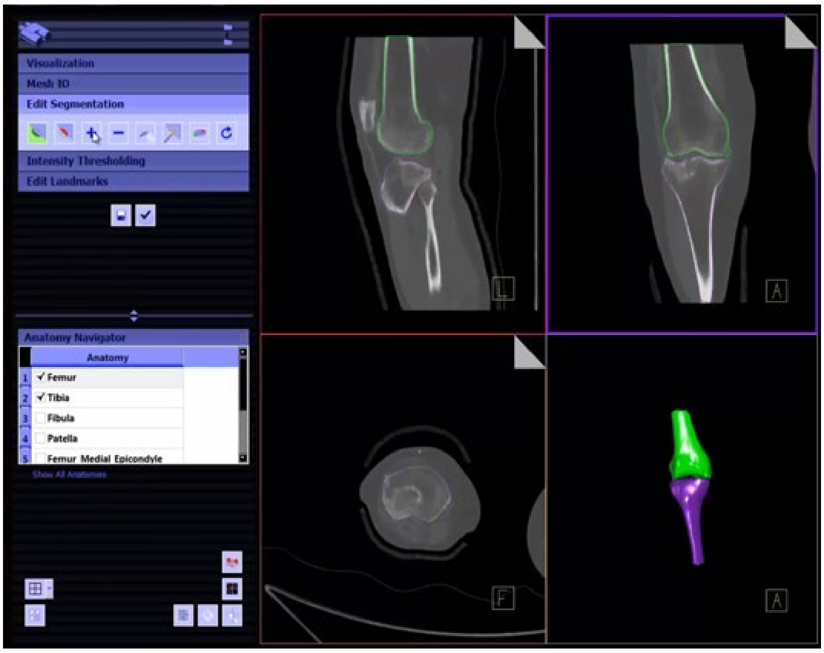

Fig. 9 Software helps surgeons design custom orthotic implants using 3D scans of the patient's anatomy (Courtesy Siemens)

Applied traceability

Medicine, and specifically the medical device industry, heavily relies on the organisation provided by serialisation and traceability. While additively manufactured joint replacements are not typically manufactured in lots as described above, surgical guides are a great example of the overall process. Historically, surgical guides came in a handful of sizes for any surgery, and it was up to the surgeon to choose the best fit. Using custom metal AM, these guides can be fitted to individual patients and produce a higher efficacy rate for surgeries, but this will only work if patients receive the correct guide for their surgery. Delivery of an incorrect guide can delay surgery or, far worse, impact the surgical procedure, the results of the surgery, and the patient's recovery.

Also, depending on the progression of Additive Manufacturing within the medical field, the serialisation of custom metal AM parts could function within the certification process. Performance simulation of devices could become a natural progression in the development of high-use implants as the cost of computation declines; in-turn, the lessons learned from high-performance implants could filter into more entry-level products. As more medical devices and implants move towards Additive Manufacturing and increased customisation, it will be vital to track efficacy over time and ensure every implant has been thoroughly tested and qualified.

Accelerating customisation through regulated processes

Additive Manufacturing holds great promise for providing custom products to customers on a mass-market basis – but to do so successfully requires that the process be organised efficiently by implementing an end-to-end solution that encompasses design, simulation and manufacturing. When every order is different from the last and the next, it is important to understand how development and production cycles are impacted. Product traceability helps ensure that the right product gets to the right customer, and process traceability ensures that the part goes through the proper steps during design and manufacturing. Throughout the design-to-manufacture process, simulation needs to be judiciously utilised to optimise quality and throughput.

Additive Manufacturing is a technology uniquely positioned to capitalise on the potential of customised products. However, to make mass customisation profitable will require a wide and deep understanding of the custom manufacturing process and its wider business implications. A well-regulated process, driven by acquired knowledge and appropriate software, can ensure the viability of customisation through Additive Manufacturing so that your business can create the parts of tomorrow, today.

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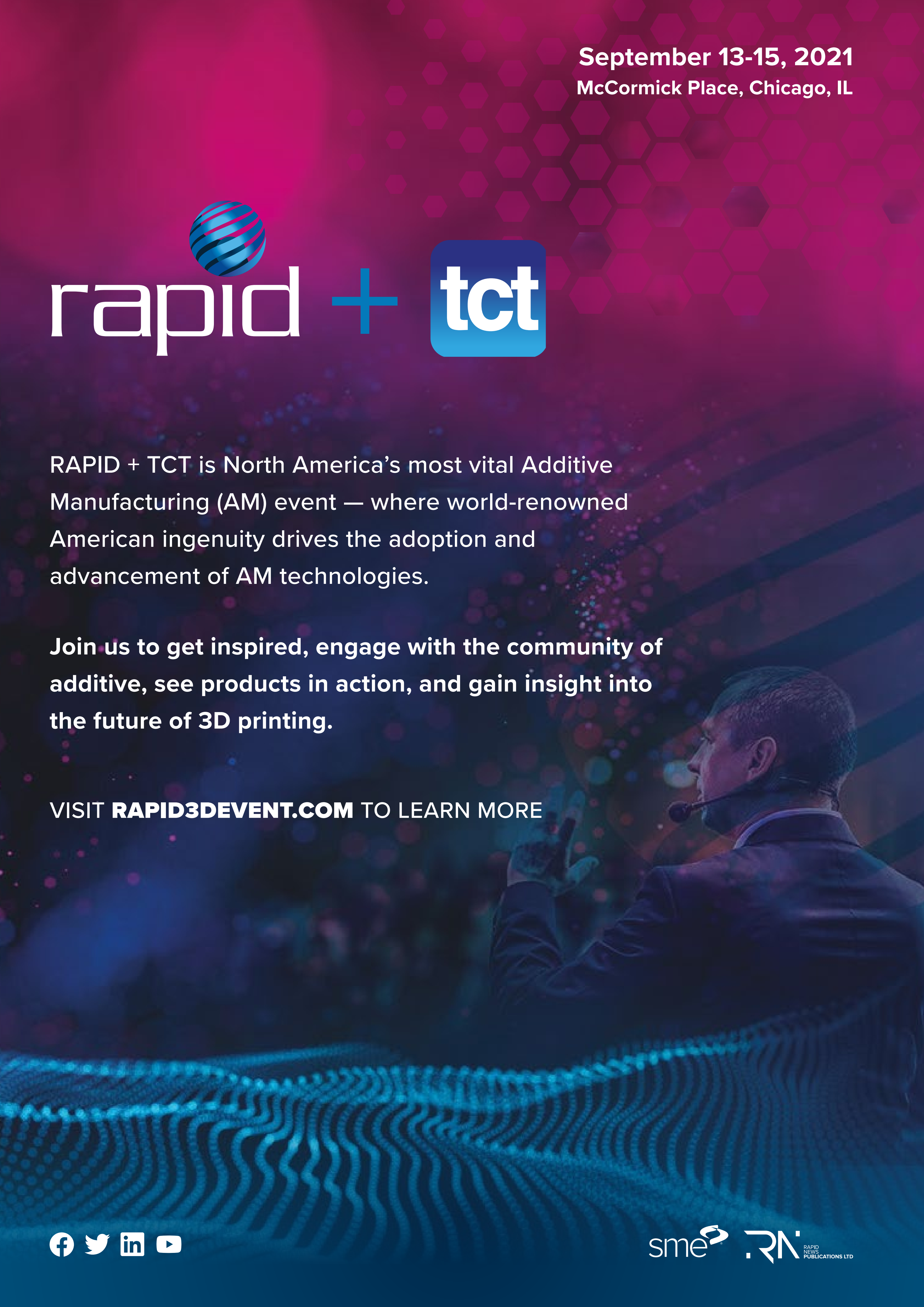
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Bringing it all together: How Materialise is integrating manufacturing and software expertise to shape AM's future

In an industry that sees a constant influx of new players hoping to forge a place for themselves in a brave new manufacturing landscape, there are only a few companies which have been on the AM scene since its earliest days, whilst remaining at the top of their game. One of these is Materialise, an AM company that has benefitted from leveraging its dual specialisms of AM parts production and AM software development. *Metal AM* magazine's Emily-Jo Hopson-VandenBos talked to Materialise's Ingo Uckelmann and reports how, now more than ever, the bringing together of manufacturing and software expertise is the future for AM.

Materialise NV, Leuven, Belgium, is one of the most recognised names in Additive Manufacturing, and a powerhouse for both software development and part manufacturing. Now, as production volumes increase and AM approaches widespread industrial adoption, the company is expanding its production capabilities and capacity, and maximising the opportunities offered by the dual roles it holds in the AM industry.

The company recently announced the completion of its new 3,500 m² Metal Competence Center for Additive Manufacturing in Bremen, Germany. This expansion was undertaken under the guidance of Ingo Uckelmann, Materialise's Technical Manager Metal 3D Printing. Uckelmann joined the world of metal Additive Manufacturing early on in the technology's history, working with one of the first metal AM machines at Fraunhofer ILT in 2000: an extremely slow Powder Bed Laser Beam Fusion (PBF-LB) machine with a single 120 W laser. Now, machine makers regularly launch PBF-LB machines with multiple lasers and an ever-increasing build volume, with one recently-launched machine having twelve lasers of 1 kW each. Following the announcement of Materialise's new Metal Competence Center in May 2021, with many parts of the world still in varying degrees of lockdown, I spoke to Uckelmann about how far the world of metal AM has come during his twenty years in the industry, the lessons Materialise has learnt along the way and his predictions for the next twenty years in metal AM.

One of the most significant developments Uckelmann highlighted from his time in the industry was not the size and speed

Fig. 1 Ingo Uckelmann, Materialise's Technical Manager Metal 3D Printing, has been in metal AM since 2000 Courtesy Materialise)

Fig. 2 Materialise's Metal Competence Center in Bremen, Germany (Courtesy Materialise)

of machines, or the ever-growing number of applications, but the underlying technology that helps make this growth possible. "Looking back at metal AM's advancements since 2000, one of the most important developments has been in the process automation we have achieved," he reflected. "Twenty years ago, everything was done manually in CAD programs, from data handling to design and print preparation. Now, much of the process has been automated through AM software."

"Aspects of build planning like support generation and optimising orientation for metal AM have been automated, which reduces the manual inputs required," he observed. "The 3D printing industry is experiencing a similar revolution to that of 2D printing, and we, eventually, will see this continue to the point where a technical drawing can be uploaded and printed with an almost entirely automated process. Throughout our thirty-plus year history, Materialise has been a market leader in this increasing automation, with our Magics 3D Print Suite providing many automated tools."

As the AM industry continues to develop and scale to volume production, automation will continue to be key, Uckelmann stated. "This is a case of history repeating itself, as all of today's widely-used manufacturing methods have gone through the process of increasing automation. Today, we are able to run the process smoothly, but post-processing and data structure is still manual. There is still a gap to fill in terms of automation before metal AM can truly work alongside traditional manufacturing in serial production."

"The 3D printing industry is experiencing a similar revolution to that of 2D printing, and we, eventually, will see this continue to the point where a technical drawing can be uploaded and printed with an almost entirely automated process."

Acquisition and expansion

Materialise hopes to expand its expertise yet further in this area through the planned acquisition of Link3D Inc, the additive workflow and manufacturing execution systems (MES) company which it has acquired the option to purchase by the end of 2021. "With the acquisition of Link3D,

Fig. 3 An operator uses an EOS metal Additive Manufacturing machine in a Materialise production facility (Courtesy Materialise)

we expect to continue our leadership in automation and take AM to its next level," Uckelmann said. "With Link3D's additive workflow and manufacturing execution systems seamlessly integrated with Magics, we are helping customers gain even more control of their manufacturing processes and scale AM capabilities to volume production. This combined software suite will reduce complexity in serial AM, helping the technology play a greater role in a connected, industrial manufacturing process."

> *"With Link3D's additive workflow and manufacturing execution systems seamlessly integrated with Magics, we are helping customers gain even more control of their manufacturing processes and scale AM capabilities to volume production."*

Within its new Metal Competence Center, the company has further plans in place to advance automation within its production workflow for metal AM. "We recently announced the Process Tuner as part of our product portfolio, which was initially developed in the Metal Competence Center," Uckelmann explained. "This gives our customers the possibility to develop new process parameters that are more efficient. In one of our current proof of concepts, we found that the Process Tuner can lead to a decrease in manual efforts and a more standardised product result, while minimising printing costs, which is a triple win for me."

On a smaller scale, the metal AM industry has seen significant evolution in the six years since the establishment of Materialise's first Metal Competence Center. For Uckelmann, the market's evolution during this period has, in many ways, tracked with Materialise's expectations. "We have seen increasing part sizes, broader applications and an increased interest in using metal AM for production parts. While many of the applications we see today are still for the production of small, unique or expensive parts, we're seeing new interest in the technology for a variety of applications in industries such as energy, automotive, aerospace, and general manufacturing. It's unbelievable the number and variety of applications that AM is being used for today compared to even ten years ago."

Fig. 4 An operator observes the build process on an EOSINT M 280 machine at Materialise's production facility (Courtesy Materialise)

A renewed focused on integration and collaboration

Of course, some recent developments could not have been foreseen by even the most talented industry forecaster. "One development that we could not predict was the impact of the COVID-19 pandemic on the metal industry as a whole," Uckelmann stated. "While the industry was affected, the pandemic also created increased interest in AM as a complement to traditional manufacturing. As companies are working to address vulnerabilities in the global supply chain that were brought to light in the past year, AM technology has played a vital role in adding more localised and personalised production capabilities, a trend that we expect to continue in the post-pandemic world."

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Are there lessons which the company has learnt, as a metal AM service provider, over the last six years? The key lesson, according to Uckelmann, has been the importance of integration between Materialise's software and manufacturing teams. While some people may expect the benefits of this relationship to flow exclusively from software to manufacturing, Uckelmann finds that both teams benefit from the opportunity to collaborate. "Over the last six years, we have learned the value of collaboration between software developers and production teams," he explained. "Each of these teams brings their unique perspective and expertise to address the key challenges of metal AM."

"With further integration at the new Metal Competence Center, we are already seeing the benefits in advancing our technology and overall processes," he noted. "Throughout the AM process, we have focused our efforts on automation, ease of use and ensuring parts are built right the first time to save cost and waste."

Collaboration at its Metal Competence Center extends beyond simply integrating its manufacturing and software teams; the value of collaboration is one of the reasons that in 2015 Materialise selected Bremen as the home for its metal AM facilities. "The Bremen area has certainly become a central hub of AM expertise," Uckelmann stated. "Since 2015, we have closely worked with institutions here. We have collaborated with the University of Bremen on several projects and often recruit University of Bremen students to work on our teams. Second, working with the companies in the region that employ AM offers additional opportunities to share knowledge and develop new applications for AM."

In the business of advancing AM technology

This attitude to collaboration extends to a somewhat unusual facet of Materialise's business: its position as a provider of software

Fig. 5 Ingo Uckelmann sees expansion on the horizon for the metal AM industry, and believes Materialise will be the company to facilitate it (Courtesy Materialise)

to customers who may be seen as competitors in the metal AM part production space. I asked Uckelmann how this relationship works, and whether Materialise sees other metal AM part producers as competitors or colleagues. The answer was clear: Materialise is in the business of advancing Additive Manufacturing technology, not a race to the top. "At this point, we believe the industry is all on the same page in terms of developing and advancing AM technology," he commented. "AM is still in its early stages when compared with traditional manufacturing processes, and collaboration is essential to continuing its advancement as a tool for serial production."

"This includes not only collaborating within our Materialise teams, but with customers and others in the industry who are focused on material or machine development," he explained. "We see ourselves more as enabler for companies that want to enter the AM market and add metal AM as complementary technology to existing classical manufacturing to employ new possibilities."

So, with twenty years of experience in the AM industry, many with one of the AM industry's biggest players, what does Uckelmann expect to see in the next twenty years of metal Additive Manufacturing? For him, the future holds a significant increase in the accessibility of metal Additive Manufacturing to the wider industrial landscape. "The prices of metal printed parts have reduced drastically during the last twenty years," he noted. "When I started with AM in the dental industry, it was the ideal market, because the parts are small, unique and expensive to produce with traditional methods. Today, more and more industries actively employ 3D printing, not only for prototypes and small series, but also for industrial production. In one case, we are working with a bicycle company to produce parts that are twenty-five times heavier and are manufactured in series more than 10,000 times greater than those of dental applications," he explained. "We have done this all at a lower cost than that of producing a dental crown twenty years ago. Over the next twenty years, we expect this trend to continue with increased interest in metal 3D printing."

In terms of metal AM's key applications, Uckelmann sees expansion on the horizon – and believes Materialise is the company to facilitate it. "We will definitely see prominent series applications in aerospace and automotive applications, among others. We believe our Mindware consultancy team will be instrumental in creating new applications for series production, by working with customers to share expertise on both the 3D printing process and the end parts to find the applications where AM can truly add value."

The drivers behind the new Metal Competence Center

This newest addition to Materialise's AM portfolio is the result of an approximately €7.5 million investment, and, by uniting the formerly-separate software and manufacturing teams already based in Bremen, the company believes that it will be better situated to enact the increased collaboration necessary to better serve its global industrial customers.

In addition to the benefits of centralisation on the company's inner workings, Uckelmann has stated another key focus of research conducted within the centre will be exploring ways to improve the sustainability of the metal AM workflow. "Metal AM has established itself as a powerful manufacturing solution, but our industry needs to continue to increase our efforts to make the AM process itself more sustainable. At the new Metal Competence Center, we will explore opportunities to optimise printing processes, improve energy efficiency and more consistently recover and reuse metal powder to create more sustainable technologies."

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Uckelmann explained that the new centre reflects the company's expanded focus on metal Additive Manufacturing. "This is due to increasing demand for the technology as companies recognise the potential of metal AM for serial production," he stated. "With the new facility, we have further integrated our software development and distribution with industrial manufacturing capabilities and tripled our production capacity in the region."

The company also hopes to leverage its practical manufacturing experience to enhance its software development, whilst simultaneously applying its knowledge of AM software to develop high-quality, cost-effective manufacturing solutions for metal AM. "This integration allows for greater collaboration between our teams to generate better solutions that ultimately allow us to go faster to market for customers," Uckelmann added. "The additional space allows us to tailor all our workflow and material flow, generating optimal efficiency and collaboration."

"This sustainability begins in the building itself," he noted. "The facility includes high-efficiency insulation, reducing environmental impact from heating and cooling; and with renewable energy from rooftop solar panels, much of the energy that powers and heats the building is already carbon neutral."

From the 1990s to COVID-19: How the history of Materialise mirrors the evolution of AM

While Materialise is, perhaps, best known for its benchmark Additive Manufacturing software offerings, it is due to its founders' desire to start a manufacturing business that it first entered the field of software. In 1990, company founders Wilfried and Hilde Vancraen encountered the emerging technology of polymer Additive Manufacturing for the first time at a facility in Bremen. Soon after, the couple pooled their savings to acquire one polymer machine and, thus, Materialise was founded. Having installed the machine in a small office in Belgium, much of the company's early life was spent trying to overcome the technological challenges of early Additive Manufacturing in order to begin manufacturing parts for customers. At this stage, it was extremely difficult for AM machines to read the computer files containing the design information for the components waiting to be built.

In response to this early challenge, Materialise developed its first software product: Materialise Magics. This data preparation software, developed by then-student Johan Pauwels (now the company's executive vice president), enabled Materialise to transform digital 3D files into a format which AM machines were able to work from, as well as implementing features such as support generation to optimise designs for manufacturing. The company was now able to pursue its ambitious manufacturing plans with the help of its first 'official' employee, Philip Schiettecatte, now a Senior AM Engineering Consultant.

One of the company's first projects was based on Wilfried Vancraen's identification of the medical industry as a potentially lucrative field for AM technology: patient-specific anatomical models, based on CT scans. Early experiments in this area by Bart Van der Schueren, then a research assistant at the University of Leuven and now CTO of Materialise, led to the creation of Materialise Mimics. From anatomical models, the company's applications in the medical sector progressed to surgical guides, drill guides, custom parts for hearing aids and more, including entrance into the dental field.

Materialise went on to expand into other fields of application for polymer AM with items such as silicone moulds for vacuum casting and sophisticated end-use products like lamps, furniture and sculptures. When, in 2006, the company began producing polymer prototype tooling for the automotive industry, they were faced with another unique challenge: how to get these parts to their destinations without the parts deforming en route. This was countered by the development of additively manufactured jigs and fixtures to hold the parts in place, and which could be adapted to each build. This solution evolved to become RapidFit, which now combines these jigs and fixtures in one standardised system used for quality testing in the automotive sector.

The move to metal

Following its acquisition of OBL, a company specialised in the creation of custom craniomaxillofacial (CMF) implants, in 2006, Materialise entered into the metal AM market with the manufacture of titanium CMF implants, which enable surgeons to achieve a more anatomically-correct result than with a standard implant. To this day, the production of these implants is one of the most recognisable success stories for metal AM; due to their porous structure, made possible only by AM's freedom of design, these implants behave like natural bone, mimic its mechanical and thermal properties, and encourage osseointegration (bone ingrowth), significantly increasing the level of comfort for the patients who have them.

The company soon began production of orthopaedic implants made using the same technique. Materialise's aMace implants became another recognisable success story; bespoke hip implants fit the patient's anatomy exactly and are designed with the same bone ingrowth-promoting surface structure as its CMF implants.

A period of rapid innovation

Between 2006 and 2014, Materialise went from strength to strength in both its software and manufacturing offerings, with developments in the ensuing years including, but not limited to, the launch of i.materialise, an online platform which enabled users to create, share, and sell designs; working with Dutch fashion

Materialise in the serial production of bike parts for Pinarello at its Bremen Metal Competence Center

Recently, Materialise collaborated with Italian performance bicycle brand Pinarello to design and produce new metal additively manufactured frameset hardware, reducing the weight of the seat clamp by 35 g. The Pinarello bicycle seat clamps were produced at Materialise's new Metal Competence Center in Bremen. (Images Courtesy Materialise)

Fig. 6 In 2017, Materialise e-Stage became the first software in the world to automate support generation for titanium, stainless steel and aluminium AM parts (Courtesy Materialise)

> *"Based on a powerful automation algorithm, e-Stage for metal reduced data preparation time for metal builds by up to 90%, and finishing time by up to 50%, offering metal AM users a dramatic increase in productivity."*

designer Iris van Herpen to produce one of the first polymer AM fashion pieces to appear on a runway; developing the Materialise Build Processor, which enables different AM machines to link directly through Materialise Magics; producing the surgical guides and anatomical models to be used by Prof Philip Blondeel at the University Hospital of Ghent in the first full face transplant in Belgium; and the launch of Materialise Streamics for quality control, traceability and automation on the AM factory floor.

Consolidating its position

The company joined the stock market with its IPO on NASDAQ on June 25, 2014, enabling it to expand its services, reach a wider range of customers and further contribute to the growth of the AM industry as a whole. In 2015, having achieved the EN9100/AS9100 and EASA.21G certifications, in addition to its existing ISO 9001 certification, it was authorised to offer manufacturing services in the aviation market. From here, the company began delivery of end-use AM parts to customers such as Airbus, helping to reduce the weight and operational costs of aircraft.

By 2015, while polymer Additive Manufacturing was experiencing something of a post-hype slump, metal Additive Manufacturing was starting to come into its own as a prototyping and small-series production technology. Following demand from its customers, Materialise expanded its metal AM offering beyond its titanium medical implants, adding aluminium to its materials offering. Led by Ingo Uckelmann, the company opened its first Metal Competence Center in Bremen, Germany, in September 2015, where it incorporated all of its metal AM activities. The company's knowledge base had been centralised in Bremen since the acquisition of Marcam Engineering four years earlier.

By this point, Materialise had become one of the world's largest providers of Additive Manufacturing services with a global capacity of more than 120 polymer and metal AM machines and use of a wide variety of technologies. At the time of the competence centre's launch, the company stated that it was producing and shipping more than 2,000 parts daily to a global list of customers. The metal production facility in Bremen was its fourth industrial production unit in Europe, joining the factory at its Belgium headquarters and those in Poland and the Czech Republic.

Software innovation that rises to the challenge of AM

In 2015, with an ever-growing focus on process and quality control, the company integrated the Materialise Control Platform into its services. This software-driven hardware solution is embedded inside metal AM machines and offers the user a higher degree of control over machine parameters and performance. In 2017, Materialise e-Stage became the first software in the world to automate support generation for titanium, stainless steel and aluminium AM parts. Based on a powerful automation algorithm, e-Stage for metal reduced data preparation time for metal builds by up to 90%, and finishing time by up to 50%, offering metal AM users a dramatic increase in productivity. Additionally, this positively benefited the working conditions of the machine operators, since hardly any powder is captured inside the optimised supports.

In the same year, the acquisition of ACTech brought together Materialise's metal AM competence with the German-based company's expertise in the production of limited runs of highly-complex metal parts. This acquisition also enabled Materialise to continue to develop and improve its metal AM software suite, taking advantage of learning from an active metal manufacturing environment.

Based on Materialise's innovative track record, BASF, the world's largest chemical producer, invested $25 million in the company as part of a strategic alliance to identify and develop new applications. Later that same year, 2018, an updated release of Materialise Magics brought the integrated Simulation module to the AM market. This new technology made process simulation accessible to a wider audience, helping production operators to optimise the build process without the need for expert knowledge. The Simulation module also presented an opportunity for production operators to optimise their machine's operations and get builds right the first time, raising their overall productivity and making it possible to scale up their operations; an important prospect for the wider industrialisation of AM.

In that same year, a productive one for Materialise, the company helped to produce the COSMOS eyewear collection by Berlin-based designer FMHOFMANN, the first to combine a titanium additively manufactured hinge with polymer AM PA frames; a further partnership between Materialise, designer Sébastien Brusset and L'Amy led to the production of a new eyewear range for automotive brand McLaren named 'Frame Technological Innovation' of the year at the 2018 Silmo d'Or Awards, a showcase of eyewear brands and manufacturers, in Paris.

Engimplan and Materialise partnered in 2019 with the aim of bringing the benefits of custom, metal additively manufactured implants and instruments to Brazilian patients. For over a decade, the company's metal AM solutions had been showing proven results in the operating theatre and in post-surgical patient recovery, and had truly set the bar for the application of metal Additive Manufacturing in the medical sector.

Conclusion

In 2020, with the outbreak of COVID-19, many AM companies turned their expertise toward the development of solutions to aid in the fight against the virus. In line with the company's proven ability to leverage AM's unique qualities, Materialise quickly developed a range of new, potentially life-saving solutions, ranging from hands-free door openers to personal protective equipment and ventilator components.

In speaking to Uckelmann and understanding this long history, it becomes clear that the advancements offered by Materialise's new Metal Competence Center reflect a culture of continuous improvement at a company which has invested years of research and millions of dollars in improving Additive Manufacturing since its earliest days. Since its founding in 1990, Materialise has worked to create a better Additive Manufacturing process through software and manufacturing expertise, addressing challenges and creating solutions which have gone some way to shaping the AM industry as we now know it, as well as bringing significant benefits to its customer markets.

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Pedal to the metal at the Digital Manufacturing Centre: Redefining what's possible for AM in hypercars and beyond

This summer, a new player arrived on the AM scene: the Digital Manufacturing Centre, or DMC. Based on the edge of Silverstone, the UK's most famous race circuit, home to numerous leading F1 teams, there could be no better place to launch a business aimed at offering AM support to the elite in performance motorsport. Jim Hadfield speaks with the DMC's CEO, Kieron Salter, to explore how metal Additive Manufacturing is enabling innovation in the booming hypercar industry, and how a truly connected digital manufacturing operation can bring the DMC a competitive advantage in this field and more.

From exciting aerospace projects to new personalised medical devices, metal Additive Manufacturing has already demonstrated its capacity to meet the needs of demanding industries. While the wider automotive sector has embraced it in a limited capacity, primarily in prototyping, there is a rapidly growing niche for which metal AM is perfectly suited.

Combining breathtaking performance, incredible designs and state-of-the-art technology, the realm of hypercars is surreal. Not to be confused with sports cars – or even supercars – hypercars distinguish themselves through market-leading performance, rarity, and, of course, price. Here, limited-run vehicles can list well in excess of £2 million, and the discerning individuals purchasing them expect nothing less than exclusivity and automotive perfection.

It may come as a surprise that this is an expanding segment, too, with the global hypercar market expected to grow between 32 and 35% over the next five years (up to an estimated $90–110 billion in 2026). With such a promising outlook, the competition is growing fierce as established players and industrious startups innovate, sculpt bold new designs, and set new lap records to attract collectors, enthusiasts and high-net worth individuals from across the globe.

While many successful hypercar programmes will sell out their allocation before production begins, financial success is by no means guaranteed. Some projects undertaken by large, global automotive OEMs are never even intended to be profitable, instead aiming to assert the brand's position and design language with a highly visible and marketed 'halo' model. However, with the rapid advance of low-volume

Fig. 1 The Digital Manufacturing Centre's striking exterior, close to the historic Silverstone Circuit (Courtesy DMC)

Fig. 2 Kieron Salter, CEO of the DMC, has decades of experience in high performance automotive engineering, including senior positions at Reynard Motorsport before establishing KW Motorsport in 2003 and KW Special Projects in 2012 (Courtesy DMC)

"...it is an incredible engineering accomplishment to see vehicles capable of travelling 300 miles per hour comfortably cruising through busy London streets. Of course, hypercars draw a lot of expertise and technology from motorsport, but it really is a whole new challenge."

production technology and the possibility of customisation, these programmes are now becoming increasingly profitable and popular.

Two worlds collide

One thing is for certain: the hypercar industry is in a league of its own. Closer to works of art than everyday vehicles, these cars represent the frontier of automotive technology and performance. While manufacturers may draw inspiration and innovations from horizontal sectors like motorsport, there are a host of other considerations for hypercar development.

"Race cars, by their very nature, are minimalist and purposeful – maximum performance in every respect," explains Salter. "Compared to a road car, there is little focus on comfort or long-term reliability, as those have little bearing on a team's ability to secure podiums and lucrative sponsorships. To your average motorist, a race car would feel stripped out, noisy, uncomfortable and utterly impractical – not to mention, illegal – on the road."

"Hypercars, on the other hand, often deliver similar levels of performance to a race car while featuring modern comforts, a measure of practicality, and meet road design and safety requirements. This is no small feat; it is an incredible engineering accomplishment to see vehicles capable of travelling 300 miles per hour comfortably cruising through busy London streets. Of course, hypercars draw a lot of expertise and technology from motorsport, but it really is a whole new challenge."

With a successful career establishing and running motorsport and engineering businesses, Salter was inspired by what he saw as a growing opportunity: the rise of Additive Manufacturing. With a broad scope of applications, AM showed immense promise in helping to solve engineering challenges. With support from a local growth fund, SEMLEP, Salter was able to realise his vision and the Digital Manufacturing Centre (DMC) at Silverstone, near Northamptonshire, UK, began early commercial operations in April 2021, launching officially in July.

Using connectivity to bring together metal and polymer AM systems with a host of additional services, the DMC serves a range of sectors from aerospace and defence to industrial. But its first customers are hypercar and motorsport manufacturers. "Compared to traditional automotive development programmes and production, hypercar manufacturers are often far more agile with an entirely different set of engineering priorities," Salter states. "While well-known manufacturers in Germany and Italy have tended to dominate the space, we see it opening up significantly. There are successful high-performance electric vehicle (EV) hypercar startups and, equally, niche brands and brilliant engineers doing something bold and different."

"Much of this comes down to the nature of the sector – world-class engineering, design and innovation are almost the basic essentials. With a high unit cost, it is possible to invest resources into R&D, creating new solutions and using novel materials," he explains. "As you can imagine, at this level of performance there is a higher degree of engineering rigour and a desire to push the limits that doesn't exist elsewhere in automotive. In this pursuit, the individual components truly matter, everything is considered. Why? Because to dominate this space requires a product that sets exceptional standards at the intersection of design, engineering, performance and luxury."

The additive advantage

So, where does metal AM fit into the hypercar equation? What benefits does it deliver to a low-volume industry that is heavily reliant on carbon composites

Fig. 3 The DMC's rapidly expanding AM production capability includes two Renishaw RenAM 500Q metal AM machines (Courtesy DMC)

Fig. 4 As well as metal AM, the DMC has a range of polymer AM capabilities (Courtesy DMC)

Fig. 5 A DMG Mori 5-axis CNC machine at the DMC (Courtesy DMC)

Fig. 6 Located on Silverstone Park, at the heart of the Silverstone Technology Cluster, DMC is close to some of the most famous names in motorsport (Courtesy DMC)

and subtractive manufacturing? Does it complement these existing technologies?

The first, and perhaps, most obvious advantage is in light-weighting. This megatrend has played an enormous role in the automotive industry over the past decade, as manufacturers look to make their vehicles more fuel-efficient. As you can probably surmise, its role in the hypercar sector serves a different purpose. Each kilogram that is shed helps to improve a vehicle's handling and power-to-weight ratio. Not only does this mean that it will accelerate faster, but it will also decelerate and change direction more easily.

Another benefit to reducing vehicle mass is that you have the opportunity to add it back in. That sounds counterintuitive, but customers in the market for these vehicles often expect high levels of NVH (noise, vibration and harshness) management and interior comfort. So, there is a requirement for effective sound insulation, quality trim, air conditioning and high-quality audio systems.

"While high-performance composites like carbon fibre play a critical role in minimising weight and maximising stiffness, there are many metal components that simply cannot be replaced by composites," explains Salter. "This is where we are seeing new and exciting applications for metal AM – helping to cut weight without any compromise to function or performance."

"We are able to develop much lighter structures, minimising the amount of metal required for the part to perform its intended function," he continues. "This is achievable in a number of ways, from hollowing components to utilising 'bionic' design. The end result is parts that could not feasibly be made by any other means. Unlike subtractive manufacturing, we can develop very specific designs to meet load and duty requirements, ensuring

"Unlike subtractive manufacturing, we can develop very specific designs to meet load and duty requirements, ensuring that we maintain strength in the right places while cutting mass everywhere else. Essentially, we put the material where we need it, rather than attempting to remove it post-manufacture."

DMC: Putting connectivity at the centre of operations

The DMC is the first company to adopt Renishaw Central, a new manufacturing connectivity and data platform from the UK's Renishaw PLC, across its complete AM and subtractive manufacturing operations. The ongoing close collaboration between the two companies has evolved from Renishaw supplying the DMC with metal AM machines, followed by several of its metrology solutions, and now the implementation of this digital platform.

"A key focus of the DMC is connectivity – bringing together data from across our processes to ensure customers receive the best possible solution," stated Salter. "From improving our efficiency to enhancing part design, our objectives rely on exceptional engineering and the meaningful interpretation of useful data."

"Renishaw Central enables us to not only connect our Renishaw AM and metrology equipment, but also provides a platform via which we can connect other equipment – like machining systems – to achieve complete end-to-end capability. This plays an important part in helping us realise the potential of additive manufacturing, allowing for the creation of a true Digital Twin and the implementation of advanced algorithms to adapt processes and parts in real-time without human input."

With the intention of helping to drive the future of AM by realising a fully-connected process chain, the DMC is leveraging actionable data to deliver a step-change in manufacturing capability. Renishaw Central will play a crucial role in this ambition and enable the DMC to embrace Industry 4.0 practices and principles; not only will the platform provide end-to-end manufacturing data capture, but it will also allow the DMC's engineers to further refine part design and processes by effectively implementing capabilities including predictive analytics and artificial intelligence (AI).

Renishaw Central's automated data collection brings together information from across the process chain, including AM systems, on-machine measurements, shopfloor gauging and co-ordinate measuring machines (CMMs). It uses process, metrology and device information to provide a single, intricate view of a manufacturing facility's data, including visualisation and reporting – an invaluable resource for engineers.

This data can then be used in applications for process automation or via Renishaw Central's new application programming interface (API) to inform product lifecycle management (PLM) and design optimisation, shopfloor monitoring systems and more advanced applications, like using algorithms to establish predictive analytics and the implementation of AI systems.

Through Renishaw Central, the DMC hopes to further improve its production intelligence by using data from all available sources to provide superior control of upstream processes. With end-to-end data collected across a number of operations, cells and time periods, it provides all the necessary information to allow for true continuous improvement. By characterising acceptable process trends and performance, the DMC will be able to predict, identify and correct errors and deviations as quickly as possible.

With shorter feedback loops, Renishaw Central will enable the DMC to react and adjust its processes to increase machine utilisation and reduce waste. Equipped with actionable metrology data from throughout the process chain, the DMC's design and process engineers will also be able to enhance product design, process performance and resulting part quality.

"Most manufacturers already have access to a wealth of metrology data, but how often is it fully utilised?" asked Jonathan Archer, General Manager, Renishaw. "Renishaw Central helps to employ this data in a meaningful way, providing the right data at the right time to better understand production and facilitate improvements. The DMC has been an important collaborator in developing – and now deploying – Renishaw Central, helping us to address significant pain points within advanced manufacturing."

"We believe that the DMC is best placed to exploit the platform's full potential. The facility's ambition is the practical implementation of connected technologies, AI and the realisation of Industry 4.0 – these rely on the collection and application of data, for which Renishaw Central will play a critical role."

Fig. 6 At the DMC, data is collected, analysed and recorded from all possible sources, including the ventilation and climate control systems seen here, so that should a manufacturing issue be encountered, all possible causes can be investigated (Courtesy DMC)

that we maintain strength in the right places while cutting mass everywhere else. Essentially, we put the material where we need it, rather than attempting to remove it post-manufacture."

"There is, however, a requirement that advanced manufacturing engineers be involved from the beginning," he added. "The primary advantage being that additive engineers will be able to help design the component for application as well as manufacture, thus ensuring an optimal solution. This was one of the core ideas behind the DMC, an engineering-led production facility – it is an approach that has already proven its value in a number of early customer projects."

It is not just hidden components either: visible and tactile areas of the vehicle have also been given the metal AM treatment. In one of the DMC's recent customer projects, the team replaced billet aluminium grab handles with hollow versions that were visually identical from the outside. How? By designing for metal AM from the inside – in other words, the engineers included an internal lattice structure to reinforce the part. Not only was the resulting part 55% lighter, it met the same performance criteria as the original design with a matching surface finish.

An ideal solution and new applications

While the performance appeal is clear, why is metal AM in particular so well suited to these high-performance road car applications? Salter says that three main factors dictate the ability of modern metal AM to meet the hypercar sector's requirements: production volume, production rate, and cost per part. With production runs in the region of 20–500 vehicles, there is a fundamental need to think differently to mainstream automotive programmes.

"When you're making limited-run, low-volume vehicles, there are economic restrictions on the manufacturing processes available to you," he explained. "Conventional tooling is incredibly expensive, limiting a manufacturer's ability to produce bespoke parts for a unique vehicle. AM requires no tooling, making it great for low volume – it has a minimum order quantity of one part. In that sense, metal AM is a revolutionary process for the hypercar sector. Taking the full product lifecycle into consideration, we can cost-effectively deliver the required part volumes and to a very high quality standard while maximising the aforementioned performance advantages. "

Salter is quick to point out another important benefit of metal AM in high-performance road applications: the ability to produce on-demand spare parts. "We are not talking about your

"Metal AM streamlines part supply, eliminates the need for inventory and warehousing, while simultaneously ensuring that a model can remain supported by the manufacturer indefinitely. All you need is to protect and preserve the digital assets – CAD and manufacturing data."

average five-door hatchback here; these are expensive vehicles made in limited numbers, and that justifies a different approach to aftersales servicing and support. Using AM, manufacturers can meet the demand for spare parts in a far more effective manner, with tool-free, on-demand component production.

"Metal AM streamlines part supply, eliminates the need for inventory and warehousing, while simultaneously ensuring that a model can remain supported by the manufacturer indefinitely. All you need is to protect and preserve the digital assets – CAD and manufacturing data. With customers all over the world, it also reduces logistics requirements; hypercar manufacturers could have a metal AM supplier in each of their key markets, for example."

Another application Salter mentions is the use of metal AM in support of legacy models and classic vehicles, a concept already embraced by one of the world's largest vehicle manufacturers. Indeed, Volkswagen Group has been using metal AM to reproduce the gearstick for the iconic Porsche 959 and water connectors for the Audi W12 engine since 2018. With spares for many classic vehicles extremely limited and support long since ended, this is certainly a market in need of supply.

"We have all seen the value of classic vehicles skyrocket over the past few decades, with many sports and luxury vehicle brands eager to service their heritage models," Salter notes. "Metal AM suppliers like the DMC are in a perfect position to help these manufacturers support their customers with on-demand part production – no tooling costs and minimal lead times."

Changing times and the electric future

So, there are applications for past vehicles, but what about looking to the future? Even the hypercar market is feeling the pressure of legislation and the UK ban on internal combustion engine (ICE) vehicles by 2030. The rise of electrification will undoubtedly result in additional pressure to make cars lighter, thereby maximising efficiency and range. Salter sees this as simply another challenge for the hypercar sector and suppliers like the DMC.

"We are fortunate to live in an exciting period of change," he states. "The drive to reduce emissions is having a major impact on the automotive industry and the long-term prosperity of manufacturers depends entirely on their ability to adapt. I think this will be far easier for agile hypercar manufacturers and hypercar programmes - those accustomed to working at the leading edge.

"If we are already using metal AM to solve challenges in hypercar design and production, then, given the passage of time, the progress of technology and stricter emissions legislation, it follows that metal AM will have a more important role to play. There are a multitude of promising applications in the EV space, from lighter motors to new motor manufacturing processes, extremely efficient heat exchangers, novel battery design, and so on. AM has the potential to solve a lot of our future transport needs. Whether it can evolve to a point where cost and volumes will enable widespread, mainstream automotive adoption is another question. That being said, we are now producing parts at volumes thought improbable, if not impossible, a decade ago."

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The future is Additive Manufacturing – if we take a more holistic view of the design opportunities

The uptake of Additive Manufacturing by industry, believes Autodesk's Paul Sohi, has been both stratospherically high and confusingly low. In explaining and addressing this dichotomy, Sohi explores the multiple potentials of AM when approached by taking a more holistic view of design challenges. Whilst there is no doubt that the popularisation of AM technology is influencing how we design products by shifting the design language to embrace more complex or nonstandard forms, Sohi believes that this is where the application of AM seems to be stagnating. So, how can we close the loop from design to manufacturing?

Additive Manufacturing, of course, is no new thing. It's something the readers of this magazine live and breathe – or at the very least, are frequently exposed to. AM has grown significantly in the last ten years, with the explosion of desktop polymer Fused Filament Fabrication (FFF) machines catering to the maker movement, all the way up to the most advanced and cutting-edge technologies for researchers and application engineers alike. Metal AM, in particular, has seen some of the most incredible innovations in the last decade. Technology developers are pioneering entirely new metal Additive Manufacturing methods, resulting in the emergence of a new wave of metal AM processes that are increasingly more affordable, from the initial cost of the machine, to the total cost of ownership and maintenance.

For example, SPEE3D's technology has managed to pull metal AM out of the bomb-proof room and into the field (Fig. 1). Leveraging the Cold Spray process for the twenty-first century, the company eliminates the need for the extreme safety measures required to operate Laser Beam Powder Bed Fusion (PBF-LB) machines. This enables machines to be deployed literally anywhere – in fact, the Australian army has used its technology to manufacture replacement parts for mission-critical hardware in the field. This is just one application, of course, but there are plenty of spaces that can benefit from on-site part replacement; ships, oil rigs, and other remote working environments, just to name a few. In addition to the remote application case studies achieved, there's also a more obvious benefit if you're looking to add metal AM to your repertoire of tools: you no longer need a made-for-purpose AM room. Instead, you can now include metal AM alongside your other digital fabrication tools.

Fig. 1 A SPEE3D cell in field trials (Courtesy SPEE3D)

Fig. 2 A generatively designed skate truck created as a research exercise into the strength of metal AM parts (Courtesy Autodesk)

Research leads tech, but not manufacturing

There's little undocumented these days about the advancements in Additive Manufacturing, whether they are emerging hardware technologies, optimisation opportunities via improved software, or radical experiments in additive – we're seeing advancements nearly every day that forecast a bright future for the industry. Research in Additive Manufacturing is in a fascinating state right now, with as much work being done in academic institutions as in private industry, but, frequently, there seems to be a missing common thread when it comes to announcements: how one might apply these bright new technologies.

The adoption of any new technology in manufacturing is slow. Designers and engineers alike are generally sceptical of unproven tech, whether in hardware or software, and the embrace generally happens once clear and identified applications are presented. That scepticism is warranted; the risk of adopting new technologies can be too much if your profit margins are thin and you simply cannot take a chance on your process being halted. That's why new technologies need to prove themselves with solutions that aren't just effective, but reliable, before we can expect them to be truly trusted in the manufacturing workflow.

What we're seeing right now is not without precedent. Research, in the traditional sense, is not driven by application, but by the desire to find new knowledge. There is an abundance of that in additive, but it leaves a chasm to be crossed for use in industry; how do we go from abstract technical solutions to recognised and expected applications for new technology? And why adopt new technologies to begin with if we already have a proven workflow?

The answer is obvious, but it can also be difficult to identify, especially when one is laser-focused on delivering products: With markets constantly shifting, it's necessary to adopt new technology into manufacturing to remain relevant and competitive. It's no coincidence that there's a correlation between the proclivity for startups to take risks on new tech, and their ability to disrupt the status quo.

The disconnect between research and application has always existed, because research lives in static – it's focused so much on the how that the what is rarely considered. This leaves the industry in the position that, while huge advancements continue to be made in Additive Manufacturing technology, the engineers and designers who might leverage that technology may be unable to see how they could apply it in their practice.

The relationship between manufacturing and AM

The uptake of AM in the manufacturing space has been both stratospherically high and confusingly low. In my experience, there's no design studio out there without at least a polymer AM machine present for prototyping, nor is there an engineering practice without AM machines installed to test new innovations – but the line between those two spaces has remained solid for most companies. While Additive Manufacturing technologies continue to advance rapidly, we're learning rather slowly and steadily how to best use it for production.

It's interesting to observe that, while we've seen many incredible innovations in AM tech, applications haven't really seen widespread adoption in products outside of niche applications. The technology has found firm footing in prototyping, enabling designers and engineers to expedite their design processes in an iterative process, reducing the lead times on receiving physical models as part of the design cycle. While integration in this field is hugely valuable, it does not exactly represent a revolution in how we design and make.

In fact, for the last ten years, the majority of stories we've seen around the use of Additive Manufacturing in design or engineering have been focused on geometry or mechanics. There's no denying that the popularisation of AM technology has influenced how we design products, shifting the design language to embrace more complex or nonstandard forms that AM enables, but this is where our application of AM seems to be stagnating.

To some extent, this is to be expected – take, for example, television. When TV broadcasting first debuted, producers were both unfamiliar and untrained in leveraging this new medium, so applied what they knew from radio. As a result, those early days of broadcasts consisted of talking heads reading the news, or the televising of dramatic performances from a live stage. As time went on, we came to understand what this new medium enabled, both in the programmes we could produce and the interesting results that intelligent (or experimental) use of the camera could achieve. Additive Manufacturing is going through a similar adolescence; the primary focus revolves around the notion that 'I can make anything', but the scope of this is limited to geometry and mechanics.

Geometry as a principle, however, needs to be separated from mechanical properties. The forms we can produce with AM enable nearly any shape we can imagine – and even some forms we don't imagine, but which the computer can propose to us as a starting point via technologies like generative design (Figs. 2-3). Additive opens entirely new worlds of material property manipulation previously thought impossible. When we can forge materials into any shape, of course mechanical properties will be the first port of call (if you're a mechanical engineer). But what about thermal and aerodynamic properties? Even this, though, is still just the surface. It's when we combine the multiple potentials of AM with a new, more holistic view of our design problems that we can truly embrace AM's capabilities in a more advanced manner.

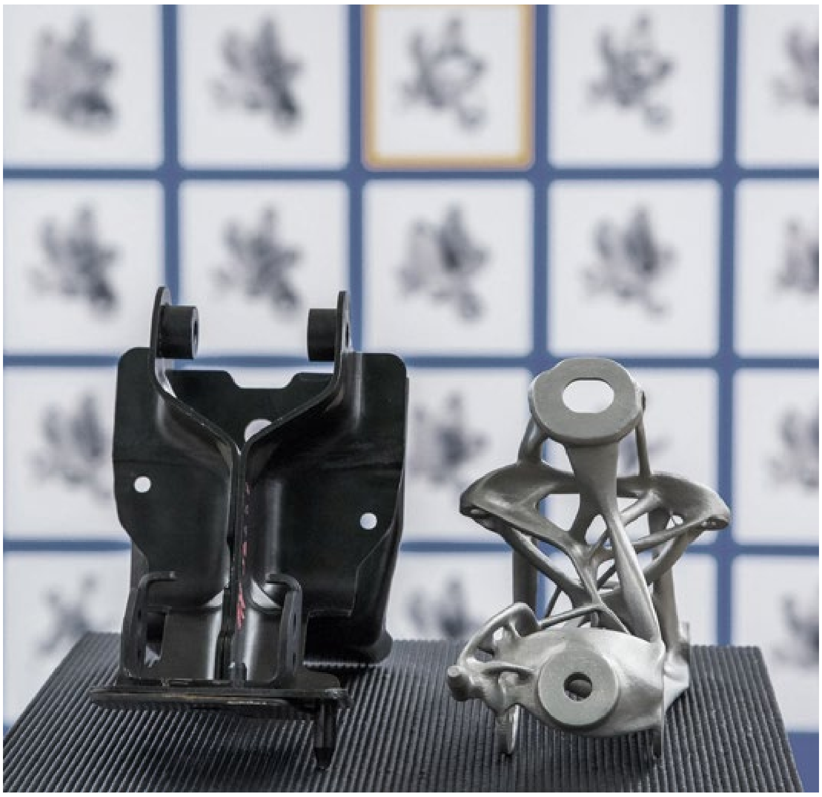

Fig. 3 The original seatbelt bracket, next to the generatively designed, metal additively manufactured solution (Courtesy General Motors)

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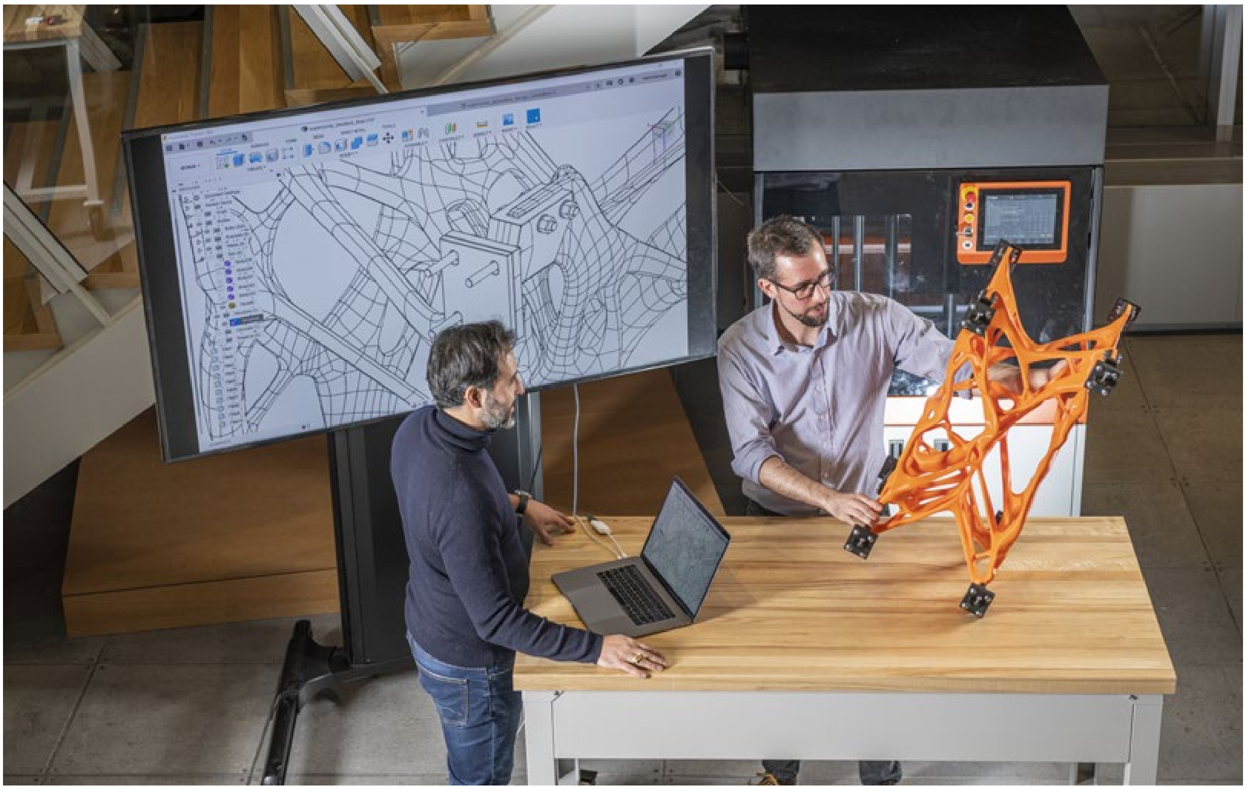

Fig. 4 With the right software, generatively designed parts can be produced in a matter of minutes, enabling you to get to manufacturing much faster (Courtesy Autodesk)

The challenge of maximising the benefits of Additive Manufacturing is two-fold: We need to increase the scope of possibility to look abstractly at material science (as opposed to just material properties), while also considering the entire assembly or system of parts the AM element may be introduced into. Imagine you are designing a high-performance vehicle, where efficiency dictates virtually all the decision making. You need to make your vehicle as light as possible, as aerodynamic as possible, and as power-efficient as possible to shave those precious fractions of a second off your lap time.

With that in mind, the obvious application for AM is reducing weight (lightweighting) while maintaining the relative strength of parts – but there are also cooling and slipstreaming optimisations to achieve. Suddenly, we are compelled to consider using AM across the entire vehicle when making decisions about how, or whether, to apply AM. From a mechanical perspective, the chassis is an obvious contender in a vehicle, where we can use AM to dramatically reduce weight, while maintaining stiffness so that the vehicle performs as intended.

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With aerodynamics, there's a whole world of complex panelling forms that can be applied to the vehicle body to manipulate how air flows over the vehicle. What if the same structure that enables sharks to move so quickly through water was to be applied to parts of the vehicle? AM enables, for example, the creation of granular vortexes that generate the necessary forces to keep the vehicle gripping the road while also flowing over the car directionally to improve how the vehicle cuts through the air. From a thermodynamic position, AM makes it significantly easier to create complex, highly efficient heat exchange forms that ensure everything on the vehicle operates at nominal temperatures, drawing heat away from critical components.

Each of these static examples is valuable individually, but it is when all of these pieces come together that we can truly harness Additive Manufacturing in a manner that leverages the potential of the technology, demonstrating the true capabilities of digital manufacturing and smart manufacturing. Think about the exhaust system of an internal combustion-powered car. Here is a system that must perform well in harsh environments, tolerate a range of ambient temperatures while dealing with the high heat it creates, and, in performance vehicles, must be as light as possible. Considering the above independent factors, and the additional element of systems thinking, it's possible to merge all the static concepts together to make something literally greater than the sum of its parts.

By leveraging the capabilities of Additive Manufacturing, an exhaust system could theoretically have a single component in its assembly that is so thermodynamically efficient that the rest of the components in the system could be replaced with extremely light, less temperature-sensitive parts. If a single element of the exhaust system can cool the exhaust fumes enough, there's no need to use metals in the rest of the exhaust system. This could enable a switch to cheaper materials that offset the cost of the metal AM part while also decreasing weight. But that's just one piece of the puzzle.

The outer casing of this hybrid exhaust/heat exchange part is the part most likely exposed to the elements, and, with splitters being commonplace on performance vehicles, any additional element further controlling how air passes under the vehicle would add value. That's where our aerodynamic considerations can play a part in the design of this single part. Lastly, the most familiar application of AM – the mechanical advantages – can also be considered within the geometry of the heat exchanger, improving stiffness by making it a structural part of the vehicle (as motorcycle engines often do).

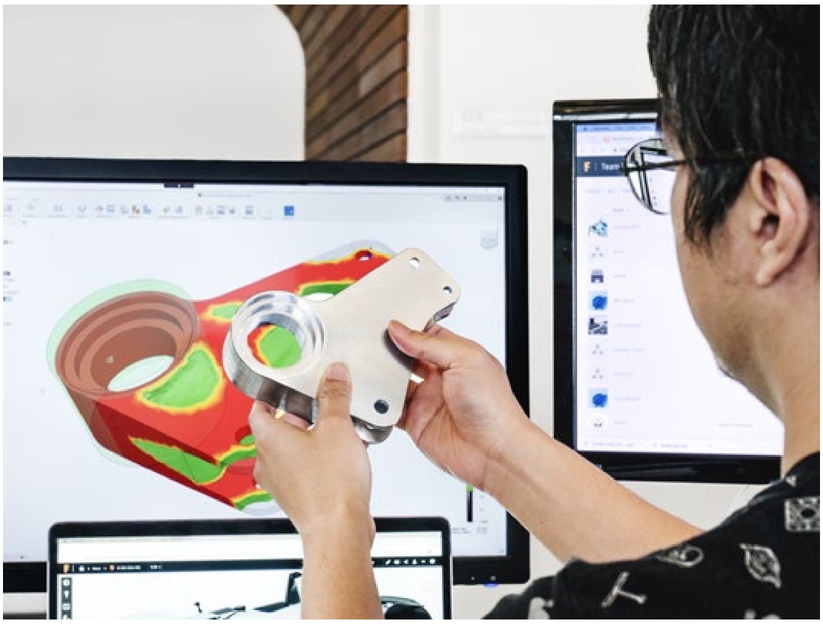

Fig. 5 A mechanical engineer checking his part against FEA data in Autodesk Fusion 360 (Courtesy Autodesk)

"One of the greatest challenges to design is the market itself. Being first to market with new products is more critical than ever, but human time remains very much the bottleneck in the process."

Grand ideas need grand tools

You may be thinking that this all sounds very exciting, but that the amount of time and research it would take to produce such a thing are completely outside the scope of possibility for all but the most elite manufacturers. But this is not the case. Three years ago, Autodesk announced the launch of generative design in Fusion 360, a radical paradigm shift for designers and engineers that enables the creation of ready-to-manufacture solutions to mechanical problems in a matter of minutes.

One of the greatest challenges to design is the market itself. Being first to market with new products is more critical than ever, but human time remains very much the bottleneck in the process. Realistically, even the most resourceful of companies can only explore a small handful of concepts before needing to make an informed decision about which strategy to commit to, lest they be left behind in the market. One of the greatest pressures to this is designing for manufacturing (DFM). Our current relationship with design tends to follow a pattern of understanding what the functional and aesthetic goals are, then iteratively inching toward them. Generative design flips the script, enabling engineers and designers alike to take all the known mechanical requirements a part must meet and make them the starting point of a design cycle, instead of

Fig. 6 Generatively designed alloy wheel from Volkswagen (Courtesy Volkswagen Group of America)

a goal to be iteratively reached. By placing mechanical requirements up front, generative design helps produce geometries that meet needs in a matter of minutes, giving designers and engineers a clear geometric representation of how to solve their mechanical problems.

Generative design factors in more than just the mechanical requirements. Designers and engineers may also define the desired manufacturing methodology, whether that's additive, subtractive, or casting. Alternatively, you can explore all of these manufacturing options at once, in order to get a sense of the geometries the mechanical requirements will require, but limited to ready-to-manufacture designs that you can quickly move to the factory floor. What this means is that generative design can factor in not just the engineering requirements, but the intended manufacturing methodologies as well, and present optimised geometries for each specific manufacturing method. If you're additively manufacturing, for example, minimum element thickness and overhang angles will be a key consideration. With generative design, you can apply your specific AM criteria to the study, along with your mechanical requirements, ensuring you have not only something that is highly optimised, but ready for manufacturing straight out of the gate.

This isn't theoretical. Companies all over the world are already taking advantage of generative design, hugely reducing their lead times to manufacturing. General Motors has introduced generative design into its workflows, alongside Additive Manufacturing, to combine part consolidation with lightweighting to help make its fleet of vehicles more fuel efficient. Volkswagen explored generative design for every aspect of its vehicle with the Type 20 Campervan concept (Fig. 6). Tarform Motorcycles uses generative design in the chassis of its bike to maximise stiffness and reduce weight. All these examples have resulted in significant reduction in design lead times, because generative design only provides ready-to-manufacture designs that are already validated against the mechanical specifications provided by the operator.

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Closing the loop from design to manufacturing

So far, we've discussed the challenges facing modern designers and engineers in their relationship with Additive Manufacturing, systems thinking with AM technologies, and generative design as a tool to expedite engineering problems. There remain two portions of the loop not yet addressed: design and manufacturing. As Autodesk's Peter Rogers explained, "We constantly strive to provide the best possible solutions for manufacturing. We've been invested in the industry for several decades, working in step with every level of manufacturing. We aim to assist everyone, from the engineer on the shop floor designing and building in

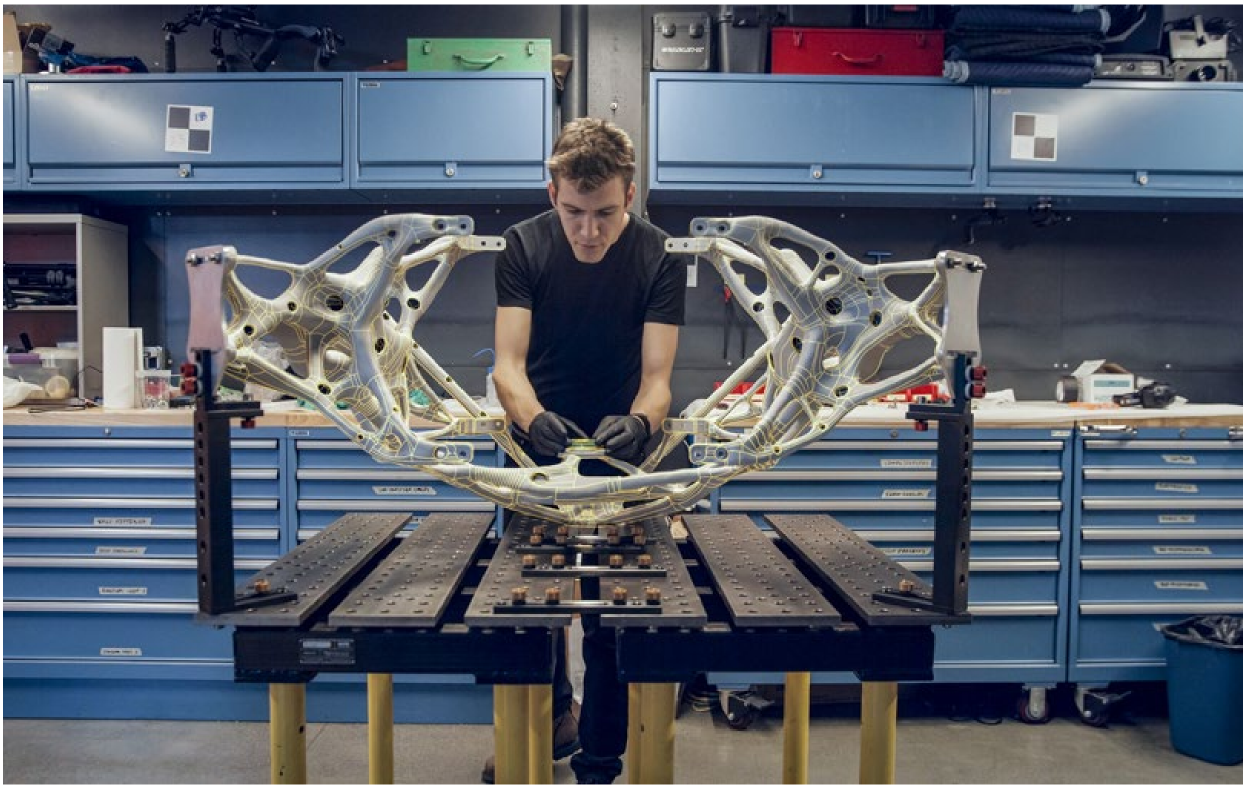

Fig. 7 A portion of the Lunar Lander concept made in collaboration with JPL, using generative design and Autodesk Fusion 360 (Courtesy Autodesk)

CAD, through to the leaders making decisions and managing projects. We strongly believe that Autodesk best serves industries by working with them closely, intimately understanding the challenges they face, and investing in the research that looks to the future of manufacturing. Our intent is to give our users the competitive edge of not only reaching market first, but also making products more intelligently, more pragmatically, and with considerations to their impact on the planet."

With tools like Fusion 360, our intent is to unite the many roles that collaborate on manufacturing problems in a common set of tools that enable all team members to work in a shared environment, with a shared dataset. As part of that, we're investing heavily in metal AM capabilities for Fusion 360 through our Additive Extension. We're bringing PBF-LB capabilities into the tool and plan extensive features that support metal AM coming through 2021 and beyond.

We also understand that, sometimes, the best solutions already exist in the field, and it's beneficial to all involved to bring that expertise into our solutions and family of products; in 2015, Autodesk acquired Netfabb with exactly that in mind. We take pride in our capabilities and our legacy, but also recognise there are leaders in advanced manufacturing in the marketplace, and sometimes it makes more sense to fold expertise in rather than building up from the ground. Netfabb now offers a world-class experience in metal AM for all levels of users, including the ability to pack parts for PBF-LB, label parts in-product before manufacturing, and the ever-popular ability to cut parts intelligently to fit into a build volume.

Looking to the future

The future is looking very bright for Additive Manufacturing. With an increasing shift into applications and out of the research lab, everyone at Autodesk is expecting a new age of advanced products making their ways into the hands of consumers worldwide. We're here to work with you every step of the way, providing tools for the challenges you face today as well as bleeding-edge technology that we see as the future of manufacturing.

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Building a case for radical collaboration plus quality standards: The pathway to growing the AM industry

While the acceleration of metal Additive Manufacturing adoption is seen as inevitable, thanks to its advantages over conventional manufacturing processes for high-complexity, customised or on-demand parts, Sigma Labs CEO Mark Ruport believes that 'radical collaboration' is required for AM to reach its true potential. In this article, Ruport discusses how the company is targeting radical collaboration and the implementation of cohesive quality standards across the value chain to grow AM and overcome the challenges posed by true industrialisation.

I can take no credit for originating the term 'radical collaboration'. I first heard this phrase several years ago, and it stuck with me because I love the concept of boosting collaboration to the next level. And while our company mission statement and overarching objective is to be the 'QA standard for Additive Manufacturing,' I know that our industry and its customers benefit from sharing data and best practices as widely as possible. We also recognise that 'everyone is smarter than anyone,' and want to leverage this fact.

When it comes to Sigma Labs, we define radical collaboration as establishing deep relationships with our customers and partners, in both technical and business arenas, to not only ensure our mutual success, but also accelerate growth of the AM industry. We envision doing this by collecting data on the Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing process, measuring that in-situ monitoring data precisely, using that data to create a machine-learning feedback loop that improves both individual part quality and the entire manufacturing process, and making that data available to our customers, partners, and eventually, everyone in the industry. At its core, our objective is to 'pull the future forward' by leveraging as much knowledge from as many sources as possible.

In practice, our vision means that when an end-user wants to build a particular series of parts, or a service provider wants to bid on a project, they will have information at hand to determine which types of designs, metals, powders, procedures, etc., are likely to produce the least number of defects and have the highest probability of success. Think of this as creating a catalogue of defect data, supported by best

Fig. 1 Sigma Labs aims to accelerate the growth of the AM industry by collecting data on the PBF-LB AM process. Pictured are test parts produced using metal PBF-LB (Courtesy Sigma Labs)

practices in using powder, metals and machines on specific classes of parts. This data is continually refined through manual and machine training, while cycle times are reduced and economics improve through scrap fraction reduction. From an economic and customer satisfaction standpoint, this type of actionable information is invaluable because it leverages critical data and reduces risks. We've seen this type of collaboration work well in other industries – for example, in cloud-based software, it is no longer necessary for a vendor to build every component from scratch when tested and proven open-source modules are available to handle significant functions.

When someone asked me recently for an example of where radical collaboration has worked, I immediately thought of YouTube: hundreds of thousands of individuals, companies, educational establishments, trade groups, and others have contributed to a massive knowledge base of how-to information. The more amateurs and professionals post videos, the better the overall quality gets, and the more everyone benefits. The feedback loop is built in, with viewer comments and suggestions. Sigma Labs' YouTube channel is an example of this, since we have many videos on both narrow-focus and broad topics related on metal Additive Manufacturing quality.

Overcoming AM industry challenges

You may have read articles that discuss a lack of adoption of Additive Manufacturing when it comes to producing end-user parts. Some have even suggested that opportunities for the metal AM industry will remain small in the coming years – and mostly focused on low-volume, highly-customised applications. Perhaps these sceptics have a relevant point to make when talking about the generic Additive Manufacturing marketplace. However, our company, Sigma Labs, as well as others, are involved with a section of the marketplace that has high potential for growth: the industrial mission-critical segment. This includes applications using the most expensive materials and a consistent standard and high quality of individual parts is mandatory. Industries in this segment include defence, aerospace, aviation, transportation, medical, oil & gas, and power generation.

I pointed out one example of this phenomenon in a recent *Proactive Investors* article. Speaking of the electric vehicle industry: "It was in 1996 when General Motors introduced the EV-1, and, of course, that failed for a lot of different reasons – primarily because of battery life and technology and refuelling, because the infrastructure wasn't there. It's a good analogy to what's happened with 3D metal printing."

"Across this broad spectrum of end-users and industry suppliers, we are in a singular position to collect a tremendous amount of data that can help improve the digital process from design, to simulation, to AM process and post-process steps."

Some twenty-five years later, the technology, the batteries, and the EV infrastructure have finally caught up to the disruptive, revolutionary promise EVs could achieve – and now offer – as the world turns toward clean-energy transportation. Interestingly, there are still plenty of naysayers regarding the EV market, despite the fact that several major automobile manufacturers have promised to go totally electric in the near future, including Jaguar (2025), Volvo (2030) and GM (2035). I predict that some of these EV naysayers will soon become cheerleaders as technologies mature and become mainstream – especially now that Tesla has a market cap of $560 billion, making it worth as much as the next ten automotive companies combined.

While not at the scale of the worldwide automobile industry, I believe metal AM has similarly matured and is poised to usher in a transformative approach to industrial production by creating lighter, stronger, and more durable parts that could not be produced with traditional manufacturing processes. This is the promise of what is now a very exciting industry to be in at a unique point in its history. One of the reasons Sigma Labs is in a good position to spearhead radical collaboration is that we are a third-party agnostic in-process quality assurance (IPQA) solution which works with many different metal AM machine OEMs and materials.

Across this broad spectrum of end-users and industry suppliers, we are in a singular position to collect a tremendous amount of data that can help improve the digital process from design, to simulation, to AM process and post-process steps. We are laying the foundation for our company – plus working with other industry leaders – to leverage our collective learning and create a win-win scenario for individual companies and the entire Additive Manufacturing industry.

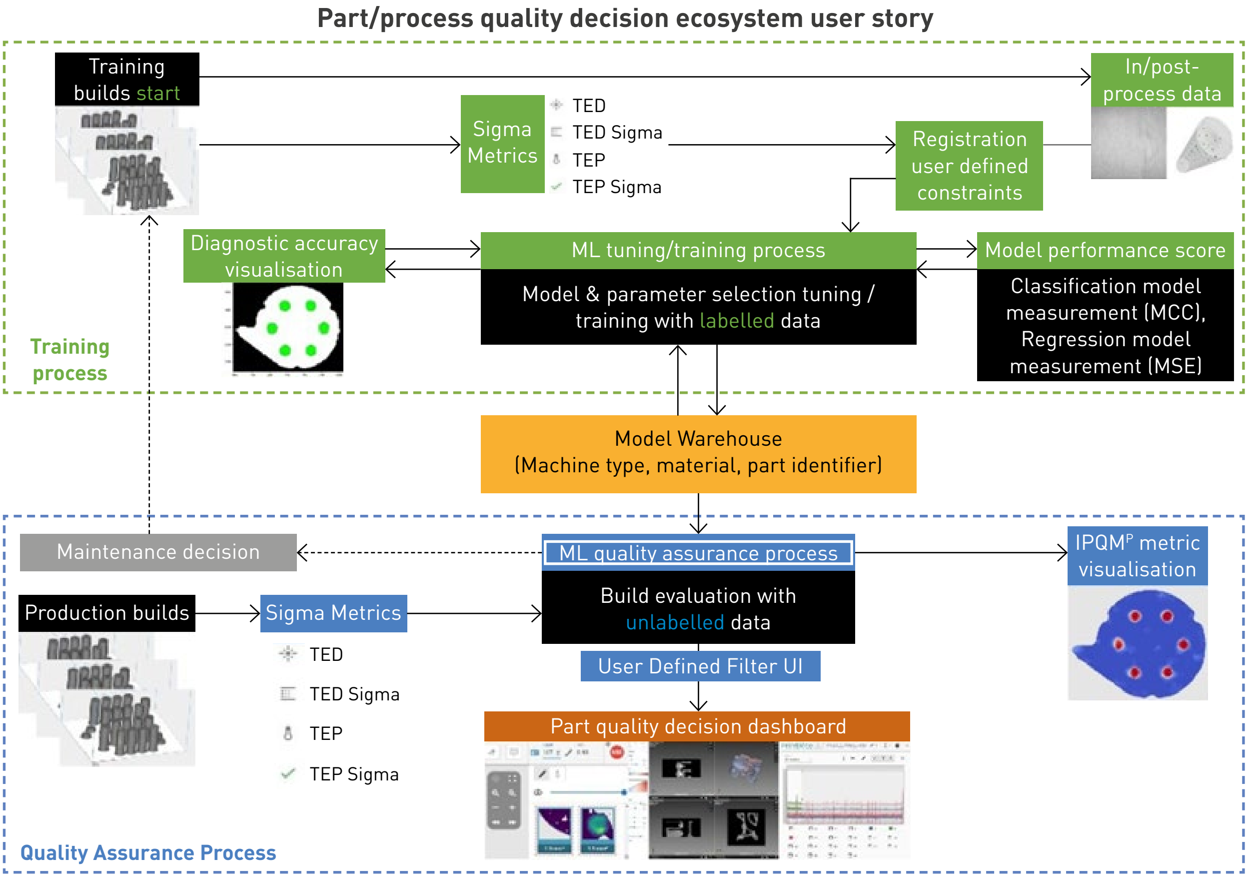

Fig. 2 A graphic showing the part/process quality decision ecosystem user story

The Additive Manufacturing parts/process quality ecosystem

Although our primary mission is to focus on AM quality standards, the data we collect supports what we call the Part/Process Quality Ecosystem. As our CTO, Darren Beckett, said in his recent article on the Sigma Labs blog, 'Machine Learning: A Game Changer for Additive Manufacturing QA', "Think of the end-to-end part/process quality decision methodology as an ecosystem that functions best if you can distinguish between part and process quality. Effective AM machine learning models are designed to both recognise anomalies in specific parts and monitor the quality of the process itself."

Fig. 2 shows how the part/process quality ecosystem benefits from a machine learning foundation. Collaboration and quality are closely linked in AM. Since much of the output of AM is mission critical (e.g. space, aviation, auto, medical parts), the stakes to get it right are especially high, both on a micro and macro level. On the micro side, part failure or rebuilds can lead to negative outcomes ranging from increased costs to damaged brand reputations – or, in the case of medical device parts, serious injury or worse. There is a strong imperative to get it right the first time, and every time thereafter. On the macro side, consistent and reliable quality standards will contribute to faster adoption of AM among companies still evaluating AM vs traditional manufacturing methodologies.

We also firmly believe that quality is best measured in-process, not post production. In this argument, we are following in the footsteps of no less an authority than W Edwards Deming, the engineer, statistician, professor, author, lecturer, and management consultant who invented The Deming System of Profound Knowledge. As reported in *A Lean Journal*, Deming stated: "Inspecting to pull out the failed items from the production before a customer sees them is a path to failure. When companies do this, they are trying to inspect quality into the product. However, 100% inspection has been shown to be only about 80% to 85% effective. If the process is this bad, the process needs to be improved." And improving the process, not just the inspection, is the real point of radical collaboration.

Cycle time is a sometimes forgotten, but essential, element, of quality. If a company needs to go through five cycles to design, simulate, produce, find defects and conduct post-process measurements, economics suffer far more than if the same results can be achieved in only two or three cycles. With the right data backed up with the right feedback loop, the aircraft can be tested faster, the customised medical device can get to the patient on time, or the rig can get online and

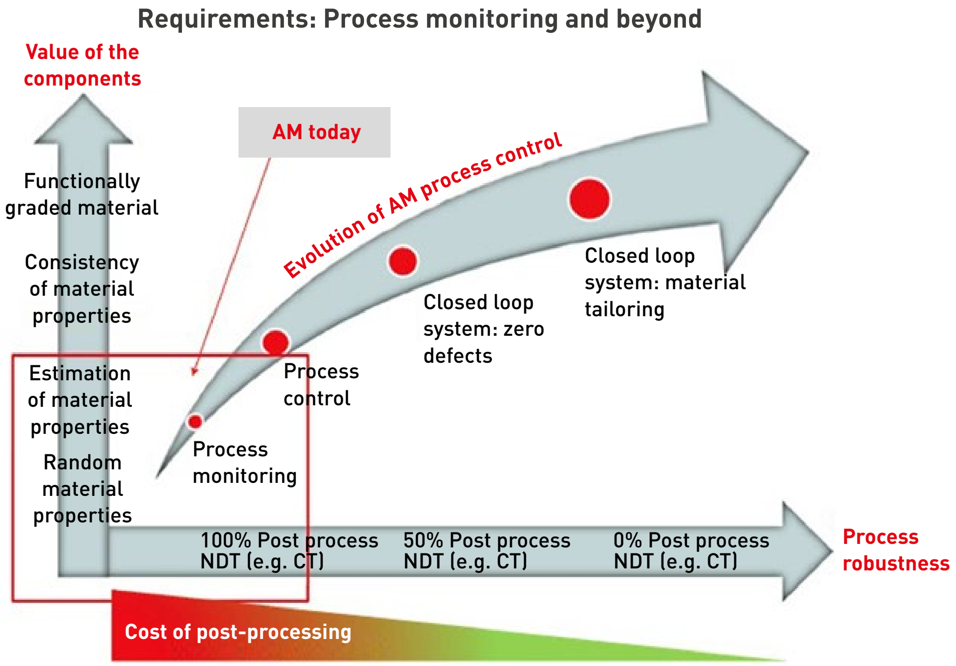

Fig. 3 Key requirements for process monitoring in PBF-LB AM

producing quicker. These results all have a large positive impact on revenue and company reputation. Of course, a lot of scrap can also be saved with shorter cycles, but that is not the primary benefit.

One of the great benefits of our focus on collaboration is its appeal to different levels of the organisation. On the micro level, it helps the production manager who is evaluated on their efficiency in producing quality parts. On the macro level, collaboration is important to the person in the executive suite who cares about overall output, revenue, profitability and brand reputation.

Creating a feedback loop

Enhanced parts and production performance depend on the feedback loop portion of the machine learning ecosystem. To accomplish this, you feed information in starting at the design and simulation phases, then create a durability analysis that produces a thermal clone of the part you want to produce. The part is then built, and the system monitors the signals during processing. Of all this data is immediately put into the knowledge base and your production team is informed about any inconsistencies between what was simulated and the actual output.

As Fig. 3 shows, if you create your AM environment as an evolutionary process that leverages radical collaboration, the cost of post-processing declines, while the value of the individual process components increases over time. The evolution works even without collaboration, but the benefits are limited. In a collaboration scenario, the manufacturer (plus machine supplier and others) benefits from data that is already in the database and, likewise, contributes data that will help others who will work with the same materials and processes in the future.

Rules for radical collaboration

Radical collaboration sounds great in theory, but I believe there are some steps you need to take and some attitudes you need to embrace, in order to collaborate effectively.

Rule 1: Be intentional

At Sigma Labs we have made radical collaboration one of our core company values and every team member knows how they contribute to making this value a reality. But this is not only true for Sigma Labs. The more this intention is shared across the industry, the more impactful our individual actions will prove to be.

Rule 2: Be radical

To be successful you need to step up your collaboration game – that's why we use the term 'radical' to describe what we are doing. We don't strive to be just another vendor competing for deals. Of course, we do compete aggressively, but our overarching goal is to achieve real impact for our customers and the entire AM industry.

Rule 3: Measure progress

Like any other objective, what you don't measure, you usually don't achieve. The two primary measurement categories of our radical collaboration initiative are, first, the number of end-user manufacturers, industry suppliers and equipment providers who contribute to, and utilise the data, and, second, quantifiable improvements in parts and overall manufacturing processing metrics for individual customers.

Rule 4: Create an actionable knowledge base
I've talked about the knowledge base quite a bit in this article because it is a key factor in the success of radical collaboration. Basically, a knowledge base is a consolidated set of data that is organised in such a manner that makes it easy to search, analyse and share. In a business context, the knowledge base needs to facilitate intelligent decision making.

Rule 5: Eliminate information 'stove pipes'
As defined by Wikipedia, "stove piping, in the context of intelligence, is information created to solve a specific problem that may be presented without proper context...often selectively presenting only that information that supports certain conclusions". A good example of where shared knowledge beat information stove pipes is the recent rollout of COVID-19 vaccines. Information sharing between pharmaceutical companies, medical research facilities, individual practitioners, and government agencies made a tremendous difference in achieving a speedy and successful rollout of these lifesaving drugs.

Rule 6: Be inclusive
The more entry points of data, the more accurate the system becomes. There is a saying in the data collection industry that the only thing better than big data, is bigger data. There is a concept called 'sparse data' where the individual piece of data may not be all that accurate or represent anything like the whole story. However, when you collect thousands or even millions (or billions, in the case of companies like Google) of pieces of sparse data, you create a powerful and accurate knowledge base.

Rule 7: No rule is more important than the mission
Our last and final rule is that no rule should override the goal of achieving radical collaboration. You can't be 'radical' if all you do is follow the rules. Our industry is still fairly young and there are no in-depth blueprints to guide practitioners. As I urge our team and everyone else in the industry: focus on what's best for the customer and the industry, and do it!

Collaboration in action: DMG Mori and Sigma Labs

A recent collaboration with DMG Mori illustrates the rules mentioned above, reported in that company's *Technology Excellence Magazine* concluded that from more simplistic uses such as small-scale component manufacturing to high-stakes applications in medical devices, aerospace, automotive, as well as oil and gas, the technology is a driving force in the innovation of the manufacturing industry.

With increasing significance of Additive Manufacturing, the requirements in terms of quality and productivity are rising, too. Ron Fisher, Business Development at Sigma Labs, was quoted as stating, "In these industries, failure of the final product is simply not an option. Even the most minor inconsistencies in small parts can create dire consequences for end users. For example, a poorly made acetabular cup used in a hip arthroplasty could result in the catastrophic failure of the replacement and extreme pain and suffering for the patient."

DMG Mori has been meticulous in its dedication to perfection in the QA process. However, the company wanted a QA solution that would allow the operator to have more control during the AM process. Ron Fisher remembers: "While post-process quality control is beneficial in catching errors before they go to end-users, that is really all it can do. Inspection is important, but usually too late to address and prevent problems." Additionally, post-process QA is time-consuming, expensive and, in many cases, destructive. This is why DMG Mori wanted a QA tool that enables its customers to overcome problems before the final product was complete, saving time and resources and maintaining the company's standards for helping its users manufacture reliable, proven and safe parts.

The aim of the collaborative effort was to qualify Sigma's in-process quality assurance (IPQA®) software PrintRite3D® and prepare DMG Mori's AM machines factory supplied as 'PrintRite3D Ready'. Specifically, a number of melt pool issues were identified and detected, including lack of fusion and keyhole anomalies using the TEP and TED metrics in conjunction with machine learning models to register and map post process CT data – helpful information for making in-process decisions that can eliminate problem parts before they start to affect other parts on the build plate.

Conclusion

This is just one example of how companies with specialised expertise can come together to create synergy – where one plus one really does equal more than two. Whatever part of the AM industry you represent, I look forward to your participation with our industry's knowledge base and radical collaboration initiatives. Time will tell whether we are successful in our quest. However, just like the acceleration of metal Additive Manufacturing is inevitable due to its many advantages over traditional processes for the manufacturing of certain high-complexity; customised; or on-demand parts, radical collaboration will be required for AM to reach its true potential. The exciting thing about being part of this initiative is that the potential is only limited by one's imagination. So, I say to the rest of the industry: Let's go amaze the world!

Author

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Distributed manufacturing: Old concept, new relevance, new technology?

In highlighting the vulnerabilities of global supply chains, events such as COVID-19 have inspired renewed interest in alternative forms of organising production. Distributed manufacturing is now seeing early use in fields such as oil and gas and for on-demand spare parts manufacturing. For the first time, large-scale on-demand manufacturing was seen in the supply of emergency PPE at the height of the pandemic. Dr Jennifer Johns discusses how AM can help to address the challenges this new business model presents, and introduces the University of Bristol's £1 million Brokering Additive Manufacturing project, which seeks to produce a revolutionary new brokering method for highly distributed and diverse manufacturing systems.

We in the industry have long debated the future of manufacturing, pondering how the organisation of production will be configured in the short and long terms. Events since March 2020 have contributed to renewed interest in how and why manufacturing could – or should – change to meet new demands. COVID-19, political shifts towards protectionism illustrated by Brexit, global recession, and events such as the container ship Evergiven's blockage in the Suez Canal, have highlighted the vulnerabilities of geographically extensive supply chains. These widespread value chains are, however, the backbone of the global economy, supporting high-volume mass production in lower cost economies, facilitating consumer demand for the rapid delivery of products, and enabling lead firms to organise their production more efficiently and flexibly. The activities of leading firms in this global economy can be characterised as being driven by three dynamics: 1) cost, 2) flexibility and 3) speed. This has created a complexity of organisational configurations based on degrees of externalisation of functions, different business models and various means of exercising control and coordination.

Until recently, we could have assumed that the current manufacturing landscape – built on the premise of standardised, high-volume production and large, centralised factories – would continue. Communication and transportation technologies enable the levels of control and governance necessary, with almost the whole globe 'conquered' by the unstoppable globalisation machine and underpinned by essential global value chains maintaining the status quo.

Now, we are all aware that there is a large question mark hanging over our understanding of the most appropriate way to organise

Fig. 1 The activities of leading firms in this global economy can be characterised as being driven by three dynamics: 1) cost, 2) flexibility and 3) speed. This has created a hige complexity of organisational configurations

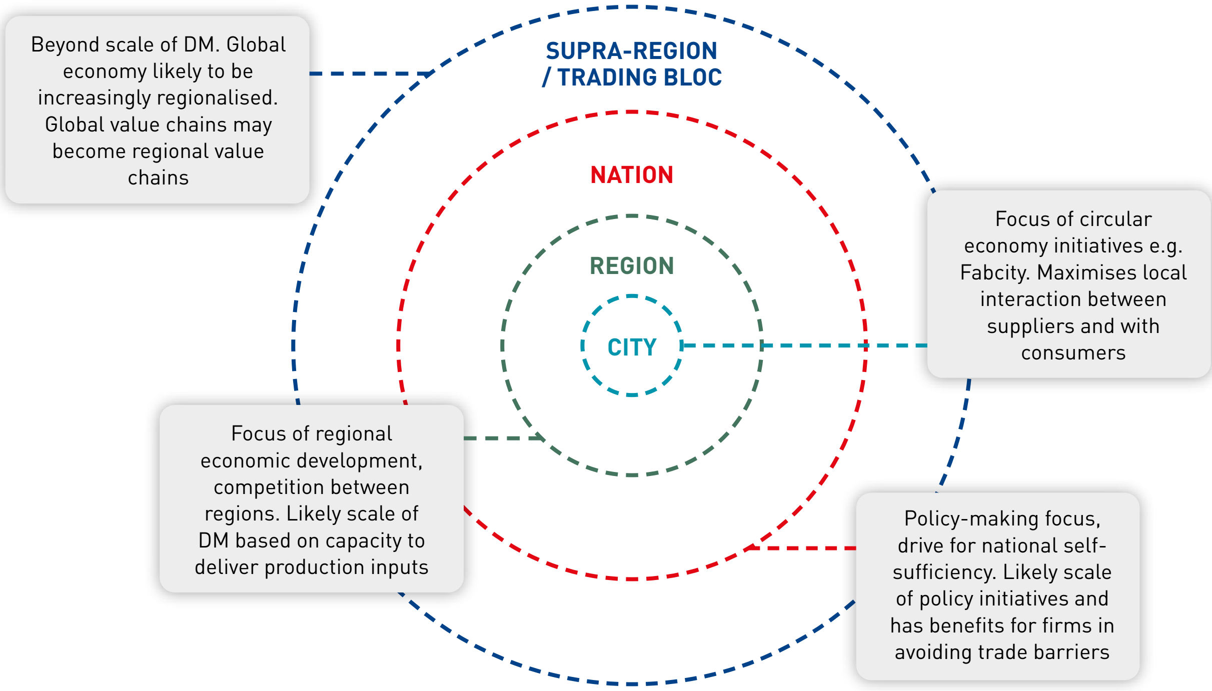

Fig. 2 Scales at which distributed manufacturing is currently being discussed and implemented

production; even the general public is increasingly aware of the challenges facing the contemporary system. All industry sectors are pondering how to respond to difficult circumstances. In the short-term, particular supply chain disruptions have to be tackled: for example, the shortage of semiconductor chips causing automotive factory closures. Meanwhile, alongside firefighting tactics, questions are being asked about what the immediate future may hold in terms of alternatives to centralised, mass production. This article focuses on distributed manufacturing and the potential role of Additive Manufacturing in new systems of production.

The conversation around distributed manufacturing has heightened since March 2020, due to the disruption to geographically extensive supply chains and the scramble for Personal Protective Equipment (PPE) production, particularly during the first wave of the pandemic. The flexibility and speed of delivery from additive manufacturers made headline news, and we witnessed the visibility of the AM community increase as it came together to meet critical demand. This seemed to herald a new age in local, collaborative production, utilising the special characteristics and capabilities of AM, signalling a maturing of the sector to those outside the industry. Buoyed by this impressive emergency response, we now have time to pause and reflect on how (or even if) this successful 'case study' could instigate broader, more systemic changes in which production is more localised.

Some clarity, therefore, is needed on precisely what 'distributed manufacturing' is. As Fig. 2 shows, there are currently multiple scales at which distributed manufacturing is being discussed and/or implemented. The term refers to the technology, systems and strategies that change the location and scale of the organisation of manufacturing. The term is now used to signal a transformative shift towards new localised forms of production, focusing less on economies of scale and more on economies of scope. Small, flexible and scalable decentralised production sites can operate through a digital network, in contrast to centralised models. Digitalisation is key to this connection between localised production sites.

Why is this model attractive? And why is now the time? The potential advantages of a distributed network of manufacturing are clear, and this manufacturing model offers the potential to solve some pressing problems.

Geographical contraction
The geographical contraction in supply chains reduces dependency on linkages that may be vulnerable to disruption by global events, including weather events and fluctuations in transportation costs (never mind global pandemics).

Greater flexibility and agility
It offers greater flexibility and agility compared to the fixed models of production. During times of uncertainty, greater flexibility is going to become an increasingly significant competitive advantage.

Proximity to consumers
Proximity to consumers can result in faster delivery, greater customisation and a more sustainable model. This helps with the broader agenda around environmental sustainability,

and shifts in consumer demands around both sustainability and customisation.

Increased communication and collaboration
Closer geographical proximity between suppliers can increase communication and collaboration, and increase the speed of innovation in design and production – at least in theory. Geographers have been debating the assumed benefits of clustering and agglomeration for decades, but the potential is there.

Greater efficiency and resilience
Distributed manufacturing has the potential for greater efficiency and resilience through local sourcing of materials and other resources.

Changing relationships
The relationship between producer and consumer may change as the user becomes more active in the design and production of goods.

Increased national reshoring
Distributed manufacturing helps meet a pressing political agenda in many countries to increase levels of national sovereignty and reshoring. While it is unlikely that this will directly drive a distribution model, political support for organisational changes could create opportunities via government funding and tax relief on new investments. (A note of caution here – the goals sought by politicians in their desire for more national production do not necessarily overlap with those of industry – and national government responses vary widely in the scope and value of their investments in manufacturing.)

Fig. 3 Early stage use of AM for distributed manufacturing can be seen in the production of spare parts in remote locations such as oil rigs

Fig. 4 At the height of the COVID-19 pandemic, large-scale polymer AM of parts for PPE demonstrated the effectiveness of distributed manufacturing to meet sharp spikes in demand for products

Where can we currently see distributed manufacturing in use?

Sectors in which we are seeing early-stage use include the production of on-demand personalised consumer goods, the supplementation of shortfalls in local demand for pharmaceuticals, and the production of spare parts in remote locations such as oil and gas rigs (Fig. 3). These examples, however, tend to be relatively isolated rather than acting as part of the kind of wider system of production that the term 'distributed manufacturing' alludes to. The closest we have come to larger scale distributed manufacturing is the production of PPE during the early stages of the COVID-19 pandemic, in which large volumes of PPE were produced by networks of SMEs and large manufacturers, typically located near the consumers (predominately hospitals) (Fig. 4).

It is clear that distributed manufacturing could offer some solutions to current manufacturing problems, and the role of Additive Manufacturing in this context is obvious. The advantages of this model mirror the capabilities of AM: flexibility; speed of delivery; sustainability gains through reductions in materials use; the broader increases in functionality through design for AM and its ability to be deployed across many parts of society, including in homes, educational settings and offices, in addition to more traditional factory

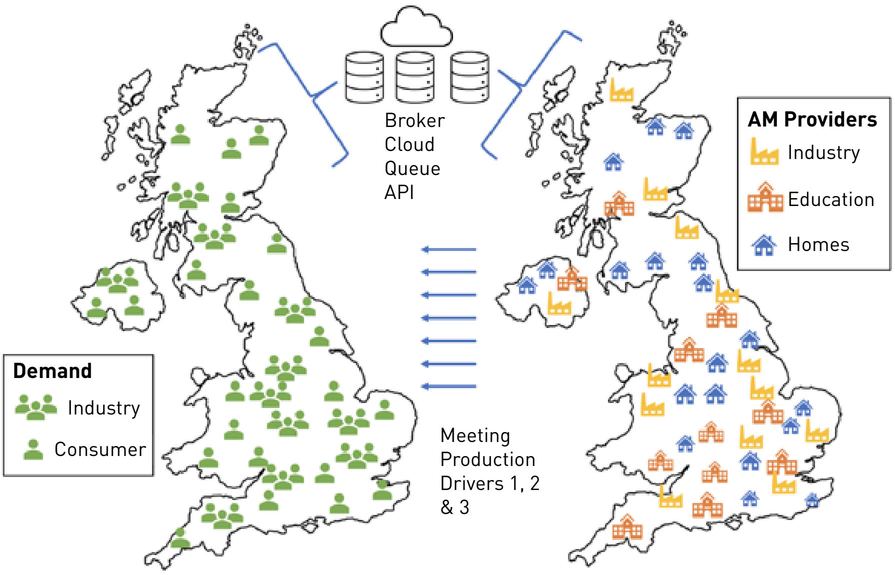

Fig. 5 A map of demand and the AM providers available to meet it in the UK, meeting the production drivers as highlighted in Fig. 1, namely 1) cost, 2) flexibility and 3) speed

> *"If manufacturing is to start shifting to more localised production, a huge window of opportunity presents itself specifically to AM, in contrast to traditional production methods."*

settings. Indeed, if we return to the advantages of a distributed network as discussed above, you may have been thinking: 'AM can do all that, too'. If manufacturing is to start shifting to more localised production, a huge window of opportunity presents itself specifically to AM, in contrast to traditional production methods.

How might this happen?

A series of interrelated processes are leading an incremental movement towards distributed manufacturing, but these are operationalised in a piecemeal fashion varying by sector and geography. We are seeing some reshoring (shift in production from low cost economies back to home countries), which necessitates local sourcing. We also see some elements of distribution in talk of the 'factory of the future' – or, digitised and automated factories which can be located in advanced economies due to the significant reduction in labour costs. Neither, however, contributes to a wholesale movement towards distributed manufacturing. AM offers us some examples of this model, such as the production of dental crowns, implants, dentures and appliances which are produced at an increasingly localised scale (ultimately being built in the dentists' offices). At present, with the exception of a handful of examples, localised production is still contained within the existing centralised production system. The status quo perpetuates.

That leads us to ask where the drivers for more transformative change may come from if there is still a degree of inertia in industrial AM. It may lie in the increasing re-integration of the community-led aspects of AM within the industrial arena. The two halves of the sector can be seen to be coming together, driven by the increasing sophistication of desktop machines. For decades, the AM community, focused on domestic applications, has long been voicing the desire to use the technology to return to aspects of artisanal production, develop circular economies, develop 'prosumers' (individuals who produce and consume their own goods), democratise digital technologies and relocalise production. As illustrated by the PPE production response, hundreds of thousands (even millions) of AM machine owners are connected through platforms such as 3D Hubs, and meeting in FabLabs, Makerspaces, Barclays EagleLabs, etc. These 'Makers' have found renewed relevance, which, when combined with expertise from AM, could contribute to the ability of Additive Manufacturing to facilitate a distributed network.

The main challenges

There are many challenges with regard to the development of distributed manufacturing, some of which apply to all manufacturing methods, others specifically to AM:

"...a key issue will be that of coordination and collaboration, something which is not easy during times of uncertainty and business pressure. Even so, there is a pressing need for independent arbitrage of communication and coordination of efforts to tackle these barriers to distributed network."

Infrastructure
There may be issues around infrastructure and the capacity of localised regions to support distributed manufacturing. Following decades of under-investment in manufacturing, the capacity of the UK to respond to increased demand is likely to need assistance. Key questions remain around where in the UK this distribution is likely to take place and the degree to which it will cluster around existing manufacturing sites. A truly distributed system would see manufacturing located in close proximity to the consumer, but the legacy of manufacturing to date is likely to skew where distributed manufacturing emerges.

What is 'local'?
Of course, this varies depending on the context. The political drive for distributed manufacturing is currently national, as part of the drive for sovereignty over manufacturing. However, if and when distribution occurs, the focus may well shift to the regional scale as different parts of countries vie for manufacturing to take place in their territories.

Governance and regulation
The governance and regulation of this sort of distributed network is embryonic and uneven. There will be issues to tackle around intellectual property (IP) which is more fluid in distributed manufacturing. IP monitoring during production will be needed to prevent copyright infringement. An associated risk is the relative immaturity of the software needed to manage the implementation of this model and the security of its networks (although some work is being done on this by organisation such as the SDAM [Secure Distributed AM] Alliance). Some regulatory issues will be broader – take for example, regulation of manufacturing production. Can we produce in neighbourhoods and cities? Will this be permitted by local government? Desired by local populations?

Material availability
The range and quality of materials, while expanding, still needs improvement in order to support distributed manufacturing. There is an increased focus on recovery and recycling of materials, but distribution will still be supported by materials supply chains that – depending on the nature of the material – may be global, given the uneven distribution of natural resources across the world. The present supply of raw materials already has some problems, with rising prices, so this needs to be considered as we consider a future that includes distributed manufacturing. Raw material supply chains will have to adapt from the centralised system to delivery to a more distributed network, making logistics in pre-production more significant than at present.

Standardisation and certification
Standards, capability and certification is a challenge that needs some elaboration in the AM context, and on which there is much work taking place. In a distributed system, greater governance to ensure standards are maintained across different sites is needed along with rigorous certification of production.

Process development
The development of design & manufacturing processes that can characterise and factor in the nature of distributed manufacturing capability so that designers are able to design products that are able to take full advantage of this network.

Business model uncertainty
More work needs to be done on understanding distributed manufacturing business models, in addition to the prevailing need to better develop and communicate viable business models for AM.

Addressing these challenges with AM

These challenges apply to traditional forms of manufacturing, but these methods of production will have their own issues when engaging with distributed manufacturing. For example, while standards and certification may be more straightforward for traditional manufacturing, there will nonetheless be issues around how this operates across multiple sites in a distributed system. As the geographies of operations shift, new problems can arise that disrupt the status quo. As a comparatively newer set of technologies, Additive Manufacturing could prove to be more flexible and responsive, given that the sector itself is constantly pressing for systemic change across

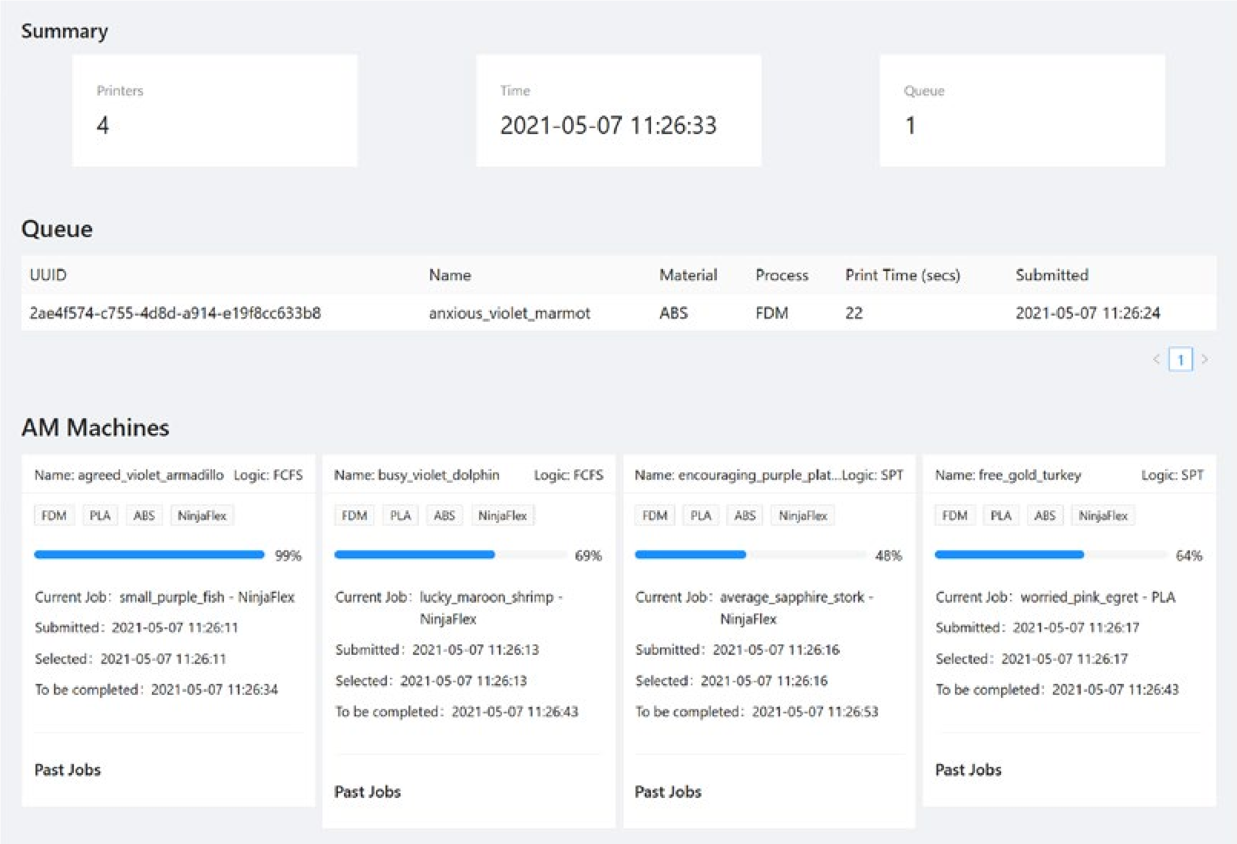

Fig. 6 A view of the Brokering Additive Manufacturing queue. Brokering Additive Manufacturing is developing novel production system technologies for highly distributed and diverse manufacturing capability. Above is an example of the technologies the project is exploring, showing a global queue where random jobs are being added, for this demo for production by Fused Deposition Modelling (FDM). Four machines are connected to this queue. Each machine is configured with its own logic. In the demo, the first two printers are set to First-Come-First-Serve while the last two are set to Shortest Process Time (SPT). Together, they are responding and meeting product demand. This type of system is known as an Agent-Based Manufacturing system. But what if the demand is different? What happens when we change the logics on the machine? What about the different manufacturing constraints? The BAM project is investigating the nature of product demand across society, modelling the UK's entire AM capability and how it could be configured using an Agent-Based approach, and creating real-world demonstrators where it can play out production scenarios with collaborators.

multiple aspects of manufacturing. Distributed manufacturing represents an opportunity for AM to demonstrate its capacity to deliver on many of the transformative claims that have been made about the technology. Indeed, AM was supposed to cause a relocalisation of production. This hasn't yet come to fruition, but the combined forces outlined at the start of the article have created a window of opportunity for AM to help drive a future in which more distributed models of production are possible. Here, the flexibility of AM – particularly its freedom from the fixed constraints of tooling new production lines – makes it a logical and central part of this distribution process.

To address many of the challenges outlined above, a key issue will be that of coordination and collaboration, something which is not easy during times of uncertainty and business pressure. Even so, there is a pressing need for independent arbitrage of communication and coordination of efforts to tackle these barriers to distributed network. History shows us that disruptive shifts in manufacturing rarely occur overnight, and when they do, a critical mass of engagement is needed from industry and its supporting institutions. At present, there are some critical limitations to the widespread adoption of distributed manufacturing, with coordination being a key factor.

Brokering Additive Manufacturing

The University of Bristol has been awarded a £1 million grant by the UK Research Council (via the Engineering and Physical Sciences Research Council/EPSRC), called Brokering Additive Manufacturing (BAM), to produce revolutionary means of brokering jobs for highly distributed and diverse manufacturing systems to meet national demand for greater supply chain flexibility in the context of uncertainty and disruption due to factors such as COVID-19 and Brexit. BAM's vision is of a queue, potentially cloud-based, where jobs can be submitted and offered to the entire AM capability of a local, regional, national and/or global community, and enabling human-led (e.g., technician, organisation), machine-led (e.g., individual AM machines and/or collective) and/or hybrid brokering. The queue would be capable of Big Demand and will enable suppliers to barter for jobs on a multi-scale basis, from single consumer to million plus components from organisations (see Fig. 6).

This approach enables governance/decision-making to be maintained with the clients and suppliers – be it human, machine or hybrid-led – and provides transparency for the clients in the AM capability and capacity afforded by the system. Suppliers can shift their production to meet the needs of the queue resulting in amorphous supply chains. In one moment, the queue may lead to a demand for one item (e.g., PPE), while, in another, a lack of demand could lead to competitive bartering. Supporting the entire spectrum of interaction, AM capability and production constraints provides the fundamental step-change in production capability.

Led by Dr James Gopsill, BAM brings together world-leading researchers from the Schools of Civil, Mechanical and Aerospace engineering and Business Management, 300 + leaders in the AM industry (including Renishaw, GTMA, AT 3D Squared), Model-Based Systems Engineering (including CFMS), and industry/government initiatives (such as Reshoring UK) to create novel brokering of highly-distributed and diverse manufacturing systems. Industry engagement is critical to the project.

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Design for Additive Manufacturing: A workflow for a metal AM heat exchanger using nTopology

Heat exchangers have become – excuse the pun – a hot topic in metal Additive Manufacturing. This is an application that can, in one go, leverage advances in equation-driven CAD design software and the capabilities of AM to produce geometries that would be impossible by any other manufacturing process. Olaf Diegel , Wohlers Associates, reports on a project exploring workflows for AM heat exchanger design using design tools from nTopology.

With the growing maturity of metal AM, new approaches to design software have been optimised for complex lattice structures. Conventional CAD software can be used, but users may experience difficulty in dealing with large arrays due to the required processing power. New software approaches are overcoming this challenge by handling features as equations rather than as solid bodies. For example, a large lattice can be processed similarly to a single feature. A few extra numbers are added in the equation, telling the program how many times to repeat the pattern in each direction. This equation-driven approach makes it easier to design products with large, complex lattice structures, textures and features.

Without this new breed of software, it would be difficult – if not impossible – to design these complex shapes. Also, a heat exchanger using gyroid structures would be impossible to produce without AM.

Heat exchangers and the gyroid revolution

A heat exchanger is a system used to transfer heat between two or more media. It allows heat from one substance, usually a liquid or gas, to pass to a second liquid or gas. The device is used to cool hot areas of a system, or vice versa. The two media do not mix or come into direct contact with one another. Heat exchangers are commonly used in both cooling and heating processes for a wide range of industrial applications, such as refrigerators, furnaces, air conditioning systems, transportation, oil refineries, commercial environments, and hospitals.

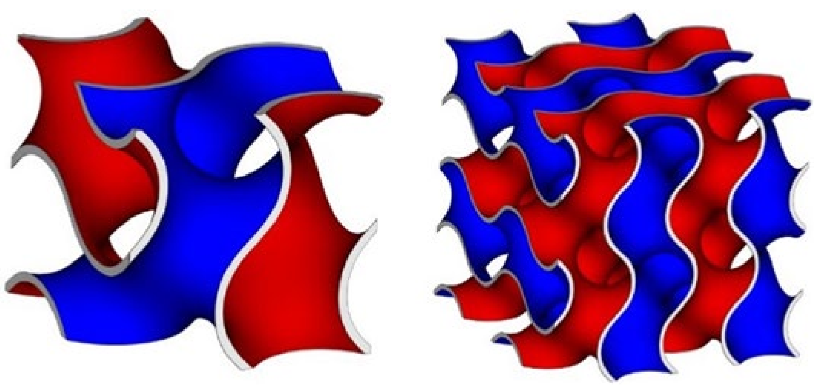

Fig. 1 Single gyroid cell (left) and network of connected gyroid cells (right). The red (hot) zone is kept separate from the blue (cold) zone

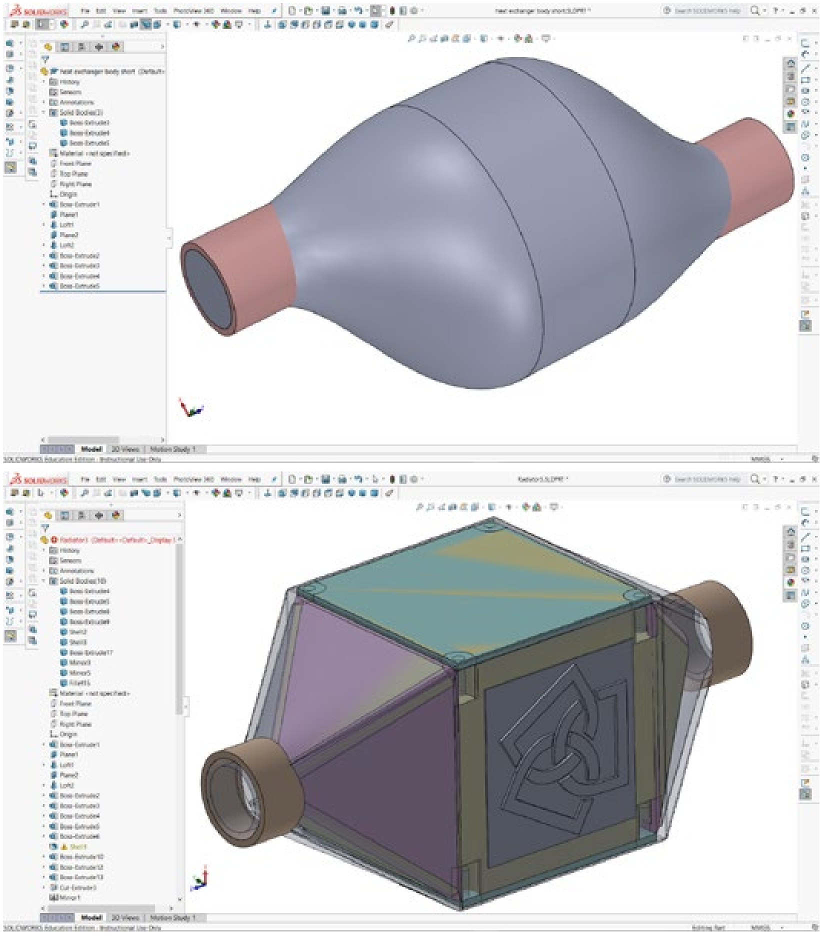

Fig. 2 Basic CAD bodies of one side of a heat exchanger (top), and basic bodies for a radiator showing ten separate bodies that form the radiator sub-components (bottom)

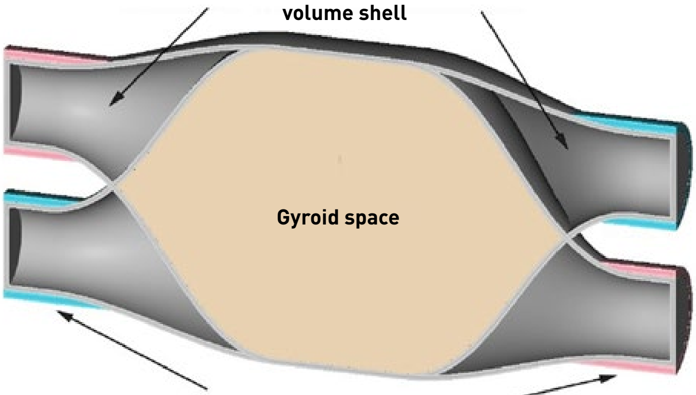

Fig. 3 Creation of various heat exchanger bodies

Historically, 'plate and frame' heat exchangers were made by forming plates into a labyrinth of channels. The plates were then laminated to create a network of hot and cold channels to transfer heat from one medium to the other. The other main conventional manufacturing option has been 'shell and tube' heat exchangers. This type combines thermally conductive tubes and plates used to transfer heat from air-to-air, water-to-water, or air-to-water-to-steam.

A gyroid is part of a family of triply periodic minimal surfaces (TPMS), discovered by Alan Schoen in 1970. It separates space into two oppositely congruent labyrinths of passages that have no lines of reflectional symmetry. In the context of heat exchangers, gyroids have two distinct advantages: they offer a large surface area for heat dissipation and cause significant turbulence, increasing the Reynolds number, which improves heat dissipation. In the context of metal AM, they have a distinct advantage of being self-supporting. Even at relatively large sizes, these structures can be additively manufactured without the need for support material. These advantages make gyroids a good candidate for creating more efficient heat exchangers.

Designing a gyroid heat exchanger

This project began as an exercise in understanding the capabilities of new equation-driven CAD design software – in this case, nTopology. As an example, a compact heat exchanger was designed for a conformal water channel cooling system for a pellet extruder.

The process begins with designing the physical structure of the heat exchanger using Solid-works. New equation-driven CAD software products are capable of basic geometric features, but they are not as advanced as conventional CAD software.

For this heat exchanger design, one side was modelled and then mirrored to produce the desired shape. The part was imported into the nTopology lattice design software. From this point, core bodies were created to make up the various parts of the heat exchanger. They included the cold and hot channel outer shells, the intersecting volume that would later become the gyroid space, and a few extra bodies, such as the extra material required at the inlets and

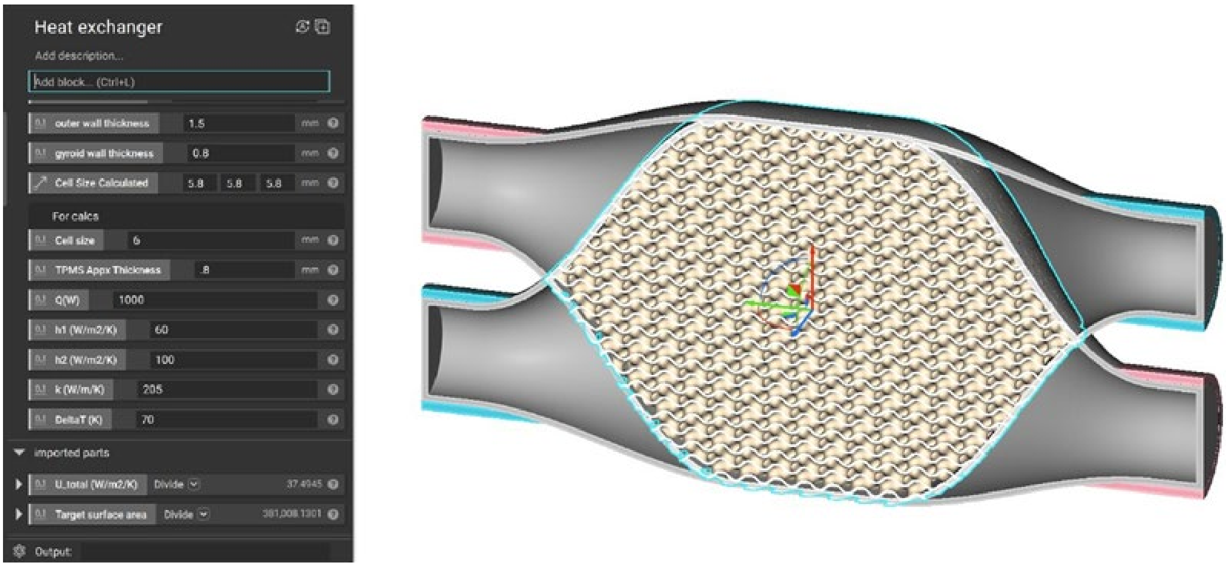

Fig. 4 Creation of gyroid with a cell size and wall thickness to meet specified heat transfer characteristics (left) with a cross section of the TPMS (right).

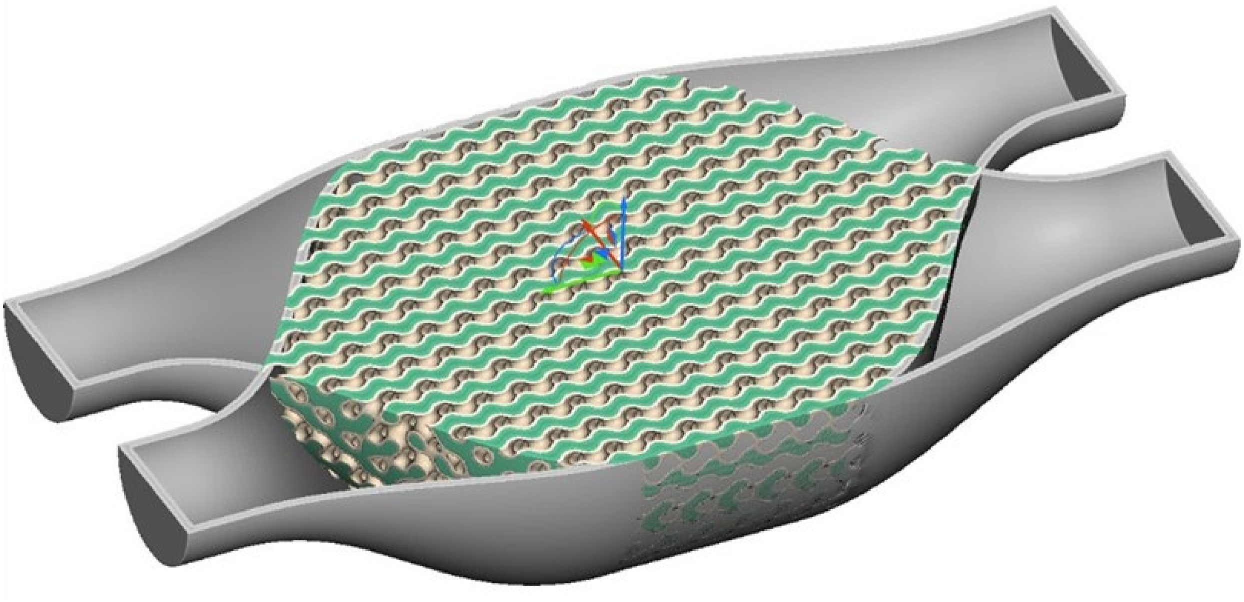

Fig. 5 Creating the hot and cold zone caps

outlets for threads, logos, and more. The overall logic is to create all the subcomponents as separate units, called blocks, using nTopology. A range of Boolean operations (i.e., unite, intersect, and subtract) were used to combine the subcomponents.

After separating the individual subcomponent bodies, the gyroid-filled lattice space was created. A few heat transfer calculations were used to determine the surface area required to meet the desired conditions. This establishes the optimal gyroid cell size and wall thickness, which are then used to convert the lattice volume into a walled-gyroid TPMS with the proper cell size and wall thickness.

Next, the gyroid structure must be 'capped' to separate the hot and cold zones and a solid TPMS volume is created. This represents the gyroid lattice that sits between the previously created gyroid walls. A few more Boolean intersection and union operations cap the cold channels on the hot side, and vice versa.

Finally, a few further Boolean operations are used to combine all the subcomponents into the single ready-to-print heat exchanger. With some basic design-for-AM techniques, it is possible to create extremely complex heat exchangers

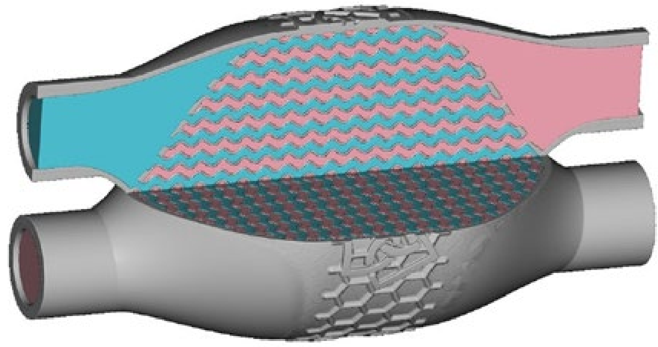


Fig. 6 Section view of completed heat exchanger, including hot and cold fluid zones (left), and the printed part showing minimal support material requirements (right).


Fig. 7 Additively manufactured heat exchanger section (left) and assembly for testing (right)

in which minimal support material is required when additively manufacturing the part.

For this heat exchanger, the unsupported angle that is possible was pushed to the limit, with a small amount of support material used to ensure it is manufactured correctly. Support material was only required in areas where removal was easy. Fortunately, the parts were manufactured successfully on the first try.

The initial test was running boiling water through the hot channel and ambient temperature water through the cold channel. A temperature differential of about 65°C (149°F) was achieved. Detailed simulations and more scientific measurements are expected in the future.

Creating the next generation of heat exchangers

With equation-driven design software, coupled with the proper workflow, one can almost instantly create a new heat exchanger with different characteristics. This makes it ideal for researching more efficient forms of heat exchange. The following example shows the transition from a fluid-to-fluid heat exchanger to an air-to-fluid heat exchanger (a radiator) using a similar workflow.

In summary, once a workflow has been created, it is possible to quickly produce gyroid-based heat exchangers of different sizes and efficiencies. With a few modifications, the workflow can be adapted to create other devices, such as radiators. This project demonstrated the power of gyroids and how they can be used as self-supporting structures to transfer heat from one substance to another. With a large surface area, these designs are excellent candidates for heat exchangers and for creating lightweight self-supporting structures with metal AM.

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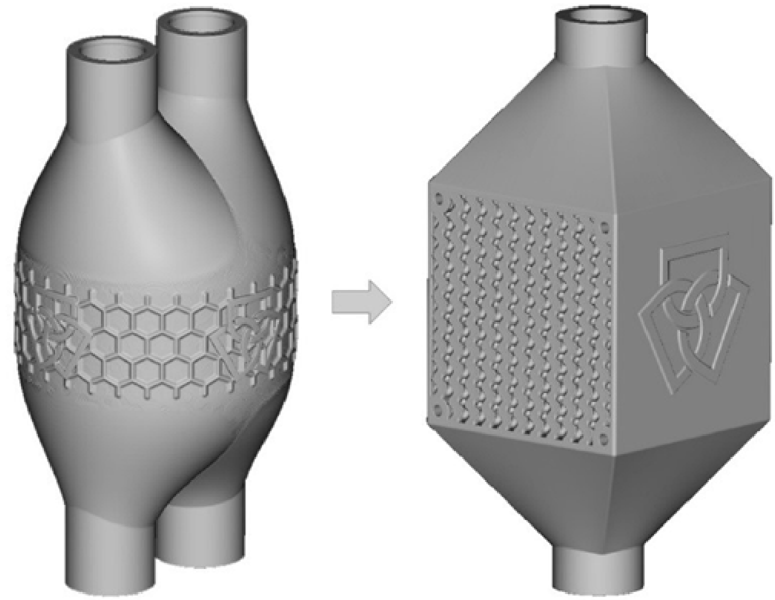

Fig. 8 Using a related workflow to go from a heat exchanger to a radiator

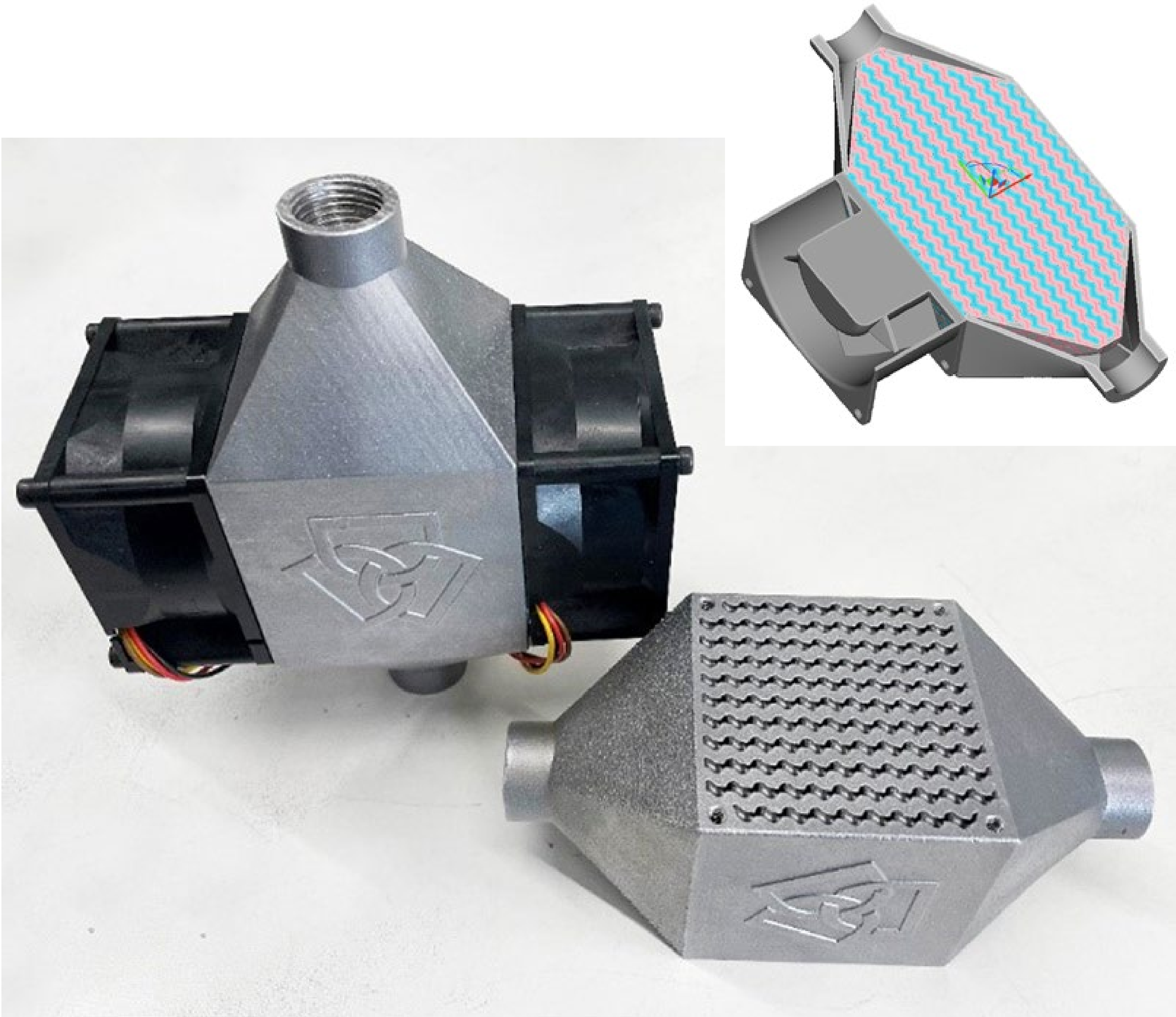

Fig. 9 Printed radiator made using same heat exchanger workflow (main image) and cross-sectional view (top right)

Taking the holistic view: Defining the state-of-the-art in the evolving PBF-LB machine marketplace

In a rapidly evolving Additive Manufacturing landscape, choosing a machine for the production of parts by Laser Beam Powder Bed Fusion (PBF-LB) is now about far more than a cost per part calculation. In this article, Sebastian Becker, EOS GmbH, considers how a host of additional factors now need to be considered when exploring the AM machine marketplace, from the specifics of a machine's operation to software, IP protection and beyond.

The world of industrial Additive Manufacturing has evolved at an incredible pace over the last ten years and seems to just keep accelerating. The days where AM was seen as only suitable for prototyping, or simple low-volume production with plastics, are a long way behind us. Metal-based AM components are being used in some of the most demanding use cases, and enabling parts to be completely reimagined. Today's parts made with AM perform way beyond the limitations of more traditional manufacturing techniques, making them lighter, stronger, with fewer components and more efficient assembly.

There was a time when a state-of-the-art AM system was defined purely by its production speed, reliability and part quality. These things still matter of course, but the world of manufacturing has moved on: Industry 4.0, distributed production, digital warehousing and improved sustainability are just some of the issues that are defining how the industry has started to evolve. Ultimately, choosing AM machinery is no longer simply about its ability to meet the mechanical properties that a production facility needs for its parts.

The old rules are more important than ever

The ability to produce high-quality parts efficiently, dependably, and consistently is vital for all manufacturing organisations. As AM continues to evolve, new features have accelerated productivity, reliability, and repeatability to new heights. That 'holy trinity' is being pushed forward by technological advances that exist inside and outside the build chamber and are helping organisations position themselves as innovators in their field.

Not too long ago, the industry focused on cost-per-part (CPP) as a top priority for metal AM purchase decisions. Still more important

Fig. 1 A vision of a modern metal AM facility (Courtesy EOS)

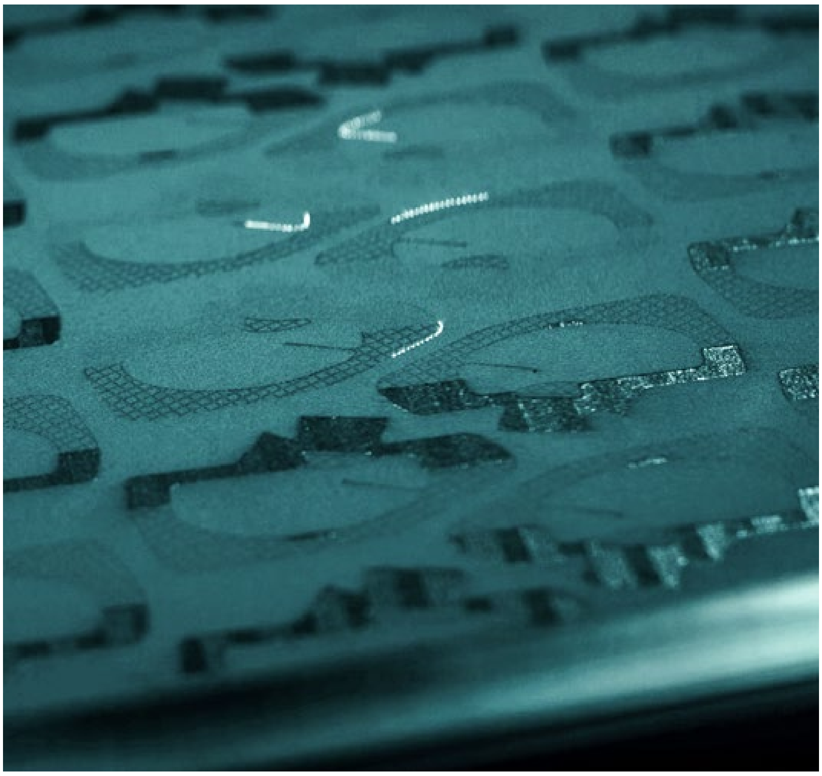

Fig. 2 A view of the AM build process in an EOS machine (Courtesy EOS)

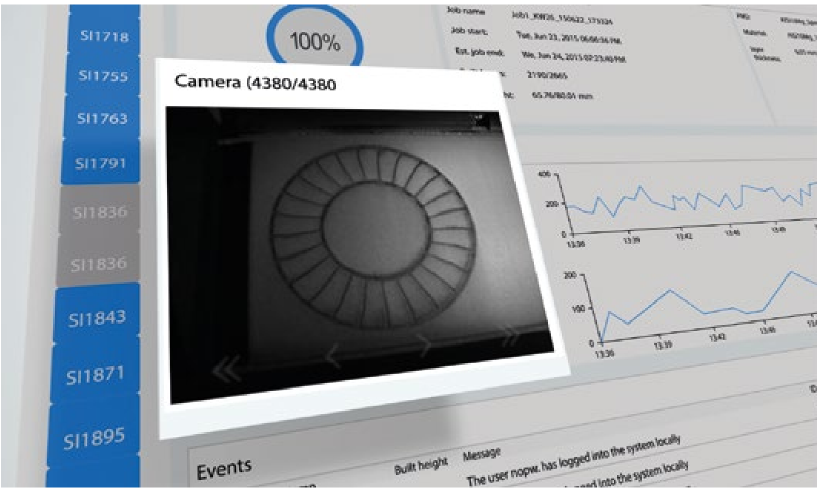

Fig. 3 EOSTATE software is used to monitor how machines are performing to enable predictive maintenance (Courtesy EOS)

than ever, but in recent years, the discussion has become more detailed around production properties. Productivity is achieved through faster build speeds, maximising machine uptime, high utilisation rates, and by reducing the time spent on non-productive tasks such as setup and recoating. Several features that are now regarded as essential for state-of-the-art systems influence how a machine performs in these areas.

Laser versatility

More lasers doesn't necessarily equate to greater productivity. In fact, the more lasers in a system, the more complexity is added to system management and calibration. It's better to focus on the versatility of the lasers, ensuring they cover the full build area, and can be assigned in various ways for production needs. Is every laser working the whole time, to achieve the highest efficiency, for example?

Predictive maintenance

An essential part of ensuring productivity levels is understanding how a machine is performing, and when, therefore, it will need maintenance. Systems that can predict the maintenance required, and when it will be needed, will help with production planning and reduce unplanned downtime.

Handling and filtration systems

The latest generation of AM machines can remain operational while handling and filtration components are being serviced. Even more impressive industrial AM machines with lifetime filters exist, which eliminates this type of service interruption altogether, improving uptime. The same is also true for loading machines with powder material which can take place while machines are running or separately preparing a powder supply container that can quickly and easily be interchanged.

Speed of setup and recoating

Ultimately, productivity is about reducing non-productive time as much as possible – and every second matters when you're talking about a complex production platform. Speed is a critical feature of any metal AM machine, and not just when it comes to build times. Consider how quickly the machine can be set up for each job, and the speed of the recoater system. New systems recoat much faster and more accurately than previous generations – meaning higher productivity, better quality, and low wastage.

Break out of the black box

So far, almost everything we have talked about can be regarded as the bare minimum of what could qualify

Fig. 4 An aerospace part produced by EOS using state-of-the-art NextGenAM processes (Courtesy EOS)

"To become a truly innovative manufacturer in this constantly evolving arena, and be well positioned for whatever the future may bring, we must look beyond the mechanics of the AM process. We can no longer view an AM machine as an isolated 'black box' that produces parts."

as a state-of-the-art industrial metal AM machine. To become a truly innovative manufacturer in this constantly evolving arena, and be well positioned for whatever the future may bring, we must look beyond the mechanics of the AM process. We can no longer view an AM machine as an isolated 'black box' that produces parts. It must be able to act as a part of the full production process, and that means not just being physically incorporated into the production floor but being able to work as part of the whole ecosystem of the production line, and across the supply chain.

Digital inventory is a great example of how an ecosystem approach can revolutionise a supply chain and lead to huge cost savings. Producing parts on demand from a digital inventory, not only removes all the costs out of making and storing components in batches, but means that will always be available, and can be produced on an AM machine anywhere in the world.

Software and data matter

Machines rely increasingly on software for their own operation, but must also be able to integrate with a host of other software applications. This software will not only initiate and report on the completion of jobs, but can provide continuous monitoring of jobs to ensure that parameters within the build chamber are within specified tolerances, not only for the machine, but the part. These might include build chamber temperatures, humidity, inert gas data and power consumption.

This data can help optimise the production environment, and over time be used to identify areas of improvement, as well as feeding directly into other production systems, such as an ERP platform. Collecting data from machines is one thing, but an organisation will also need the tools to analyse it, and this is where techniques such as machine learning and AI come in. Make sure that any AM solution chosen can not only produce data that is

"A fundamental mistake is to think that collecting data alone is going to make a difference. Data can be screaming an opportunity for improvement, but if the manufacturer as the user of AM machines isn't analysing the data, it falls on deaf ears."

granular and accurate, but does so in formats that can easily be consumed and analysed by other systems. A fundamental mistake is to think that collecting data alone is going to make a difference. Data can be screaming an opportunity for improvement, but if the manufacturer as the user of AM machines isn't analysing the data, it falls on deaf ears.

The digital elephant in the room

Let's not pretend that all this talk of more connectivity, software and big data doesn't raise one big concern in the mind of any manufacturer – cybersecurity. It is an area that should be taken very seriously when evaluating any new system, but don't make the mistake of thinking it is all about protecting your network from being hacked and production taken offline. You must also consider how the system will protect your IP, and that of customers, through a combination of encryption and rights management that locks down build jobs in a way that IP cannot be viewed or stolen by anyone.

Making the move to state-of-the-art

Deciding to upgrade an industrial AM arsenal to a state-of-the-art solution is a big investment, and no easy decision. Whilst the benefits might be clear – it is an investment in the future – a future that is not yet entirely clear to manufacturers or even AM technology providers in terms of the dominant design of AM production facilities. Therefore, organisations should look for systems that are modular and extensible so they can evolve with changing business needs and the industry. Here are some of the key considerations to take into account when evaluating where to invest:

- Have a clear vision for where some of the features we have talked about here can make a big difference in a business today, and in the future. Buying a new industrial AM machine, to just maintain the workflows in place today, is not an investment in the future.
- Productivity, reliability and repeatability still count more than anything. Don't lose sight of this when choosing a vendor.
- Don't get duped into 'shiny' features that won't be used. Be pragmatic about the evolution your business is going through and what features will ultimately get used over the lifetime of the solution.
- Pick a technology partner that can help with achieving the efficiency gains of implementing their system in your workflow, not their testbed. This should include simulations, CPP analysis, as well as multiple production parts for review.
- Choose a partner that can support the lifetime of the printing platform, far beyond installation and initial training. Ask, can they remotely support the machines? What is their roadmap for software updates and feature additions?
- Driving innovation with your business should be a central expectation placed on any prospective partner. Make sure their experience can be used to support the wider innovations you plan in your manufacturing operations, such as digital warehousing and click-to-print.

Looking ahead

The future is exciting: state-of-the-art solutions with the capabilities we have discussed exist today, and are making a huge difference in a host of production settings, and creating some of the hardest working final products in brutal environments. They are saving money, lowering CPP, and allowing manufacturers to take on a host of production jobs that would have just been too complex in the past.

Whilst the future of digital manufacturing may still be unfolding, today's state-of-the-art machines bring a new level of performance in terms of reliability, productivity, and repeatability. Such systems allow manufacturers to set out their own future and seize new opportunities.

Contact

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Industry events

2021

5th Additive Manufacturing Forum Digital Edition 2021 [ONLINE EVENT]
July 21–23
www.am-forum.eu

AM Summit 2021
August 19, Nordhavn, Denmark
www.amsummit.dk

Formnext + PM South China 2021
September 9–11, Shenzhen, China
www.formnext-pm.com

RAPID + TCT 2021
September 13–15, Chicago, IL, USA
www.rapid3devent.com

Workshop Sinter-Based Additive Manufacturing 2021
September 15–16, Bremen, Germany
www.ifam.fraunhofer.de/en/Events/sinter-based-additive-manufacturing-workshop-2021.html

TCT 3Sixty
September 28–30, Birmingham, UK
www.tct3sixty.com

Space Tech Expo USA 2021
October 6–8, Long Beach, CA, USA
www.spacetechexpo.com

AMTC – Advanced Manufacturing Technology Conference [ONLINE/IN PERSON]
October 12–14, Aachen, Germany
www.amtc.community/amtc/en/

Euro PM2021 [ONLINE EVENT]
October 18–22
www.europm2021.com

3D PRINT Congress & Exhibition Paris
October 20–21, Paris, France
www.3dprint-exhibition-paris.com

ICAM 2021 - ASTM International Conference on AM [ONLINE/IN PERSON]
November 1–5, Anaheim, CA, USA
www.amcoe.org/icam2021

Metal Additive Manufacturing Conference 2021
November 3–5, Vienna, Austria
www.mamc2021.org

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Space Tech Expo Europe 2021
November 16–18, Bremen, Germany
www.spacetechexpo.eu

Formnext [ONLINE/IN PERSON]
November 16–19, Frankfurt, Germany [In person]
November 30–December 1 [Online]
www.formnext.com

Hagen Symposium 2021
November 25–26, Hagen, Germany
www.pulvermetallurgie.com/symposium-termine/symposium-aktuell

4th International Symposium Additive Manufacturing [ONLINE EVENT]
December 7–9
www.isam.network

2022

MIM2022 - International Conference on Injection Molding of Metals, Ceramics and Carbides
February 21–23, West Palm Beach, FL, USA
www.mim2022.org

EBAM 2022 – International Conference on Electron Beam Additive Manufacturing
March 30–April 1, Erlangen, Germany
www.ebam.fau.de

AMUG 2022
April 3–7, Chicago, IL, USA
www.amug.com

3D PRINT Congress & Exhibition Lyon
April 5–7, Lyon, France
www.3dprint-exhibition.com

International Conference and Exhibitions on 3D Printing and Additive Manufacturing in Middle East and Africa
April 13–14, Dubai, United Arab Emirates
www.additivemea.com

Hannover Messe 2022
April 25–29, Hanover, Germany
www.hannovermesse.de

PM China 2022
May 23–25, Shanghai, China
www.pmexchina.com

The 20th Plansee Seminar
May 30–June 3, Reutte, Austria
www.plansee-seminar.com




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Alphabetical index

more >>>

more >>>

Metal powder production technology

Consulting, training & market reports

Laser technology and calibration

Part manufacturers / service bureaux

AM Solutions - Rösler Group 13
www.solutions-for-am.com

GKN Sinter Metals Engineering GmbH 55
www.gknpm.com

Indo-MIM 87
www.indo-mim.com

Kennametal Inc. 30
www.kennametal.com

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www.kamsolutions.com

Oerlikon Additive 41
www.oerlikon.com/am

Parmatech Corporation 83
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Sintavia, LLC 26
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HIP systems & services

Bodycote 45
www.bodycote.com

CREMER Thermoprozessanlagen GmbH 96
www.cremer-polyfour.de

Toll debinding & sintering

DSH Technologies 106
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- Parts are 3D printed with HydroFuse™, an innovative water-based paste containing metal powders
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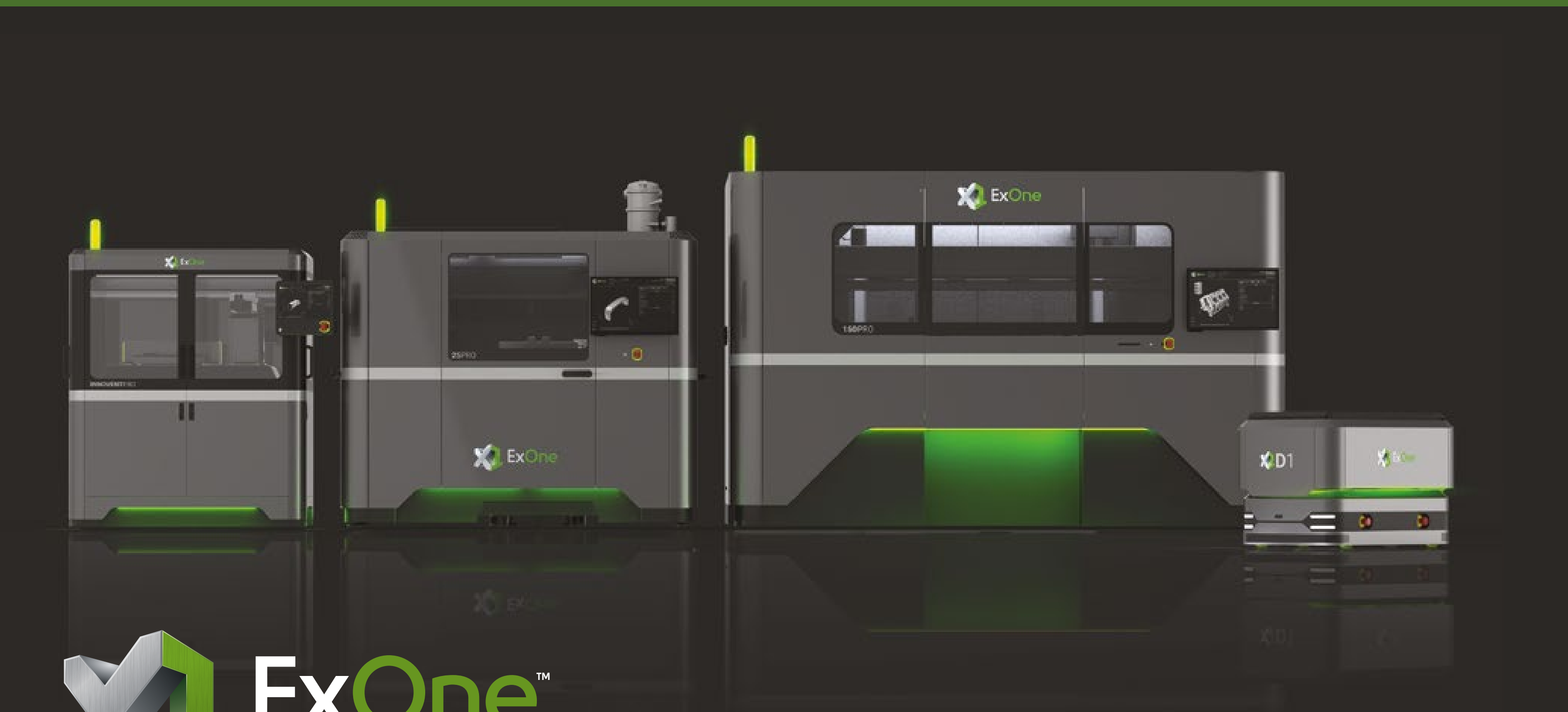
- The ExOne family of production metal 3D printers, shown below, can process 20+ metals and ceramics
- InnoventPro™, shipping by year-end, will be the most advanced entry-level binder jetting system for metal



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Pictured left to right: InnoventPro™, X1 25Pro®, X1 160Pro™ and X1D1 automated guided vehicle.