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THE MAGAZINE FOR THE METAL ADDITIVE MANUFACTURING INDUSTRY

METAL AM

in this issue

BEAMIT: A JOURNEY TO INDUSTRIAL AM

WHY WE NEED WOMEN IN 3D PRINTING

EQUISPHERES AND THE NEED FOR SPEED

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METAL ADDITIVE MANUFACTURING

Industry consolidation in anticipation of growth

The past few months have been quite extraordinary in the world of Additive Manufacturing. One after another, a steady flow of M&A announcements signal that things are getting serious for our industry. There is certainly a buzz of anticipation that part production is set to see significant growth across all AM technologies.

The most mature metal AM technologies, Laser Beam Powder Bed Fusion (PBF-LB) and Electron Beam Powder Bed Fusion (PBF-EB), have today reached a level of production readiness that makes them very attractive to a broad range of end-user companies, many of whom may have never previously considered investing in metal AM.

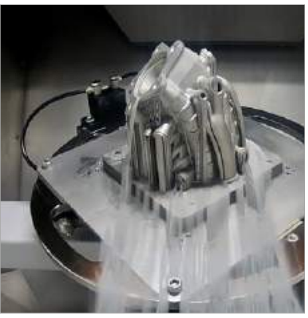
Binder Jetting, meanwhile, has a momentum of its own, rapidly accelerating towards the end-goal of high-volume series production, thanks in large part to the enthusiasm and expertise of leaders in established high-volume sinter-based manufacturing sectors such as Metal Injection Moulding.

Key enablers of this growth are, of course, material producers, who have been ramping up production capacity as well as providing the innovation and expertise that enables AM machines to operate to their full potential – everyone now understands that even the best AM machine cannot deliver without the right powder.

Last but not least, AM-related software developers have risen to the multiple challenges of maximising the potential of AM as a true production technology, from part design and optimisation to Manufacturing Execution Systems. To see the fruits of the labour of so many coming together at this intersection for the technology is extremely exciting, and we at *Metal AM* magazine can't wait to see what else the year brings.

Nick Williams
Managing Director

Cover image
The reimagining of an old KTM 250 GS motorbike with a futuristic approach, featuring a carbon fibre/AM titanium rear swingarm, and AM aluminium front fork mounts (Courtesy BEAMIT / Bercella SRL)



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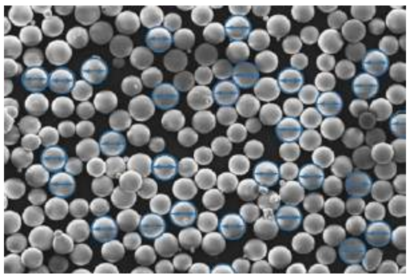
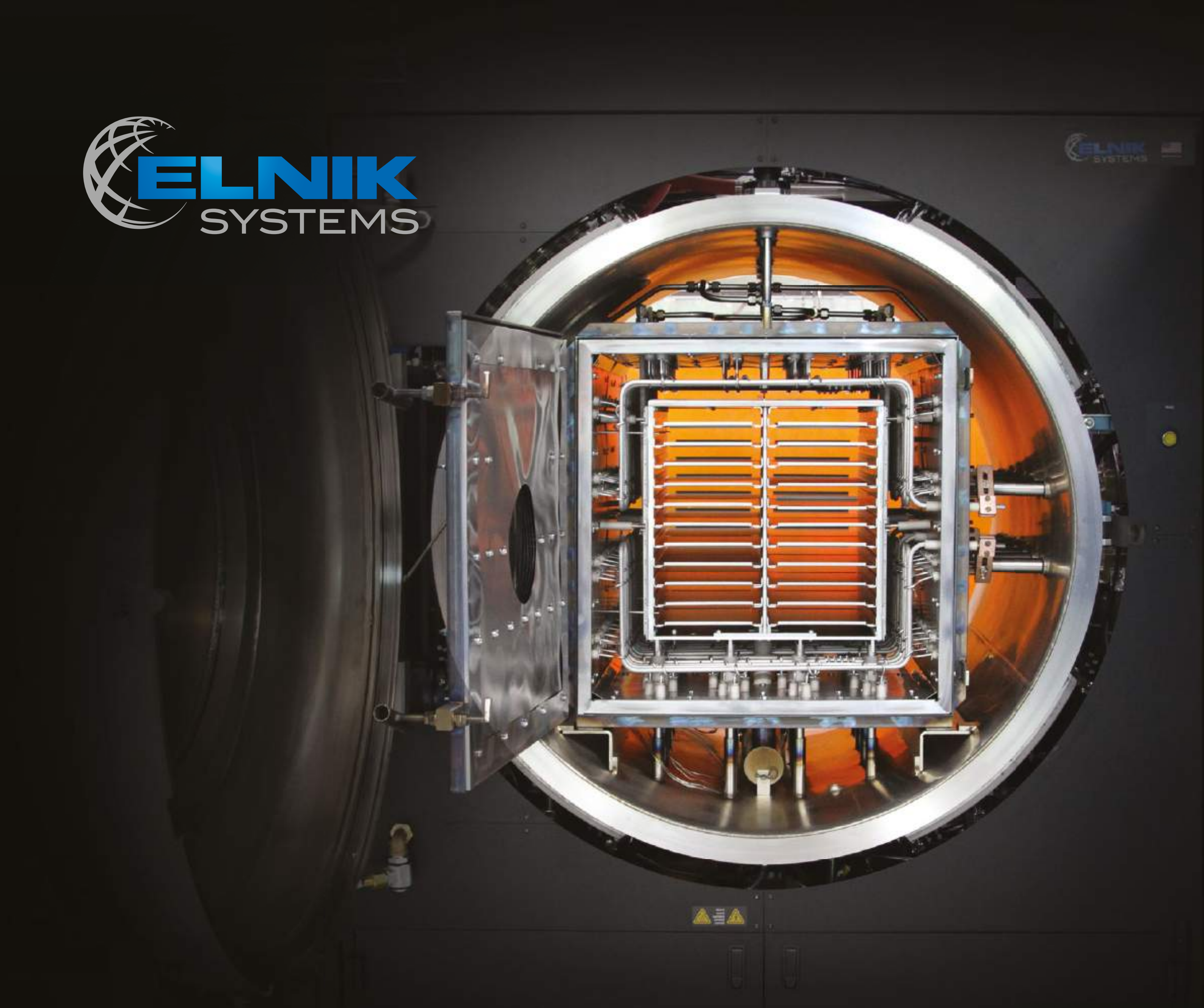



ELNIK
SYSTEMS

Industry news

BEAMIT Group acquires 3T Additive Manufacturing

The BEAMIT Group, Fornovo di Taro, Italy, has acquired Additive Manufacturing service provider 3T Additive Manufacturing, Newbury, Berkshire, UK, from AM Global Holding GmbH. This follows the acquisition by Sandvik of a large stake in the BEAMIT Group in 2019, which established a strong partnership across the AM value-chain. The purchase of 3T Additive Manufacturing was made in order to continue with the group's plan of further integration and industrialisation of AM for the serial production of high-end components in demanding industries.

3T Additive Manufacturing will bring to the BEAMIT Group twenty years of industrial expertise and capabilities for metal AM, where it holds some of the highest-quality certifications for deliveries to aerospace (AS9100) and medical (ISO 13485), and is an approved supplier for serial production by many leading OEMs across the UK, the US, Europe and Japan.

Following mergers with Zare, Pres-X and Proxera®, 3T Additive Manufacturing complements the BEAMIT Group's value chain with established qualified operations serving key industries such as aerospace, industrial gas turbines, medical and automotive. This acquisition represents the first planned step towards the BEAMIT Group's goal of global expansion.

Mauro Antolotti, president of the BEAMIT Group, stated, "BEAMIT has spent some time looking into new ways to leverage synergies, and the 3T Additive Manufacturing acquisition adds great value and expertise into this leap forward we are making. We are now more well equipped than ever, having consolidated and strengthened our AM service offering, established a footprint in the UK and prepared for further expansion and growth with our customers in the coming years."

The group has already transitioned into serial production with OEM customers, and produces upwards of 10,000 high-end components every year. It has also integrated operations digitally, with certification requirements such as IATF16949, AS9100 and NADCAP. Alongside Sandvik's materials and metal powders knowledge, 3T Additive Manufacturing will be positioned to expand its Additive Manufacturing capabilities across the value chain, including special processes in advanced heat treatment, NDT, as well as complex machining and post-processing, complementing a joint group R&D programme on next-generation materials and processes.

"The AM sector is developing fast and there is a need for dedicated AM partners with specialist skills across the AM valuechain, not to mention the resources required to help industrial customers develop and launch their AM programmes," commented Kristian Egeberg, president of Sandvik Additive Manufacturing. "Not many AM service companies in the market are able to offer a complete end-to-end process for the additive manufacturing of complex, high-end, components. With our investment in the BEAMIT Group – now also including 3T Additive Manufacturing – we look forward to helping even more industrial customers create value through the application of AM."

www.beam-it.eu
www.3t-am.com
www.additive.sandvik

Discover more about the BEAMIT Group in our exclusive interview with Mauro Antolotti, on page 111 of this issue, conducted prior to the purchase of 3T Additive Manufacturing.

Inside 3T Additive Manufacturing's Newbury plant (Courtesy BEAMIT Group)

Protolabs to acquire 3D Hubs in $330M deal

Proto Labs, Inc., (Protolabs) a global provider of digital manufacturing services headquartered in Maple Plain, Minnesota, USA, has entered into an agreement to acquire 3D Hubs, Inc., an online platform that provides engineers with on-demand access to a global network of approximately 240 premium manufacturing partners.

Under the terms of the agreement, closing consideration of $280 million will be funded with $130 million in cash and $150 million in Protolabs common stock. An additional $50 million of contingent consideration is payable subject to performance-based targets over two years after close, funded with 50% cash and 50% Protolabs common stock. Protolabs has also established an employee incentive fund payable to 3D Hubs employees based on achievement of both financial performance and employee retention targets.

"The acquisition of 3D Hubs is part of the continued evolution of Protolabs as the digital manufacturing leader, serving more and more of our customer's needs," stated Vicki Holt, Protolabs' CEO. "Protolabs' leading in-house, technology-enabled manufacturing services combined with 3D Hubs' global network of premium manufacturing partners will yield the greatest value to our customers for years to come."

The transaction is reported to create the world's most comprehensive digital manufacturing offering for custom parts, providing Protolabs with a network of manufacturing partners to fulfil a breadth of capabilities outside of its current envelope, as well as a broader offering of pricing and lead time options.

"The addition of 3D Hubs provides Protolabs a platform to evolve our service model to provide unprecedented manufacturing flexibility to our customers," commented Rob Bodor, Protolabs' current VP and GM of the Americas and incoming president and Chief Executive Officer. "Our combined organisations will provide the market with an industry-leading digital manufacturing solution to serve their needs from idea to prototype to full end-use part production. Together we can fulfil nearly every custom manufacturing need across the product lifecycle."

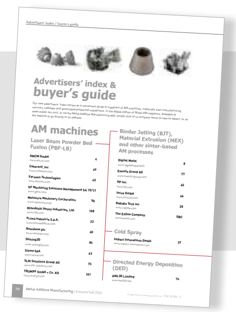
Protolabs offers a range of digital manufacturing services, including metal AM (Courtesy Proto Labs Inc)

Founded in 2013, 3D Hubs has facilitated the production of over six million custom parts and products through its digital platform. 3D Hubs provides customers with instant pricing and design feedback, with orders fulfilled through thoroughly vetted premium manufacturing partners in over twenty countries worldwide, offering vast manufacturing capacity and a broad range of manufacturing capabilities at a variety of competitive pricing levels.

"3D Hubs' company culture lives and breathes engineering and fast-paced innovation; our team is very excited to partner with Protolabs to build the best on-demand manufacturing solution imaginable," stated Brian Garret, 3D Hubs' co-founder and Chief Product Officer.

"The entire 3D Hubs team is thrilled to join Protolabs and continue to revolutionise the manufacturing industry through innovation. At 3D Hubs, our goal is to empower companies to create revolutionary products through supply chain efficiency and reliability," added Bram de Zwart, co-founder and Chief Executive Officer at 3D Hubs. "We are confident that partnering with Protolabs will help us advance that mission."

www.3dhubs.com
www.protolabs.com



AM solutions
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Velo3D to become public company valued at $1.6 billion

Velo3D, Inc, Campbell, California, USA, and the JAWS Spitfire Acquisition Corporation, a special purpose acquisition company, have entered into a definitive business combination agreement. Upon completion of the transaction, expected in the second half of 2021, the combined company will operate as Velo3D, listed on the New York Stock Exchange under the new ticker symbol VLD.

The transaction values the combined company at an enterprise value of approximately $1.6 billion, at the $10 per share PIPE subscription price and assuming no public shareholders of JAWS Spitfire exercise their redemption rights. Velo3D will receive up to $345 million in proceeds from JAWS Spitfire's cash in trust and a $155 million private placement of common stock at a $10.00 per share value. The private placement will be led by strategic and institutional investors, including Baron Capital Group and Hedosophia.

Upon completion of the transaction, Velo3D is set to benefit from a flexible capital structure with approximately $470 million of cash on the company's balance sheet, net of debt and assuming no redemptions are effected. Velo3D's current management team, including founder and CEO Benny Buller and CFO Bill McCombe, will continue to lead the company through this next stage.

"Velo3D partners with the world's most innovative companies leading the future of space travel, transportation and energy," stated Buller. "I am proud that such visionary partners continue to trust Velo3D to build products through methods that were previously impossible. With JAWS Spitfire's long-term partnership, we expect to extend the reach of Velo3D's technology and bring its solutions to even more customers globally. As we scale our business and advance our growth strategy, we expect to expand the high value metal Additive Manufacturing market and strengthen our competitive position."

Velo3D's financial model is asset light, backed by significant investments and positioned to rapidly scale to meet demand. The company's growth strategy is to focus on specific products that are tailored to its abilities within the $100+ billion total addressable market for high-value metal parts. The additional capital provided from this transaction will allow Velo3D to make substantial investments in engineering, product development, sales, marketing and customer support.

"Benny and the Velo3D team have placed technical innovation at the core of their business model, and we are excited to partner as they bring their technology to a broader set of similarly innovative customers across the world," added Barry Sternlicht, co-founder and chairman of JAWS Spitfire. "Since commercialisation, Velo3D has attracted an impressive customer base, showcasing the seamless, cost-competitive production of previously-unattainable designs. Velo3D is well-positioned for robust growth in an established and expanding market."

Velo3D is ready to release its newest Laser Beam Powder Bed Fusion (PBF-LB) offering, Sapphire XC, expected to ship in the fourth quarter of 2021. Sapphire XC is designed as a scale-up of the previous Sapphire machine and will support the production of parts that are up to five times higher volume and three times lower cost than existing Sapphire technology.

Assuming no public shareholders of JAWS Spitfire exercise their redemption rights, Velo3D's existing shareholders will own approximately 72%, JAWS Spitfire's existing shareholders and sponsor will own approximately 21% and PIPE investors will own approximately 7% of the issued and outstanding shares of common stock, respectively, of the combined company at closing.

The transaction was unanimously approved by the boards of directors of both companies, though is still subject to approval by JAWS Spitfire's shareholders and other customary closing conditions.

www.velo3d.com

Submitting news...

For truly global reach, publish your news in *Metal AM* magazine. Contact Paul Whittaker: paul@inovar-communications.com

Materialise acquires option to purchase Link3D

Materialise, headquartered in Leuven, Belgium, has acquired an option to purchase Link3D Inc., an additive workflow and manufacturing execution systems (MES) company headquartered in Boulder, Colorado, USA. The acquisition will allow Materialise to accelerate its roadmap to offer cloud-based access to its integrated software platform. It also is expected to broaden the company's industrial customer base across North America, Europe and Asia-Pacific, offering Link3D customers a seamless connection to the Materialise Magics 3D Print Suite. Materialise expects to exercise the option before the end of 2021.

"By joining forces with Link3D, we expect to be even better positioned to provide our customers with a solution to plan, manage and optimise their AM operations," stated Fried Vancraen, CEO of Materialise. "This agreement exploits the synergy between the two companies and will help us to remove some of the complexity associated with scaling 3D printing as part of a connected, industrial manufacturing process."

Link3D offers additive MES workflow software to help companies scale their digital manufacturing operations across complex supply chains and IT environments. Its MES and workflow solutions help bolster the overall adoption of AM for series production in major manufacturing industries, including aerospace, automotive, consumer, medical and energy.

Additive Manufacturing continues to transform the factory floor as companies increasingly turn to AM for large-scale production. However, as these companies scale their AM processes and integrate these operations with existing production infrastructures, they are confronted with increasingly diverse, complex and distributed manufacturing environments. Materialise and Link3D both offer MES solutions that help these organisations gain control over their manufacturing floor.

"At Link3D, it has always been our mission to help companies unlock the full potential of AM into their existing supply chains," commented Shane Fox, Link3D CEO.

Vishal Singh, Link3D's co-founder and CTO, added, "By teaming up with Materialise, a global pioneer of the 3D printing industry, we expect to be able to offer our combined user base access to a robust and comprehensive manufacturing suite of solutions, enabling them to take Additive Manufacturing to the next level."

www.materialise.com
www.link3d.co

Materialise has acquired an option to purchase Link3D (Courtesy Materialise)

PyroGenesis Canada applies for NASDAQ listing

PyroGenesis Canada Inc., Montreal, Quebec, Canada, a developer and manufacturer of plasma atomised metal powders and a supplier of plasma-based metal powder production technology, has submitted an application to list its common shares on the NASDAQ Stock Exchange. The company will reportedly continue to maintain the listing of its shares on the Toronto Stock Exchange (TSX), and would trade on both exchanges under the ticker symbol 'PYR'.

The listing of PyroGenesis' shares on the NASDAQ remains subject to the stock exchange's approval and the satisfaction of all applicable listing and regulatory requirements. Based on its typical review process, this usually takes 6–8 weeks, PyroGenesis expects that its shares will be listed before the end of Q1 2021.

According to the company, there will be no concurrent financing associated with this listing nor a reverse stock split. PyroGenesis has engaged Nelson Mullins Riley & Scarborough LLP as its US legal counsel to process the listing and, in connection with its application, the company states that it will file a Form 40-F Registration Statement with the United States Securities and Exchange Commission (SEC).

"We believe the company is entering a heightened growth phase and the timing could not be better for uplisting our shares to NASDAQ," stated P Peter Pascali, CEO & chair of PyroGenesis. "We expect that the move to NASDAQ will increase awareness of PyroGenesis and its offerings, both within the financial community and amongst potential clients."

"We believe this listing will also enhance trading liquidity by broadening our appeal to a larger shareholder base, in the US and internationally, as we execute our business plan and drive long-term shareholder value," he concluded.

www.pyrogenesis.com

Markforged to be publicly listed through merger with one

Markforged, Watertown, Massachusetts, USA, has announced it will become a publicly listed company through a merger with one, a special purpose acquisition company sponsored by A-star and founded and led by technology industry veteran Kevin Hartz. The merger is expected to be completed in summer 2021. Markforged will retain its name and will be listed on the New York Stock Exchange under the ticker symbol 'MKFG'.

Founded in 2013, Markforged is reported to have products across 10,000 global facilities, with 170 patents issued or pending, a full suite of AM machines, widespread use of its Digital Forge platform and a history of some 10 million parts additively manufactured so far.

"When I co-founded Markforged, our mission was to reinvent manufacturing by driving innovation and creating products and technologies that have the potential to transform an entire industry," stated Greg Mark, the company's founder and chairman. "I've been thrilled that Markforged has thrived in its successful pursuit of these ambitions with a growing network of customers across major sectors and around the world. As we take Markforged to the next level, we have found the ideal partner in one. Kevin and his team recognise not only Markforged's ability to transform the way businesses innovate, but also the brilliant, passionate employees that make this company so unique."

Kevin Hartz commented, "Markforged has already reinvented the Additive Manufacturing industry and is well positioned for robust growth benefiting from the velocity of digitisation. When launching one, our priority was to partner with a company with exceptional founders, visionaries and operators taking a differentiated approach in large and growing markets – Markforged ticked all of those boxes and more. We're thrilled to be working closely with the entire Markforged team, comprised of highly engaged founders, visionary leaders and world-class engineers, uniquely positioned to lead a revolution in modern manufacturing."

Transaction overview

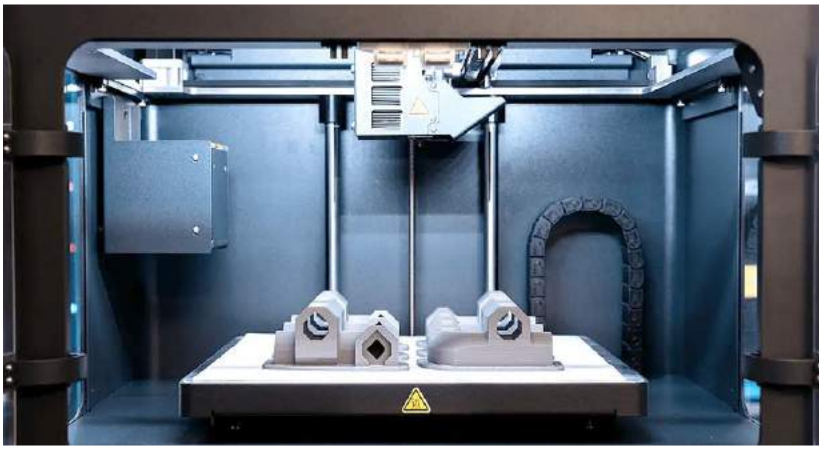
The combined company, upon closing, will have an approximate equity value of $2.1 billion, with over $425 million in gross proceeds to Markforged, assuming no redemptions by one shareholders. This includes $210 million PIPE at $10 per share from investors such as Baron Capital Group, funds and accounts managed by BlackRock, Miller Value Partners, Wasatch Global Investors and Wellington Management, as well as commitments from Microsoft's Venture Fund M12 and Porsche Automobil Holding SE, existing Markforged shareholders. Net transactions proceeds will support the company's continued growth across its key verticals and into new products, proprietary materials and expanded customer-use cases.

The transaction, already unanimously approved by the boards of directors of Markforged and one, will be subject to approval by both companies' stockholders and regulatory approvals, as well as other typical closing conditions. Immediately after the combination is completed, current shareholders in Markforged are expected to hold 78% of the issued and outstanding shares of common.

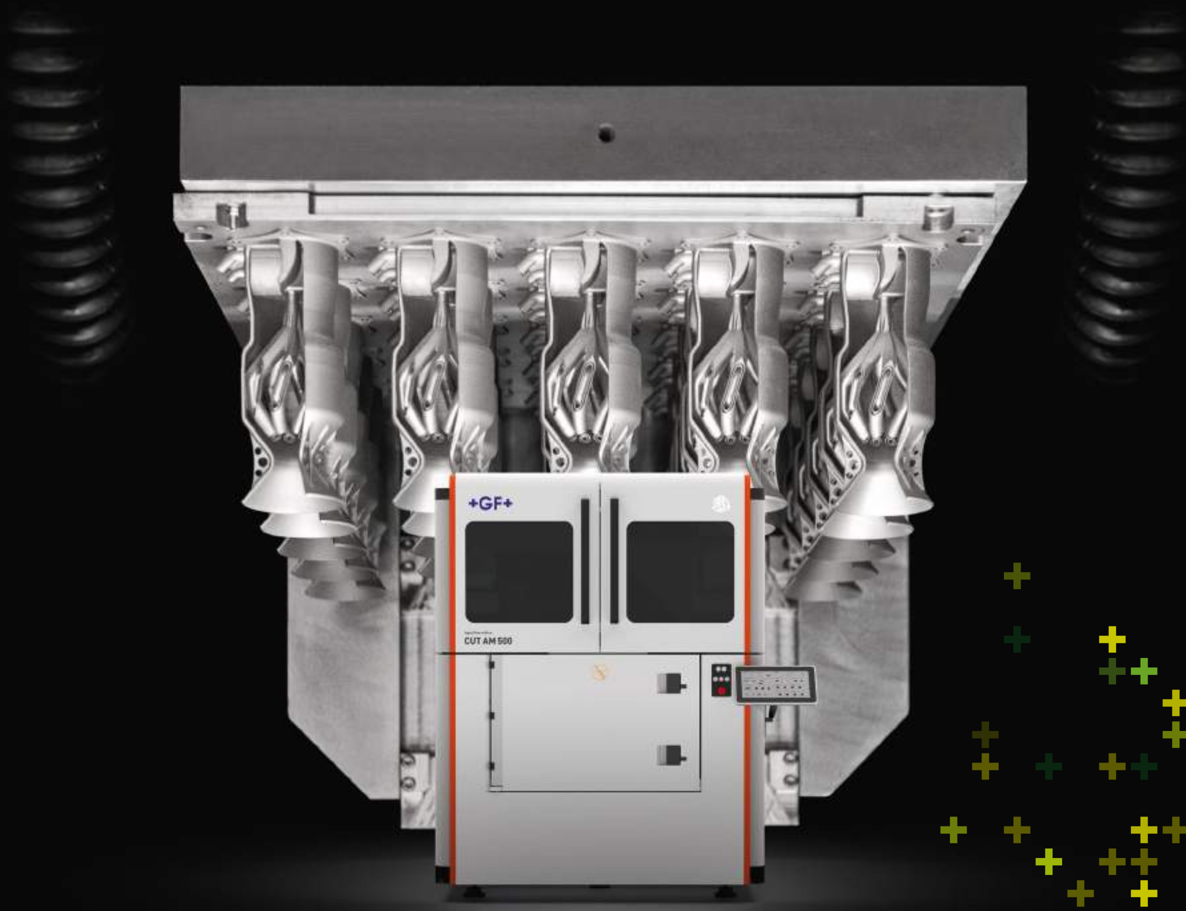
Following the transaction's completion, Shai Terem will continue in his role as Markforged president and CEO, and Kevin Hartz will join the board. "Our mission and vision are to reinvent manufacturing by bringing the power and agility of connected software to the world of industrial manufacturing," added Terem. "Today is a pivotal milestone as we progress towards making that vision a reality. We've been at the forefront of the Additive Manufacturing industry, and this transaction will enable us to build on our incredible momentum and provide capital and flexibility to grow our brand, accelerate product innovation and drive expanded adoption among customers across key verticals."

"We're focused on making manufacturing even better by capitalising on the huge opportunity ahead, and we are making this important leap through our new long-term partnership with Kevin Hartz and the entire team at one, a group of seasoned founders and operators with unparalleled experience. Their expertise and guidance will be invaluable as we continue to reinvent manufacturing today, so our customers can build anything they imagine tomorrow," he concluded.

www.markforged.com
www.a-star.co



The Metal X system from Markforged allows users to print a wide range of materials, from stainless steels to copper (Courtesy Markforged)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CUT AM 500

Renishaw for sale following founders' decision to sell stake

Engineering company Renishaw, headquartered in Wotton-Under-Edge, Gloucestershire, UK, has announced the commencement of a formal sale process. The company states that its founders, Sir David McMurtry, Executive Chairman, and John Deer, Non-Executive Deputy Chairman, have indicated their intentions to sell their entire combined shareholdings, totalling some 53% of the issued share capital.

In considering its options, the board is reported to have concluded unanimously that it would be appropriate to investigate the sale of the company. The board is seeking a buyer which will respect the unique heritage and culture of Renishaw, its commitment to the local communities in which its operations are based, and which will enable the company to continue to prosper in the long-term.

Since its beginnings in 1973, Renishaw has become one of the world's leading engineering and scientific technology companies, with specialist knowledge in precision measurement and healthcare. The company believes that, at the heart of its activities, rests a culture of innovation and a fundamental belief that success comes from patented and innovative products and processes, high-quality manufacturing and the ability to provide localised customer support throughout global markets.

Sir David McMurtry and John Deer stated, "We are both grateful for our continued good health, however we recognise that neither of us is getting any younger. Now finding ourselves in our eighties, our thoughts have increasingly turned to considering the future of our shareholdings in the company and how we can actively contribute to securing the future success of the business. With that in mind, we approached the rest of the board to indicate that we felt the time was now right to discuss the best way to achieve this."

"As the founders of Renishaw, we understand the importance of Renishaw's culture, our place in the communities in which we operate, our commitment to research and development, and the loyalty of our staff, our suppliers and the customers we serve; these together have been the foundation of our success for almost fifty years. With the board, we are, therefore, focused on ensuring that we find the right new owner for our business – one who respects and will continue to nurture these important attributes."

The Takeover Panel has agreed that any discussions with a third party will take place within the context of a 'formal sale process' as defined in The Takeover Code, enabling conversations with interested parties to take place on a confidential basis.

Neither Renishaw nor McMurtry and Deer are said to be currently in discussions with any potential offeror, or in receipt of a possible offer for the company or for the shareholdings at the date of the announcement.

www.renishaw.com

Renishaw manufactures a wide range of metal Additive Manufacturing machines (Courtesy Renishaw)

Uniformity Labs appoints former GKN Sinter Metals president Christon Franks to its board

Uniformity Labs, Fremont, California, USA, has appointed Christon Franks, former president at GKN Sinter Metals, to its board of directors, further strengthening its group of industry advisors. His appointment follows the additions of John Ferriola, former Nucor Corporation CEO, and General Motors veteran Alan Batey to the board.

Franks is a metals industry executive with more than thirty years of experience leading successful international businesses that industrialise product solutions for the automotive, electronics, and general industrial industries. He brings deep commercial and operations experience with a metals focus, having led international companies while residing in the USA, China, and Germany.

Most recently, Franks served as president at GKN Sinter Metals, a position which he held for eight years. In this role, he was responsible for GKN operations in North and South America, Europe, and Asia. He also led the global commercial strategies for GKN Sinter Metals and established the path to market for new technology introductions such as Additive Manufacturing.

"Chris is a highly respected and proven leader in the field of powder metallurgy," stated Adam Hopkins, Uniformity CEO. "He brings global commercialisation skills and deep knowledge of the metal component manufacturing landscape to our board, which we will call on to help us deliver the full potential of AM. We have put together a team of executives and advisors who are some of the best technical and commercial minds in the industry; their experience will be invaluable as we continue to grow our business."

www.uniformitylabs.com

Desktop Metal completes Trine business combination, becomes publicly listed

Desktop Metal, Burlington, Massachusetts, USA, has completed its business combination agreement with Trine Acquisition Corp. (TRNE), and become a publicly listed company. Trine is a special-purpose acquisition company led by Leo Hindery, Jr., and HPS Investment Partners, a global credit investment firm. The resulting company is Desktop Metal, Inc. and, from December 2020, trades common stock and warrants under the new ticker symbols 'DM' and 'DM.WT' on the New York Stock Exchange.

The transaction was unanimously approved by the Board of Directors of Trine and was also approved at a special meeting of the company's stockholders on December 8, 2020. As a result of this transaction, Desktop Metal has received approximately $580 million of gross proceeds from Trine's trust account and concurrent equity private placements.

Founded in 2015, Desktop Metal has quickly grown to become a global enterprise offering a wide range of Additive Manufacturing solutions. The company has distribution in more than sixty countries and adoption from leading companies in the automotive, consumer products, industrial automation, medical devices, aerospace and defence industries.

"Today is an exciting moment and major milestone for our company and for the Additive Manufacturing industry at large," stated Ric Fulop, co-founder and Chief Executive Officer of Desktop Metal on the day of the public listing. "With a broad portfolio of solutions offering revolutionary ease of use and productivity for the AM industry, Desktop Metal is uniquely positioned to disrupt how parts are made across a wide range of industries."

"The capital raised through our transition to a publicly-traded company will accelerate our global go-to-market efforts, enhance our relentless efforts in R&D, and allow us to capitalise on the tremendous growth opportunities we see over the next decade as we integrate industry-leading technology and intellectual property with strong secular growth trends around AM. We are excited to bring Desktop Metal to the public markets as the only pure-play Additive Manufacturing 2.0 company and offer everyone the opportunity to invest in a company aiming to transform the manufacturing industry."

According to Desktop Metal, the AM industry grew at a 20% annual compound rate between 2006–2016, accelerating to 25% compound annual growth over the last three years — a rate that is expected to continue over the next decade as the market grows from $12 billion in 2019 to an estimated $146 billion in 2030.

Fulop added, "We believe the AM industry is at a major inflection point and that Desktop Metal is at the forefront of this transformation. This market inflection is being driven by the emergence of AM 2.0 a wave of next-generation AM technologies that unlocks throughput, repeatability, and competitive part costs with a focus on making AM an easy to use, economic solution for mass production. These solutions feature key innovations across printers, materials, and software to pull AM into direct competition with conventional processes used to manufacture $12 trillion in goods annually."

Leo Hindrey, Jr., Desktop Metal board member and chairman and CEO of Trine Acquisition Corp. commented, "Desktop Metal is poised to revolutionise the manufacturing industry by applying transformative AM 2.0 technologies to the products and industries that will drive the economy in the 21st century. The company has a distinct first-mover advantage over competitors and the injection of capital from this transaction, a large portion of which will be dedicated to continuous product innovation, will protect and extend this first-mover advantage."

www.desktopmetal.com

Expansion at VBN Components follows fully-subscribed funding round

Despite the challenges caused by the coronavirus (COVID-19) pandemic, hard material specialists VBN Components AB, Uppsala, Sweden, has continued with its planned expansion to meet the growing interest and demand in its additively manufactured Vibenite products. The company has now expanded sales channels with new distributors and sales representatives in Asia, Europe and North America.

Thanks in part to the completion of its latest funding round, the company plans to move to larger premises this spring in order to accommodate its growing workforce. The additional space will also allow for investments in production equipment, thus increasing its range of services.

"The fully-subscribed funding round shows that our owners strongly believe in our global vision, which makes me proud, and is very motivating," stated Johan Bäckström, CEO. "Our expansion of both sales channels and sales worldwide have begun to yield results, which shows that our offer is right on time."

VBN Components develops metal alloys with extreme wear and heat resistance, including alloys such as Vibenite 290, said to be the world's hardest commercially available steel, and Vibenite 480, an additively manufactured cemented carbide.

www.vbncomponents.se

AM Ventures launches €100 million venture capital fund for industrial AM

AM Ventures, Munich, Germany, has announced the initial closing of its venture capital fund for industrial Additive Manufacturing. Along with its major shareholders the Langer Group, AM Ventures has partnered with KGAL, Grünwald, Germany. This closing brings the fund to nearly half of its targeted commitment.

The parties involved have stated that this closing represents a strong signal, not only for the AM industry itself, but also for investors looking to benefit from the strong dynamic in advanced manufacturing. The fund is expected to continue to strengthen support in seed and early-growth stage hardware, software, materials and applications in AM globally.

Dr Hans Langer, representative of the Langer Group and a founding partner of the newly-formed fund, added, "After six years of successfully investing in AM-based startup companies, we decided to jointly take our business to the next level and join forces with the international asset manager KGAL. I am thankful for the achievements the AM Ventures team has made since we started in 2015 and I am very happy to now be working alongside my two former managing directors as new managing partners in the fund. This step is a massive opportunity for all AM startups around the world and will help to further accelerate the adoption of Additive Manufacturing."

KGAL is a leading independent investment and asset managers for capital investments in Europe. It has an investment volume of €15 bn and more than 390 funds launched since its foundation in 1968. Alongside the Langer Group and managing partners Johann Oberhofer and Arno Held, KGAL has become a shareholder in the newly formed AM Ventures Management GmbH.

"This is a perfect match," stated Dr Klaus Wolf, Chief Investment Officer at KGAL. "The expertise of AM Ventures and KGAL ideally complement each other. AM Ventures, through their shareholder base, bring in-depth knowledge of industrial 3D printing, thanks to their long commercial presence in this field; KGAL in turn has a proven track record in access to investors. Additive Manufacturing offers impressive potential to produce industrial goods in a resource effective and sustainable way. Through this joint venture we are laying the foundations for a long-term partnership and for further funds in a strong growth market."

www.amventures.com

www.kgal.de

Sandvik to focus on growth following a challenging year

Sandvik AB, Stockholm, Sweden, has published its Annual Report for 2020, highlighting a challenging year with a number of strategic decisions which Stefan Widing, president and CEO, believes will strengthen and shape the future of Sandvik as it prepares for a shift towards growth.

The group reported a total order intake of SEK 86,287 million, down from SEK 104,075 in 2019. Revenues totalled SEK 86,404 million compared with SEK 103,238 million in the previous year. An operating profit of SEK 11,216 million was noted, down from the previous SEK 13,386 million. A breakdown of revenues by customer segment showed that 40% was generated in mining; 23%, engineering; 11%, automotive; 10%, energy; 8%, construction; and 5%, aerospace, with the remaining 3% generated from unspecified segments. By region, 35% of Sandvik's 2020 revenues came from Europe, 22% from North America, 20% from Asia, and a further 9% from Africa/Middle East, 9% from Australia and 5% from South America.

In 2020, the group acquired Allied Construction Products, CGTEch, Summerill Tube Corporation, Quimmico Centro Technológico and Miranda Tools; an agreement was also signed to acquire DSI Underground. Sandvik Materials Technology was made a separate listing and reorganisations were made within Sandvik Manufacturing and Machining Solutions, as well as Sandvik Mining and Rock Technology.

During the year, Sandvik's Board of Directors made the decision to continue preparations for the distribution of the Sandvik Materials Technology business area to its shareholders. The board's intent is to propose the distribution and listing of Sandvik Materials Technology on Nasdaq Stockholm at a shareholders' meeting in 2022, provided that the circumstances at the time are deemed to be right. "I am convinced that this is the correct way forward, both for Sandvik Materials Technology and for Sandvik as a whole," added Widing.

In line with its goal of strengthening the group's offering, a new business area focusing on digital solutions, Sandvik Manufacturing Solutions, was established. Assets were also divested: the oil & gas operations of Sandvik Drilling and Completions (Varel), as well as an agreement signed towards the divestment of its mineral exploration business.

Moving forward, Sandvik has set a growth target of at least 5% (CAGR) through a business cycle. The company aims to increase its acquisitions and add products and technology, as well as services and digital solutions, to its existing offerings. This growth target means that Sandvik will become a SEK 115 billion company by 2025.

www.home.sandvik/en

Wayland Additive launches Calibur3 with NeuBeam metal AM technology

Wayland Additive, Huddersfield, UK, has launched Calibur3, the company's first Additive Manufacturing machine, using its NeuBeam® metal AM technology. During a virtual launch from its headquarters in Huddersfield, the full capabilities of the NeuBeam process embedded into the Calibur3 were explained.

NeuBeam is said to represent a completely new system architecture based on a stable, reliable and flexible Electron Beam Powder Bed Fusion (PBF-EB) process. It is able to produce fully dense parts in a wide range of materials, many of which are not compatible with traditional electron beam or laser-based processes, such as refractory metals and highly-reflective alloys. As a result, the NeuBeam process can demonstrate vastly improved metallurgy, without many of the compromises that existing metal AM processes necessitate.

"It was a privilege for me to explain the genesis of our work at Wayland Additive and the 'why' behind the NeuBeam process and Calibur3," stated Will Richardson, CEO of Wayland Additive. "All the hard work by the Wayland team that has gone into the development of the process and this new hardware platform has been realised today. I am so proud of our team and their dedication to the launch initiative. Now it is our mission to really demonstrate the difference that Calibur3 can make for metal AM applications."

Peter Hansford, Wayland's Director of Business Development expanded further on the potential for new applications and shared the real opportunities Calibur3 brings for business. "The Calibur3 system featuring the NeuBeam process offers a true third way that sits between SLM & EBM systems, and provides a leap forward compared with any existing alternatives. In addition, Calibur3 promotes innovation, which should be key to any advancement in technology. And because it overcomes the compromises that most companies have to contend with when using metal AM, they can now revisit applications that were previously seen as troublesome or impossible and/or begin development projects with a clearer view of the process and more room to operate in. NeuBeam is a metal AM process that saves both time and money from end-to-end, one that can benefit commercial objectives through true production partnerships."

www.waylandadditive.com

The Calibur3 metal AM machine (Courtesy Wayland Additive)

Additive Industries expands leadership team with new CEO and CFO

Additive Industries based in Eindhoven, the Netherlands, has appointed Ian C Howe as its new CEO and Carlien Siebelt as CFO.

Previously Head of the Precision Components Business Line at Oerlikon Surface Solutions AG, part of the Swiss Oerlikon Group, Howe has experience leading and delivering growth within high-technology businesses. In a career spanning over twenty-five years, he has developed and implemented growth strategies to address market and customer needs, as well as leading teams and people towards a common goal.

As well as his experience with Oerlikon, Howe held management positions at Höganäs AB and the GKN Group. He holds a master's degree in Engineering (Materials) and an MBA in Finance, Strategy and Marketing, both from The Open University.

The company's new CFO, Siebelt, joins Additive Industries from Energyst CAT Rental Power where she worked in a variety of leadership positions. Siebelt is an experienced senior financial manager with twenty years of experience in finance, thirteen of those in the field of audit and assurance at Big Four audit firms with a client portfolio that consisted of large, international trading and production companies. Siebelt has over seven years of experience as a manager at a multinational's finance department and has a master's degree from Nyenrode Business University, Breukelen, the Netherlands.

Commenting on the new appointments, Jonas Wintermans, co-founder and current CEO, stated, "We are proud to welcome Carlien and Ian in the Additive Industries team. During a period of leadership change last year, I felt privileged to be part of the team again, albeit for only a short period. I'm glad we took the time to search extensively to find the right additional leaders for the future of Additive Industries. Ian's and Carlien's extensive experience in various aspects of our business makes them perfectly suited to support our growth ambitions, together with our CTO Mark Vaes, who has been with the company from the start."

www.additiveindustries.com

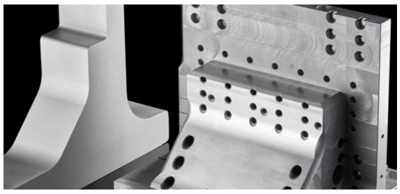
Ian C Howe is the new CEO (Courtesy Additive Industries)

Gränges targets AM with new Gränges Powder Metallurgy division

Gränges, a leading global supplier of rolled aluminium products for heat exchanger applications and other niche markets, headquartered in Stockholm, Sweden, has established Gränges Powder Metallurgy.

With a responsive organisation and two powder production sites, Gränges sees great opportunities in the Additive Manufacturing sector and believes that this newest division will serve as an important platform for growth within the fast-paced markets of powder materials and Additive Manufacturing. The main production facility is located in St Avold, France, with sales and technical development based in Velbert, Germany.

"We are a slim and flexible organisation with focus on partner and stakeholder management," Filip Fernqvist, Managing Director at Gränges Powder Metallurgy, told *Metal AM* magazine. "We are both a powder producer and alloy developer, able to produce powder in house, both in France as well as in Germany."



Gränges Powder Metallurgy's goal is to become a leading manufacturer of niche and custom AM-grade aluminium powders (Courtesy Gränges)

Gränges has stated that its objective is to become a leader in the manufacture of niche and custom AM-grade aluminium powders for a range of applications. The company is targeting the aerospace and automotive industries, which are undergoing the fastest growth, without losing sight of other areas such as heat exchangers and automation, where the company still sees great potential.

Greta D'Angelo, Additive Manufacturing Business Development Lead, told *Metal AM* magazine: "Gränges has a combined experience and in-depth knowledge in several key areas – for example, Powder Metallurgy, aluminium market and alloy development for heat exchanger applications. This heritage plays an important role and puts us in a position of competitive advantage. AM powder is our core business, but we are looking into engineering services and down-streaming opportunities as well for prototype production."

Delivering premium powders of high quality with fast development times is one of Gränges' core values. The company believes a key to its success is a close collaboration with customers and partners, which ensures a strategic positioning within the AM ecosystem.

"It is very important for us to be on the market with a competitive product that is relevant to our customers," Fernqvist added. "That's why we are always on the lookout for partnerships and beta testers for our new materials."

www.granges.com

Matexcel expands offerings to include wide selection of metal powders

Matexcel, Bohemia, New York, USA, has acted as a service provider in materials science since 2007 in the supply of polymers, nanoparticles and natural materials. The company has announced it is expanding its range to provide a selection of metal powders for research requirements.

Matexcel is now offering hybrid water/gas and plasma atomisation technology to meet the needs of its customers working in Powder Metallurgy, metal processing and Additive Manufacturing research and development. Bespoke manufacturing strategy services are also offered by the company.

"Besides advanced production equipment and standard production technology, we also have modernised testing laboratory that can ensure the high quality and consistency of the final products. Providing professional solution of metal powders to our customers is our aims," commented Johnson Brown, one of Matexcel's representatives.

The company states its most popular metal products so far include titanium alloys and nickel-base superalloys, which are atomised by a plasma rotating electrode process (PREP). Other available metal powders include those based in Co, Cu, Fe, Ni, Pd, metal oxide, pure metal powders and more.

www.matexcel.com

NanoAL signs agreement with Mitsubishi Corporation RtM to bring Addalloy powders to Asia market

NanoAL, LLC, Boston, Massachusetts, USA, has signed a Commercial License Agreement with Mitsubishi Corporation RtM Japan Ltd. (RtMJ), Tokyo, Japan, to bring its Addalloy® family of advanced aluminium alloy powders to the growing metal Additive Manufacturing market in Asia.

Addalloy is an aluminium alloy technology designed and developed for Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing. Currently, Addalloy consists of 5T, 7S, and HX compositions, each with application-specific performance levels tailored to the demands of the automotive, motorsports, aerospace, and industrial markets. Addalloy powders are reported to be suitable for a number of platforms for metal AM including EOS, SLM Solutions, Renishaw, Concept Laser, and many others.

"This announcement is an enormous signal of the market need for Addalloy powders," stated Dr Nhon Vo, CEO of NanoAL LLC. "In partnership with RtMJ, a wholly-owned subsidiary of Mitsubishi Corporation, a global integrated business enterprise, we will now be able to reach across the globe to deliver the promise of our aluminium alloy technologies' excellent performance and economics."

Takehito Nagashima, General Manager of New Business Development and DX Office, Mitsubishi Corporation RtM Japan Ltd, commented, "We believe the aluminium alloys developed by NanoAL are the essential materials for the next generation to achieve decarbonisation, electrification and a circular economy. NanoAL and RtMJ will play an important role in creating a cleaner and greener society by combining the advanced technology of NanoAL with the global business network of RtMJ."

www.mitsubishicorprtm.com
www.nanoal.com

EOS and Audi expand range of applications for tool production

Audi AG is reportedly relying on Additive Manufacturing for the production of selected tool segments at its Metal 3D Printing Centre in Ingolstadt, Germany. Audi uses EOS GmbH's metal AM technology to produce twelve segments of four tools for hot forming, and plans for significantly more segments to be additively manufactured this way. Audi uses the tool segments, which are produced using an EOS M 400 machine, in its press shop to make body panels for models, including the Audi A4. The company plans to do the same for future electric vehicles.

According to Audi, shifting part of its tool segment production activities from conventional manufacturing to AM is an important step, highlighting both the quality and reliability of industrial Additive Manufacturing and the design freedom advantages this production method offers.

This outcome is the result of a longstanding cooperative relationship between Audi and EOS in Ingolstadt. EOS provided support in the form of technology and know-how before and during the construction of Audi's AM centre back in 2016. Since then, experts from both companies have been making steady progress in the use of AM, and Audi has established an ideal application in the area of hot forming for series vehicles. Several hundred thousand parts are said to have already been produced using the additively manufactured tools and installed in selected models.

For hot forming segments and high-pressure die casting tool inserts, the design department in Ingolstadt creates entire tools which can measure as much as 5 x 3 m. The individual additively manufactured tool segments in turn can be up to 400 mm in length and weigh 120 kg.

The size and complexity of the tool segments mean that construction times of up to twenty days are not uncommon. AM makes it possible to create highly-complex cooling channels configured for the specific component within the tool segments. This provides contoured, more even cooling, making it possible to shorten cycle times with outstanding quality – a critical point for series production of the actual vehicle component.

Matthias Herker, Technical Project Manager at the Audi Metal 3D Printing Centre, stated, "From initial qualification by EOS to internal further development and refinement of the entire process chain through to standardisation of a new production method, we are now reaping the fruits of years of development within Audi's production organisation. Whenever conventional manufacturing methods reach their limit, we use Additive Manufacturing – which lets us meet quality standards and comply with production times."

Markus Glasser, senior vice president EMEA at EOS, added, "The latest examples show that 3D printing has become an established part of operating materials production at Audi. We're especially proud that the tool segments made using AM are created exclusively using an industrial 3D printer from EOS. Audi is a partner we can work with to continue to drive the use of AM in automotive production – a key industry for us."

www.eos.info | www.audi.com

The EOS M 400 metal AM machine in Audi's Metal 3D Printing Centre in Ingolstadt, Germany (Courtesy Audi AG)

BASF Ultrafuse 316L Stainless Steel now supported on MakerBot METHOD

MakerBot, a Stratasys company, headquartered in Brooklyn, New York, USA, has announced that the BASF Ultrafuse® 316L Stainless Steel material by Forward AM, the AM brand of BASF 3D Printing Solutions GmbH, Heidelberg, Germany, has been qualified for the MakerBot LABS™ Experimental Extruder for the MakerBot METHOD® AM machines.

With an open materials platform and a growing portfolio of advanced engineering-grade materials, MakerBot states that METHOD is the only industrial desktop AM machine in its price range with a heated chamber that can additively manufacture metal, polymer and composite materials.

Once the part is built with Ultrafuse 316L, it can be sent out to post-processing or specialised manufacturing facilities for debinding and sintering, which turns the part into solid stainless steel. This process allows users to create stainless steel parts without investing in expensive debinding and sintering equipment.

MakerBot states that final parts can achieve up to 96% of the density of pure 316L metal material. Users can produce lightweight, hollow metal parts with high tensile strength.

www.makerbot.com
www.forward-am.com

Atomising Systems Ltd invests in new laboratory facilities for rapid powder analysis

Atomising Systems Ltd. (ASL), a Sheffield, UK-based metal powder producer, has invested £150,000 to upgrade its in-house chemical analysis facilities with the addition of an ICP-OES system. The new equipment expands the range of elements that can be reliably analysed in-house and covers almost all alloys in regular production, such as stainless steels, nickel and copper alloys, for Additive Manufacturing, Metal Injection Moulding, press and sinter Powder Metallurgy, brazing, thermal spraying, etc.

To house the new equipment, some of which involves the use of aggressive acids to bring such corrosion-resistant alloys into solution, a new specially-ventilated laboratory has been constructed, meaning ASL now has three laboratories for different types of powder testing.

ASL reports that current staff have now been trained and the equipment is performing well. It expects to employ extra staff as demand increases.

This new facility now means that ASL's laboratories can test:

- Chemical composition via ICP-OES and XRF
- Powder oxygen, nitrogen, carbon, and sulphur by Eltra systems
- Particle size by laser diffraction and sieving
- Particle shape by Hall and Carney funnels, density cup, tap density, optical microscopy
- Compressibility and green dtrength

Discussing the increased capability of the quality department, Dan Lodge, ASL's Quality Manager, stated, "We now measure our laboratory turnaround time in hours, while external analysis can take up to a week. Rapid results from the new equipment will allow our Production department to be much more responsive and will also support our extensive R&D projects."

Simon Dunkley, Managing Director, commented, "We are pleased with this major investment; this is the first step in our current expansion plans which by 2022 will see a 50% increase in capacity enabling more efficient production of high-grade powders for our increasingly demanding customers in Europe and the USA."

www.atomising.co.uk

Wohlers Report 2021 finds 7.5% growth in AM industry despite COVID-19 pandemic

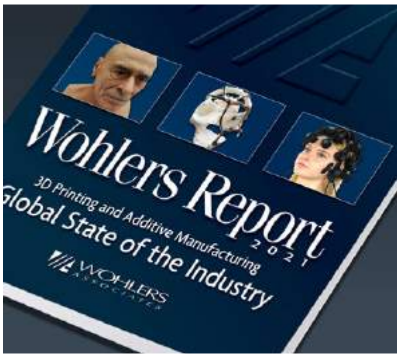
Wohlers Associates, Inc., Fort Collins, Colorado, USA, has published its *Wohlers Report 2021*, marking the twenty-sixth annual instalment of the industry-leading report on Additive Manufacturing. The study provides trends, perspectives and forecasts as a tool for decision making, education and knowledge acceleration. The report offers readers new to AM a comprehensive understanding of the technology and industry, and veterans of the technology can benefit from up-to-date information.

The 375-page report discusses the impact of the coronavirus (COVID-19) on the AM industry, most notably that, despite the pandemic, the industry expanded 7.5%, reaching near to $12.8 billion in 2020. Growth was down considerably, compared to the average growth of 27.4% over the previous decade. Most established manufacturers of AM machines saw a decline in equipment sales, but many less-established companies grew in 2020. An increase in business by AM service providers supported industry-wide growth. There was a 7.1% growth from independent service providers worldwide, resulting in nearly $5.3 billion of revenue from this group.

The report includes commentary on seventy-four early-stage investments and thirty-five acquisitions and public offerings. *Wohlers Report 2021* was created with the support of 124 service providers, 113 manufacturers of AM machines, and twenty-four producers of third-party materials. Eighty-eight co-authors and contributors from thirty-four countries provided expert views and perspectives.

New and expanded features of *Wohlers Report 2021* include:

- Additive Manufacturing of food, medicine, and electronics
- Pricing of metals and polymers and the hidden costs of AM



Wohlers Associates, Inc has published its Wohlers Report 2021 (Courtesy Wohlers Associates, Inc)

- Methods of AM part inspection
- Pandemic's impact on the AM industry
- Compilation of expert reports from thirty-four countries
- Tables of AM systems, software tools, service providers, and third-party materials

The report includes fifty-four charts and graphs, 104 tables, and 397 images and illustrations. It also includes eighty pages of supplemental online content available exclusively to the buyers of the report.

www.wohlersassociates.com

Desktop Metal launches new P-1 and Studio System 2 AM machines

Desktop Metal, Inc., headquartered in Burlington, Massachusetts, USA, has launched two new metal Additive Manufacturing machines, adding the P-1 and Studio System 2 to its growing range.

Desktop Metal P-1

The new P-1 Binder Jetting (BJT) machine expands the company's Production System™ range, sitting alongside its flagship P-50, and has already begun shipping, with the Ford Motor Company cited as an initial customer. Designed to serve as a bridge from process development to full-scale mass production of end-use metal parts, the P-1 leverages the same patent-pending Single Pass Jetting™ (SPJ) technology as the P-50. The new AM machine features a 1200 dpi print bar, advanced printhead technology that supports a wide variety of binders, and an inert processing environment to allow both non-reactive and reactive materials, said to be a key benefit for businesses and research institutions looking to experiment with a variety of materials. As a result, materials research and new application development conducted on the P-1 can be transferred directly onto the P-50 to scale to mass production.

Desktop Metal's SPJ technology used on the P-1 is designed to build each layer in less than three seconds, including powder deposition, powder compaction, anti-ballistics, binder deposition, and printhead cleaning.

Desktop Metal's new P-1 metal Additive Manufacturing machine (Courtesy Business Wire)

The new Studio System 2 incorporates a two-step process, removing the debinding stage found in earlier systems (Courtesy Desktop Metal)

The P-1's open material platform and inert process environment allow customers to use third-party Metal Injection Moulding (MIM) powders across a variety of materials, making the P-1 suitable for cost-effective serial production of small and complex parts in addition to smaller-scale process development activities.

Desktop Metal Studio System 2

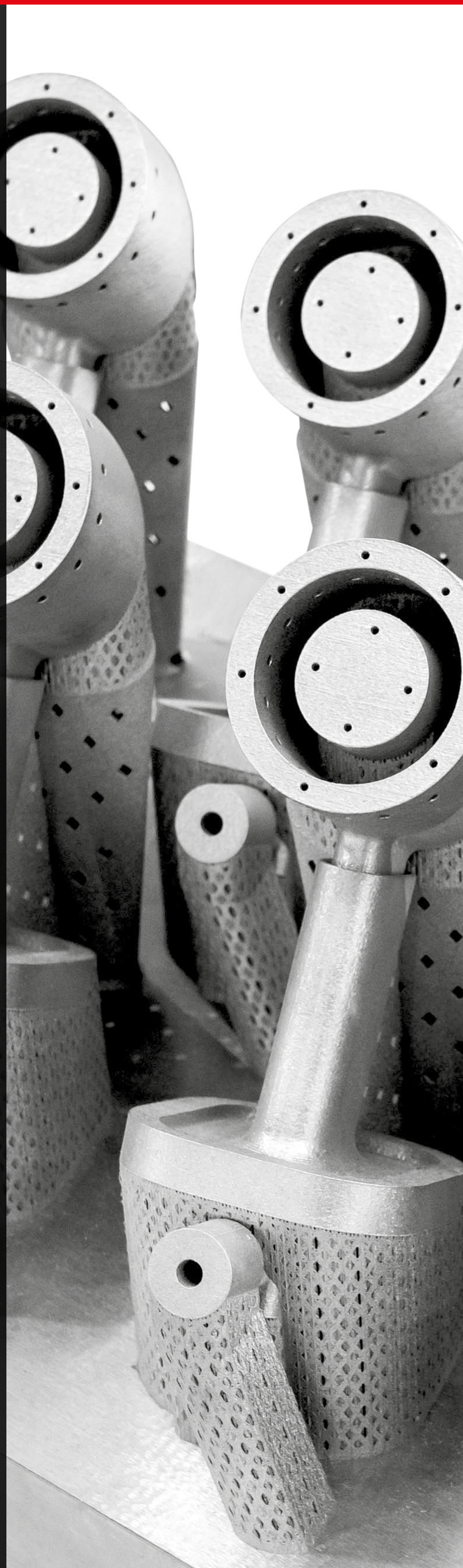
The Studio System 2 is a simplified, office-friendly metal Additive Manufacturing system aimed at low volume, pre-production and end-use applications. The new system incorporates a new, two-step process based on Desktop Metal's Material Extrusion (MEX) technology it calls Bound Metal Deposition (BMD). The two-step process now eliminates the use of solvents, removing the debinding stage needed with earlier systems. All-new material formulations allow parts to be transferred directly from the printer into the furnace.

The Studio System 2 retains all the critical features of the original Studio System, first debuted in 2017, while delivering advancements that are said to make metal Additive Manufacturing even easier, more reliable and accessible. Vacuum sintering in the Desktop Metal furnace, at temperatures of up to 1400°C, produces parts and mechanical properties that are similar to castings and reportedly meet or exceed Metal Powder Industries Federation (MPIF) standards.

The Studio System 2 is launching with 316L stainless steel, but a broad portfolio of additional materials, that take advantage of the new streamlined two-step process, is under development. In addition, the Studio System 2 will be backwards-compatible through the use of the debinder, with all materials previously supported by the Studio System, including 17-4PH stainless steel, 4140 low alloy steel, H13 tool steel, and copper.

The Studio System 2, which is set to begin worldwide shipments in the first quarter of 2021, will also be available through an upgrade for all existing Studio System customers.

www.desktopmetal.com



Metal AM Ecosystem

CONSISTENT PERFORMANCE

· Innovative gas flow management and optimized filter system
· Outstanding sealing capability optimizes oxygen content
· Precise laser beam quality control

HIGH PRODUCTIVITY

· Dual-Laser system equipped with build volume of 305x305x450mm³
· Non-stop operation during filter change
· Optimized recoating strategy shortens coating time

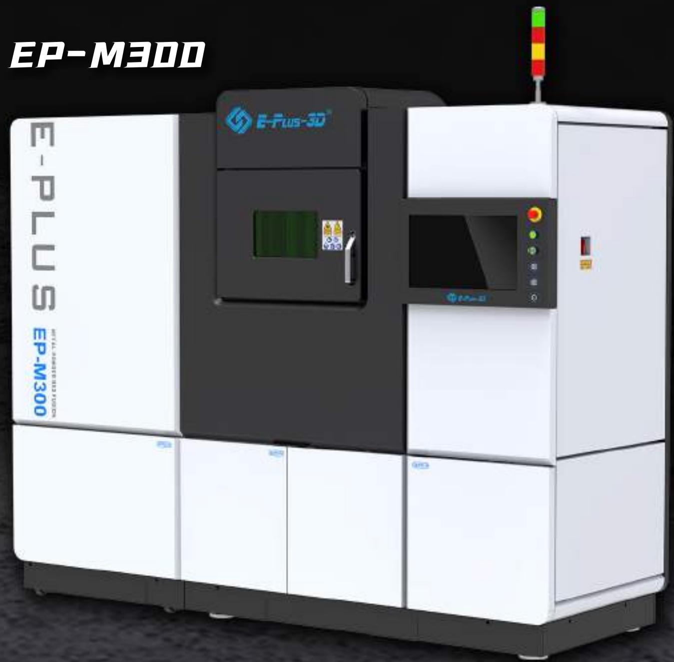
LOW OPERATION COST

· Quantitative powder feeding and coating ensure less powder waste
· Advanced filtration system significant increases filter lifetime
· Low inert gas consumption during purging and operation

EP-M300







Eplus 3D www.eplus3d.com info@eplus3d.com

Nikon to acquire majority ownership of Morf3D

Morf3D expanded its range of AM machines earlier this year (Courtesy 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 defense 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

Vulcan Technology launches new version of VM120 PBF-LB AM machine

Vulcan Technology, a metal Additive Manufacturing company that offers Laser Beam Powder Bed Fusion (PBF-LB) solutions, has launched a new version of its successful VM120 metal AM machine.

The VM120 is a compact Laser Metal Additive Manufacturing machine developed mainly for the dental market, explains Vulcan Technology. It has a small footprint of 70 x 85 cm and enables a building platform of 120 x 120 x 100 mm (X x Y x Z).

Since 1999, Vulcan Technology has developed and produced PBF-LB Additive Manufacturing machines and completed the development of its first commercial one, the VM120 in 2019. The VM120 has reportedly sold rapidly since its launch, with many being utilised successfully in dental laboratories.

Cenk Sinirlioglu, Vulcan Technology, stated, "For longer than a year, many VM120 machines are working day and night, many times in a single day for our happy customers. Vulcan Technology develops its own electronics, embedded programs, user interface and CAM software for this technology. New Vulcan Technology machine models will also come on the market soon."

www.vulcan-3d.com

Vulcan Technology has launched a new version of its VM120 metal AM machine (Courtesy Vulcan Technology)

3D Metalforge starts trading on the Australian Securities Exchange

Metal Additive Manufacturing provider 3D Metalforge, with offices in Singapore, USA and Australia, has commenced trading on the Australian Securities Exchange (ASX) following an Initial Public Offering (IPO). The company raised AUD$10 million before costs, with strong support received from investors.

A total of 50,000,000 fully paid ordinary shares at $0.20 per share were issued under the IPO and 3D Metalforge listed with an initial market capitalisation of $38 million. Alto Capital acted as Lead Manager to the IPO.

Funds from the IPO will be directed towards revenue growth-initiatives, which include increasing production capacity at the company's Singapore facility, and opening a new production centre in Houston, USA. Following the ASX listing, 3D Metalforge also plans to upgrade its Perth office and pursue opportunities in the Australian energy, resources, industrial and defence sectors.

Founded in 2015, 3D Metalforge uses proprietary technology and processes to offer a full range of in-house Additive Manufacturing services from design and engineering, material advisory, diagnostics and testing to building and post production.

A part is said to be additively manufactured every eight minutes in the company's Singaporean facility, supporting a growing blue chip client base across the energy, maritime, defence and manufacturing sectors. 3D Metalforge has already generated revenue of AUD$1.3 million in 2019, providing a strong underlying commercial foundation for the business, with the scope to scale growth.

Matthew Waterhouse, 3D Metalforge CEO, commented, "We are excited about becoming a listed company and welcome our new shareholders and thank them for the high level of interest and support. We now have a robust capital base to execute our expansion plans and are listing at a time when strong industry tailwinds are driving growth and innovation across the Additive Manufacturing sector."

www.3dmetalforge.com

Hybrid Manufacturing Technologies introduces AM subsidiary

Hybrid Manufacturing Technologies (HMT), Moira, Leicestershire, UK, has opened a new subsidiary, Hybrid Advanced Manufacturing (Hybrid AM). Hybrid AM now offers Manufacturing-as-a-Service (MaaS) using HMT's expertise and equipment.

For over eight years, HMT has been working towards the transitioning of hybrid systems into commercial realities. Despite industry disruption caused by the coronavirus (COVID-19), HMT was able to double the size of its facilities. This expansion houses the new AM division, headed by Peter-Jon Solomon, MSc, CEng. The division hosts capabilities for laser metal deposition as well as polymer & composite extrusion additive, integrated with subtractive, and inspection.

"We understand that many would like access to our technology, but do not yet have enough demand to purchase their own system," stated Dr Jason Jones, CEO & co-founder. "This new division furthers our mission to enable wider access to hybrid technology. Our integrated approach to digital manufacturing drives untapped value for customer applications not practical with other approaches."

www.hybridmanutech.com
www.hybrid-am.com

ITS Bilbao receives Nadcap accreditation for heat treating

Isostatic Toll Services Bilbao SL (ITS Bilbao), Spain, recently received Nadcap accreditation for its heat treating services. Nadcap provides independent certification for manufacturing processes for the aerospace industry. With over fifty subscribers among the most relevant OEMs, the Nadcap accreditation is seen as the reference in developing industry-wide audit criteria for special processes and products, and the cornerstone in quality supply surveillance and risk mitigation activity in the industry.

ITS Bilbao, sister company of Isostatic Toll Services (ITS), Olive Branch, Mississippi, USA, is equipped with an AIP52 HIP unit, with a hot zone diameter of 1100 mm and depth of 2500 mm at 103 MPa. The AIP52 is capable of processing large components, such as engine blades, vanes and integral rings used in the aviation industry. The investment for a second identical unit in Bilbao is said to have already been confirmed and will be in operation by October 2021.

"It is indeed a remarkable achievement to directly meet the stringent requirements of Nadcap accreditation, whose credit is shared among all the people that with passion and competence made this possible; the US sister company, the manufacturer of the HIP unit, the customers, our specialised consultants, and our key people on-site. One word among many: Teamwork," Fernando del Val, Plant Manager in ITS Bilbao, stated.

In addition to its Nadcap and ISO 9100 achievements, ITS Bilbao has received special approval from Rolls Royce, ITP, Safran, and Pratt & Whitney. Honeywell Aerospace's approval process is said to be currently ongoing. The AIP52 unit can currently HIP parts in aluminium, titanium, and nickel alloys up to 1250°C.

www.isostatictollservices.com
www.isostatictollservices.eu

ECM Group launches ECM Lab Solutions

The ECM Group, headquartered in Grenoble, France, has launched ECM Lab Solutions, a laboratory furnace division dedicated to offering solutions to laboratories and research centres.

ECM Lab Solutions gathers all products from the ECM Group that are designed and adapted to research and development for four main fields, which include metallurgy & heat treatment, crystal growth, semiconductor and renewable energies.

The group states that its laboratory furnaces are the perfect tools to work on samples up to small-scale production. The systems are based on its industrial technology and equipment from ECM Technologies, ECM Greentech, Semco and Cyberstar.

www.ecmlabsolutions.com

ValCUN raises €1.5 million to further develop its novel AM technology

ValCUN, a developer of a novel metal Additive Manufacturing process based in Ghent, Belgium, has raised €1.5 million in capital to further develop its patented technology. In contrast to many existing AM technologies, ValCUN is reported to not use lasers or metal powder in its process. The company explains that a more efficient heat input results in considerable energy savings, adding that shape requirements for the filler material are non-existent. As a result, wire, granulates, residual flows, and even recycled metal or previously-additively manufactured parts are suitable as raw material.

Through its innovative process, the startup aims at making metal AM economically competitive for all sectors of the manufacturing industry. The patent application for the technology – approved late 2020 – and the demonstration parts it has produced are reported to have convinced the investors.

"ValCUN has touched me with its passion, people and technology: a team with ambition and a drive for innovation, and a potentially ground breaking metal 3D print technology," stated Piet D'Haeyer, a private investor in the company. Other investors so far are reported to include government support agencies PMV and VLAIO in Flanders, as well as various business angels.

The team at ValCUN has developed a unique metal AM process (Courtesy ValCUN)

"The COVID-19 pandemic made it challenging to raise capital, but the approval for additional financing will allow us to further expand our activities," added Jonas Galle, CEO and co-founder.

ValCUN already has several pilot projects in the pipeline. The company's prototype AM machine is to be fine-tuned to meet the specific needs of target applications, such as heat exchangers – crucial for battery developments – and other near-net-shape products. The aim of which is to put ValCUN in prime position as a supplier for the growing electric vehicles market.

The increasing need for higher energy density and performance has a major impact on the need for cooling of components. The company has also identified the potential in IT infrastructure, where there is a growing need for heat exchangers for data centres.

"We didn't take the easy road, developing a new technology and new hardware simultaneously – a combination that many investors are opposed to," commented Jan de Pauw, co-founder. "We are steadily pursuing our sky-high ambitions by thinking globally and we see potential at renowned companies such as Google and Tesla. From the outset, we have positioned ourselves as an international company. To implement this vision, we are currently looking for business/customer development and engineering talents."

www.valcun.be

Dr Chloe Cunningham joins Fehrmann Alloys team to advance its alloy development

Fehrmann Alloys GmbH & Co KG, Hamburg, Germany, recently welcomed Dr Chloe Cunningham to its team as a Materials and Process Engineer, in order to advance its alloy development. Dr Cunningham brings with her a PhD in Additive Manufacturing and a Masters in Mechanical Engineering with Manufacturing and Management from the UK's University of Bath. She has previously worked for Renishaw, amongst other AM companies.

Fehrmann Alloys is a joint venture of Fehrmann GmbH, a leading developer of high-performance aluminium and the Hamburg-based trading firm Cremer. The venture is involved in the development of new high-performance alloys, global distribution of standard powders and data science for customer-individualised Additive Manufacturing materials.

As part of her role, Dr Cunningham will provide international Fehrmann customers with technical support and sales. The position also includes market development in cooperation AM machine manufacturers and powder suppliers. "I want to be part of the revolution in the materials landscape for metal 3D printing," added Dr Cunningham.

www.alloys.tech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Sintavia publishes guide to powder condensate disposal procedures

Sintavia, LLC, Hollywood, Florida, USA, has published an overview of handling procedures for powder condensate waste generated as part of the Powder Bed Fusion (PBF) Additive Manufacturing process. The article, 'Overview of Disposal Procedures for Powder Condensate' was written by Ashley Wallace, Sintavia's Quality & EHS Engineer, in collaboration with the Additive Manufacturer Green Trade Association (AMGTA) and Triumvirate Environmental, a provider of enterprise waste management and environmental services.

Powder condensate is the term used to describe solidified particles which result from the evaporation of metal alloys during the PBF process. This condensate, a waste stream unique to AM, is either deposited into a collection chamber within the AM machine ('dry' condensate) or wet-vacuumed out of the chamber ('wet' condensate, along with the melt spatter removed at the same time). Both of these forms of condensate may be hazardous and must be disposed of in line with applicable environmental regulations.

As metal AM has only recently entered its maturity with regards to production, powder condensate as a waste stream was previously neither a major concern for operators nor widely studied. However, as the production volumes increase industry-wide, manufacturers must allocate increasing resources for the safe disposal of the material. In order to do so, powder condensate should be classed as a separate waste stream and appropriately documented with cost-effective disposal methods.

According to Wallace, "Knowing where each condensate stream is going is just as important as the proper preparation of each type of waste. As Sintavia has grown, we have recognised that proper disposal of all of our waste streams must be a priority. We have worked with Triumvirate Environmental and other experts within the industry to manage the final disposal of these streams according to regulatory requirements."

"We were pleased to work with the Additive Manufacturer Green Trade Association and Triumvirate Environmental on this paper," added Brian Neff, Sintavia's CEO. "By sharing what we've learned with other industry stakeholders, we hope these published guidelines can help other Powder Bed Fusion AM manufacturers as they develop their own process to determine the safe and proper handling and disposal of powder condensate."

www.sintavia.com
www.amgta.org
www.triumvirate.com

Formnext 2021 to take place with in-person and digital elements

Formnext organiser Mesago Messe Frankfurt GmbH reports that, following a year in which trade fairs globally went almost entirely digital, Formnext 2021 will include both in-person as well as digital elements in a hybrid concept. The in-person event will take place in Frankfurt, Germany, from November 16–19, and the digital event will run from November 30–December 1, 2021.

In planning its hybrid concept for the upcoming trade fair, the organiser is said to be building on the experience it gathered holding the digital Formnext Connect 2020 event last year. To offer a counterpart to the in-person event for the very first time, the Formnext Digital Days are being planned to run two weeks later for those who cannot attend in person. Hosted alongside the trade fair will be a conference organised by content partner TCT, which will also have a digital component.

"The feedback we've received from exhibitors, attendees, and the exhibitor advisory board has made it clear that a genuine in-person event is essential to this industry. Everyone is longing to visit some real booths and have some face-to-face conversations," stated Sascha F Wenzler, vice president of Formnext at Mesago Messe Frankfurt GmbH. "Digital elements can definitely complement Formnext, but they'll never replace the real thing. Like in years past, Formnext 2021 is scheduled to take place at the state-of-the-art facilities on the western premises of Messe Frankfurt."

In order to provide Formnext's exhibitors with as much flexibility as possible in their planning, both the related deadlines and the event's general terms and conditions have been adjusted. It was stated that exhibitors can, for example, cancel their bookings free of charge until the end of June. In light of the current situation, Formnext 2021 is also offering modified, turnkey booth concepts that are said to make planning an entire trade-fair appearance a simple affair without any major additional effort.

"An array of highly innovative companies from the various sectors of this industry can't wait to present their latest developments to our audience in person," added Wenzler. "In this way, Formnext can also aid the economic recovery of a lot of areas by serving as a catalyst of innovation."

"We're hoping that these two days provide an intriguing digital platform, especially for attendees and exhibitors who can't make it to Frankfurt in November due to travel restrictions," Wenzler concluded.

Further information is available via the event's website.

www.formnext.com

Holo introduces PureForm technology for metal AM

Holo, a volume production Additive Manufacturing company based in Newark, California, USA, has launched its PureForm™ metal AM platform, ramping up production capacity to manufacture thousands of parts per month from its newly opened facility in the Bay Area. The company's sinter-based AM platform is based on the Vat Photopolymerisation (VPP) process.

"Most companies developing additive technology are focused on selling their printers," stated Hal Zarem, CEO at Holo. "We are lowering the barriers to adoption by offering additively manufactured parts to our customers and addressing the largest sector of the AM market with finished parts."

PureForm is a Vat Photopolymerisation-based technology (Courtesy Holo)

PureForm uses a patented polymer binder compatible with a wide variety of materials, including metals and ceramics. Combined with what is described as a proven back-end processes based on Metal Injection Moulding (MIM) technology, the platform provides scalable production tailored for high-volume manufacturing.

The company's first commercial material is reported to be pure copper. At over $170 billion, copper is the third largest material market in the world – a material widely used for its electrical and thermal conductivity properties. Although processing copper is challenging for certain metal Additive Manufacturing technologies, Holo has developed a 99.9% pure copper material that retains the bulk conductivity properties of copper.

The ability to process this material has enabled the company to focus on developing cooling solutions for the rapidly growing high-performance computer market, electric vehicles (inverters and e-motors), complex three-dimensional electrical interconnects, RF antennae and heat exchangers. Holo is now sampling stainless steels to customers, opening up applications across a gamut of industries, from aerospace to medical.

"The challenge today with metal 3D printing is that the technologies are either too expensive and unable to scale for production, or low resolution, which limit applications," added Arian Aghababaie, co-founder and Chief Strategy Officer at Holo. "Holo's PureForm technology enables us to produce high-resolution components directly for our customers, at a fraction of the cost of existing AM technologies and in production volumes."

Holo is quickly ramping up volume and has begun supplying parts from its 1850 m² production facility in Silicon Valley, where it is said to have the capacity to produce tens of thousands of parts per month.

www.holoam.com

Consortium formed to further Wire Arc Additive Manufacturing in industry

Seven specialist organisations have come together, supported by £1.2 million in funding from Innovate UK, to launch High Productivity Wire Arc Additive Manufacturing (HPWAAM), an academic-industrial partner project. The business-led, commercially-focused project will commence using seminal research carried out by Cranfield University as a basis to develop a novel solution for the UK's industrial sector. The project will focus on supporting an ecosystem for the widespread adoption of AM technologies in industries such as construction and resources.

"This project is an exciting opportunity to focus on the distinct research capabilities of our partners, towards developing an economically feasible way of printing large scale, complex designs at entirely new speeds," commented a spokesperson for the consortium. "The critical funding provided by Innovate UK reflects the credibility of the project as well as our ambition to create future value for our partners and the wider UK economy."

"3D printing has proven numerous benefits over traditional processes in terms of speed, design, sustainability and cost. This research will explore the next generation of solutions that High Productivity Wire Arc Additive Manufacturing can unlock. We are grateful for the full support of all our partners as we embark on the next chapter of Additive Manufacturing."

The organisations committed to HPWAAM are:

- BOC, Guildford, Surrey: industrial gas provider and member of the Linde Group
- Cranfield University: post-graduate university
- Foster + Partners, London: international design studio
- Steelo, London: lean manufacturer of construction systems
- WAAM3D, Milton Keynes, Buckinghamshire: a spin-off company of Cranfield University
- Weir Group, Glasgow, Scotland: global mining equipment engineer
- Wintwire, Sheffield, South Yorkshire: specialist SME wire manufacturer

www.waam3d.com

ExOne launches office-based metal AM system in Rapidia partnership

The ExOne Company, North Huntingdon, Pennsylvania, USA, has announced the launch of the ExOne Metal Designlab Additive Manufacturing machine and the X1F advanced furnace in an exclusive partnership with Rapidia, a Vancouver, Canada-based technology company. Deliveries of the new office-safe metal AM machine and furnace are expected to begin in Q2 2021.

Rapidia's two-step AM technology, developed over several years and first revealed in 2019, sees water-bound metal and ceramic parts go directly from the build stage into a furnace, without a debinding step. The process is made possible by HydroFuse, a water-based paste containing metal or ceramic powders, which does not require debinding before final sintering.

HydroFuse paste replaces 98% of the typical binder used in similar Material Extrusion (MEX) AM processes with water, which evaporates while printing. According to ExOne, the Metal Designlab can produce 100% solid metal of any thickness, delivering maximum-strength parts suitable for a wide variety of demanding pre-production and end-use applications.

Under terms of this strategic partnership, ExOne has right of first refusal for majority ownership of Rapidia, founded by Dan Gelbart, who will also become a technology advisor to ExOne. Gelbart is an electrical engineer who co-founded companies such as Creo, Inc, a laser technology company sold in 2005 to Kodak for $1 billion, and Kardium, a medical device company. He has 135 US patents for inventions ranging from package tracking technology to atrial fibrillation treatment. His popular YouTube series on prototyping is used for instruction by several universities.

"We are delighted to partner with the visionary Dan Gelbart and the Rapidia technology team to offer the new ExOne Metal Designlab and X1F furnace," stated John Hartner, ExOne's CEO. "This technology is a true time-saving innovation that complements ExOne's portfolio. Now, researchers, educators, and industrial designers will be able to bypass days of waiting and produce high-quality parts without the limitations faced by parts that require traditional debinding."

The ExOne and Rapidia teams are reported to be collaborating on system and process enhancements, with more innovations expected. Two materials are currently offered: 17-4PH and 316L stainless steels, with other metals and ceramics to follow soon.

"We set out to develop a simple, environmentally-friendly system that creates the toughest, most intricate parts overnight," added Gelbart. "Today, we're excited to leverage ExOne's global marketing and sales team to help customers around the world enjoy the benefits of our revolutionary technology. I also expect a lot of innovation to come from combining the deep technical knowledge of both companies. Now, users can 3D print complex parts today without any thickness limitations for solid parts and produce high-strength parts overnight."

The new X1F furnace, with around 10 litres of usable volume, will also be offered across ExOne's Binder Jet lineup, where it is seen as a complement to the Innovent+ and InnoventPro 3L or 5L printers.

www.exone.com

The ExOne Metal Designlab is a two-step process, where water-bound metal parts go directly from the build stage to the furnace without a debinding step (Courtesy ExOne)

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Based on our 60 years' expertise in manufacturing and development of refractory metals, we have developed **AMtrinsic®** Atomized Tantalum and Niobium Spherical Powders and their alloys for demanding Additive Manufacturing Technologies. Our ability to adjust specific intrinsic material properties enables us to push the limits according to the requirements of your application.

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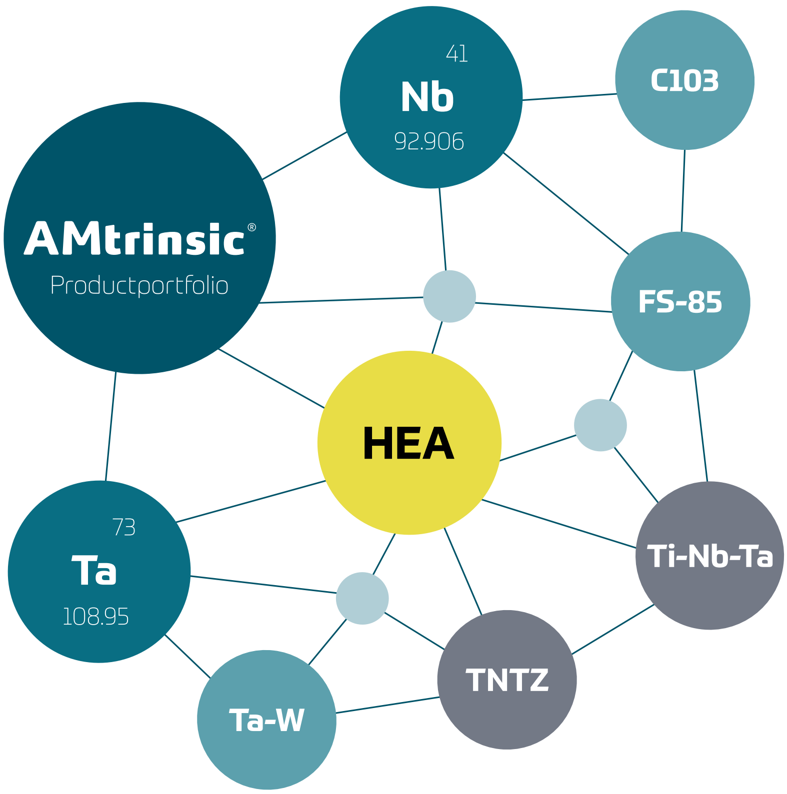

With the **AMtrinsic®** biomedical material portfolio, including pure Ta, Ti-Nb-Ta and Ti-Nb-Ta-Zr, we are setting new standards regarding elasticity, strength, ductility and superior biocompatibility for medical implant applications.

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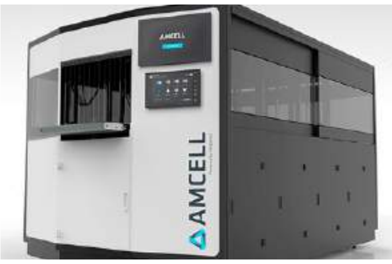
Triditive closes $1.8 million seed funding round for industrial automated AM

Triditive, Gijón, Spain, has completed a $1.8 million series seed investment round, which will be used to provide automated Additive Manufacturing machines in order to accelerate and support creating the factory of the future with the AM industry at its heart.



Triditive's AMCell AM machine (Courtesy Triditive)

The company provides advanced robotics powered by machine learning, bringing AM to the production floor and, due to its mass production and metal-polymer AM capacity, the cost of scaling production is reduced.

The seed round was supported by new investors and industry leaders: Stanley Ventures (Stanley Black & Decker), Techstars, Hunosa empresas, Fourth Funding, IDEPA, and a selected group of 'business angels' from Spain, France and Switzerland.

"We are delighted to welcome our new investors and thankful to our existing shareholders for their continued support," stated Mariel Diaz, CEO at Triditive. "This funding validates our approach to industrialise Additive Manufacturing through automation and enables us to expand our market presence."

Sean Wright, Stanley Ventures Managing Director, commented, "We see tremendous growth potential in the Additive Manufacturing industry. Triditive demonstrated its ability to innovate and create a novel product. We look forward to working with the team to extend our impact in the Additive Manufacturing industry."

www.triditive.com

Rusal America partners with Mexican manufacturer Almexa for low-carbon aluminium

Rusal America Corporation (RAC), Rye Brook, New York, has announced its entrance into a five-year partnership with Almexa, a Mexican manufacturer of aluminium products, for a 100,000 ton low-carbon primary aluminium slab contract. This deal is said to underscore the growing determination among manufacturers to source materials sustainably. To date, RAC has delivered 4,800 metric tons of green aluminium slabs under its ultra-law-carbon brand, ALLOW.

As well as its more traditional aluminium offerings, 2021 has seen RAC expanding into aluminium powders for metal Additive Manufacturing applications. The powders, atomised from its ALLOW feedstock, reportedly have a carbon footprint 75% lower than the global average.

"With the growing demand for sustainable products, companies are sourcing materials that reduce the carbon footprint of their products across the entire value chain," stated Brian Hesse, president and CEO of Rusal America. "Lightweight, durable and infinitely recyclable, aluminium is the metal of the future low-carbon economy. We are proud to partner with Almexa, a company that shares our commitment to doing the right thing, and collaborating in a true partnership that will deliver innovation, value and efficiency to its customer end-users."

The En+ Group, RAC's parent company, is the largest producer of aluminium outside of China and the second largest supplier of a vital industrial commodity for North American manufacturers, supplying over 300,00 tons of environmentally-friendly, low-carbon aluminium to the US economy. This is largely facilitated by the group's hydropower resource which generates 16 GW of power – for comparison, the Hoover Dam in Nevada generates 2 GW.

The contract will provide Almexa slabs to feed its plant in Mexico City, positioning the company as one of the greenest and most cost-competitive mills in North America. Rusal America's low-carbon aluminium helps North American companies minimise environmental risks across the supply chain and reduce their overall carbon footprint.

"Our partnership with Rusal America has been the cornerstone of our new company growth strategy," commented Mike Otero, CEO of Almexa and a member of the Aluminum Association Board of Directors. "Rusal America has helped Almexa at every step of the process – from our initial conversations, to coordinating the first loads of slab hitting the port of Veracruz, Mexico in record time. Our experience with Rusal America has been amazing from not only the product perspective, but also the delivery and technical follow-up. Almexa is proud to call Rusal America a business partner and we look forward to growing with them as we triple our output over the next twenty-four months."

The company has also announced its goal of achieving net-zero greenhouse gas (GHG) emissions across all global operations by 2050. It plans to achieve a 35% reduction in GHG emissions by 2030, said to be the most ambitious carbon reduction targets yet seen in the global aluminium industry.

www.almexa.com.mx
www.rusalamerica.com

3D Systems announces expansion plans at South Carolina HQ

3D Systems has revealed expansion plans for its Rock Hill, South Carolina, USA, headquarters, adding some 9,300 m^2 to its existing campus and enabling the company to consolidate its materials manufacturing, quality and logistics operations with new and expanded materials development laboratories. The additional capacity is expected to improve operational efficiencies, accelerate solution development and reduce time to market.

The company will also expand its customer collaboration and training facilities and its advanced manufacturing capabilities for both metal and polymer components. These capabilities are said to be critical to accelerating the move from proof-of-concept to industrial production. The additional customer collaboration space will provide an enhanced environment for 3D Systems' application engineers to help customers address their unique market needs.

Advanced materials enable the design and manufacture of parts for a variety of applications including medical implants, orthodontics, aerospace, motorsports and appliances. The company's materials innovation is driven by the desire to meet new application challenges presented by its customers, and as part of the expansion, investment is planned in new laboratories to foster this activity.

"While 3D Systems is a global company, our headquarters in South Carolina has been its centre for many years," stated Dr Jeffrey Graves, president and CEO, 3D Systems. "This expansion of our Rock Hill campus allows us to bring together key elements of the business to gain efficiencies, and to accelerate innovation and customer adoption of Additive Manufacturing on an industrial scale."

"Through our restructuring and investment activities, we will bring new jobs to the area over the next five years which will contribute to the economic development of Rock Hill and South Carolina," Graves continued. The combination of state-of-the-art facilities; renowned hardware, materials, and software and our leadership in application knowledge will be a catalyst for us to take our innovation to new heights – providing Additive Manufacturing solutions for specific, high-value applications in growing markets."

The activity is part of the company's restructuring and organisation plans announced last year and it is expected the expansion will be completed in early 2022.

www.3dsystems.com

ExOne launches online cost estimation tool

The ExOne Company, North Huntingdon, Pennsylvania, USA, has launched a new online estimation tool for companies considering moving production of metal parts to high-speed binder jet (BJT) Additive Manufacturing.

The ExOne Production Metal Cost Calculator is designed to provide manufacturers with a per-part estimate for Binder Jetting a precision metal part so they can quickly compare the technology to other forms of traditional and Additive Manufacturing.

The company explains that the new tool requires a few easy inputs – material, machine, part dimensions and volume – and is based on the purchase of any one of its four Pro series AM machines.

"As customers compare new Binder Jetting options in the marketplace, we wanted to provide greater transparency into the affordable costs of Binder Jetting with ExOne technology," stated John Hartner, ExOne's CEO. "Our new estimating tool takes a comprehensive range of costs into account, such as initial capital investment, throughput speeds, material, binder, replacement printheads, and more. Our team is confident that our high-speed systems offer the best value in terms of build area, throughput, consumable costs, material flexibility, and experience."

ExOne's production-ready lineup includes:

- X1 25Pro® large metal AM machine, launched in 2019. It offers a maximum build rate of 3,600 cm^3/hr
- X1 160Pro™ extra-large metal AM machine with a maximum build speed of 10,000 cm^3/hr, which is in production at ExOne's German facility and shipping to customers soon.
- InnoventPro™, which comes to market in late 2021 with a 3- or 5-litre build volume and is a faster version of thme Innovent+®.

ExOne's complete family of Pro series AM machines are capable of Additively Manufacturing more than twenty materials, including eleven single-alloy metals, five composite metals and four ceramics. Usable metals include 17-4PH, 316L, 304L, cobalt chrome, copper, H13 tool steel, Inconel 718, Inconel 625, M2 tool steel, titanium, and tungsten heavy alloy.

Aluminium, which is already qualified for R&D use on ExOne AM machines, has been fast-tracked for ExOne's highest third-party qualification status, explains the company, which indicates general market readiness. ExOne's first aluminium alloys are expected to receive this status upgrade during 2021.

www.exone.com

Uniformity Labs closes $38 million Series B finance round

Additive Manufacturing company Uniformity Labs, Inc., (UL), based in Fremont, California, USA, has completed a $38.35 million Series B funding round. It was stated that the proceeds will predominantly drive the expansion of its production capability and the development of additional specialised materials. It will also fuel the growth of the senior team, particularly in the sales and marketing function – a process that will ramp up substantially over the course of 2021.

"This marks a significant milestone in our next phase of growth as we scale our game-changing metal feedstock and print applications businesses to greatly improve the 3D printing value proposition for major manufacturers," stated Adam Hopkins, founder and CEO of Uniformity Labs. "What's important about this round is the level of commitment from new financial and strategic industry investors, which stands as an important endorsement of our technology and business model."

Uniformity Labs completed a recent $38.35 million funding round (Courtesy Uniformity Labs)

The Series B funding round included existing investors as well as new financial and strategic investors.

Michael Burychka, CEO of IP Group, Inc., commented, "As its founding investor, IP Group is excited to see Uniformity Labs poised to disrupt the AM market. Adam Hopkins and his team have done a tremendous job developing the core technology created in Professor Sal Torquato's labs at Princeton University to unlock the potential of powder-based manufacturing. UL is an excellent example of our focus on supporting the commercial development of innovative hard science from premier research institutions like Princeton."

An investment to finance plant construction was made from a fund managed by Orion Resource Partners, a global alternative investment management firm with approximately $6.3 billion under management. Orion is one of the world's leading investors in the mining, metals processing, and metal commodity trading industries.

"Orion is pleased to make its first investment into the Additive Manufacturing and metals atomisation industries through Uniformity Labs. We look forward to supporting their growth within this rapidly evolving industry," added Oskar Lewnowski, the Chief Investment Officer of Orion Resource Partners.

Uniformity Labs develops material and software solutions to accelerate and expand global commercial/industrial Additive Manufacturing markets. Its patented technology is said to enable significant cost savings, speed, and quality improvements across all mainstream AM machines. UL states that its feedstock materials and AM build processes dramatically impact the value chain by increasing the reliability and efficiency of AM.

Armory Securities acted as exclusive financial advisor and placement agent for UL for the Series B round. Mercator Partners, an asset manager located in Princeton, New Jersey, USA, helped to arrange and close the financing.

www.uniformitylabs.com

ASM's titanium powder approved for Additive Manufacturing

Korean Additive Manufacturing group HANA AMT, Cheongju, Korea, is reported to have performed a detailed analysis of titanium powder supplied by Australia Strategic Materials (ASM), headquartered in Burswood, Australia, confirming a purity of 99.918% and its suitability for metal AM.

The test 20 kg of titanium powder was produced from a 75 kg run at ASM's metallisation pilot plant in January 2021. ASM and HANA AMT signed a non-disclosure agreement (NDA) as they progress their negotiations towards an initial 1,500 tonne-per-year off-take agreement for titanium powder.

"This independent review of ASM's titanium metal powder is a great validation of our patented metal process, confirming the high purity and the environmental benefits of the metal ASM can produce for the manufacturing sector in Korea," stated David Woodall, ASM Managing Director. "We look forward to progressing negotiations and continuing discussions with other potential off-take and strategic partners during our time in Korea."

"This is a promising start of the year, with 2021 a foundation year for ASM, as we progress our vision to become a fully integrated critical metals producer – supplying metals from the mine direct to manufacturers, through the delivery of the Dubbo Project and the establishment of our metals business," he continued.

ASM's metals business is founded on a novel metallisation process that converts oxides into high purity metals, alloys, and powders using less energy than conventional methods. The pilot plant in South Korea has proven the commercial scalability of the process and is reported to have successfully produced a range of high-purity metals and alloys, including titanium, neodymium, praseodymium, dysprosium, and zirconium.

www.asm-au.com
www.hanaamt.com

Mantle launches precision metal AM technology aimed at the tooling market

Mantle, an Additive Manufacturing startup based in San Francisco, California, USA, has launched its True-Shape™ technology, a proprietary AM process to make high-precision metal parts, similar to Material Extrusion (MEX) AM processes. Having previously secured an unannounced $13 million investment by Foundation Capital, Hypertherm Ventures, Future Shape, 11.2 capital, Plug and Play Ventures, and Corazon Capital, the company has developed what it believes is the most precise and efficient metal AM technology for the tooling market.

Historically, product development cycles have been gated by tooling, since manufacturing companies cannot launch new products until the exact moulds and dies to produce them are created. These tools are made from high-hardness steel through a multi-step process that includes programming, cutting, and finishing the tools. This intensive process takes months and can cost tens to hundreds of thousands of dollars. Mantle's process takes just days, which allows companies to deploy new tools within a few weeks while cutting costs by at least half.

The AM industry has pursued the tooling market for many years. The sector requires precision, as a tool that is too big or too small by just half the width of a human hair can be the difference between a product that works and one that does not, Mantle explains.

"Manufacturers require proven part quality and performance. By using Mantle printed tooling, they can continue to use the same high-performance thermoplastics and get parts of equivalent or superior quality in less time and at a lower cost," stated Ted Sorom, CEO and co-founder of Mantle. "We help companies speed their products to market with dramatically faster new product introductions while leveraging their proven mass production expertise."

Mantle claims that its TrueShape process is the first AM technology that can meet these requirements because it combines both Additive Manufacturing and subtractive finishing into a single hybrid process to yield superior accuracy and surface finish. The process uses unique metal pastes that produce high-hardness steels that meet or exceed the tooling industry's demanding requirements.

"Mantle's TrueShape technology delivered the dimensional tolerances and surface finish that are needed for the precision moulds we use at L'Oréal," commented Blake Soeters, Director Product Conception, L'Oreal. "We are excited because of the positive impact this technology will have on our ability to rapidly bring new products to market."

At the foundation of the TrueShape process is a line of proprietary Flowable Metal Paste (FMP) materials. FMP materials incorporate metal particles within a liquid to ensure safety and consistency during the build process. Different particle types and sizes within the paste minimise dimensional change during sintering and tailor the final metal for optimal material properties.

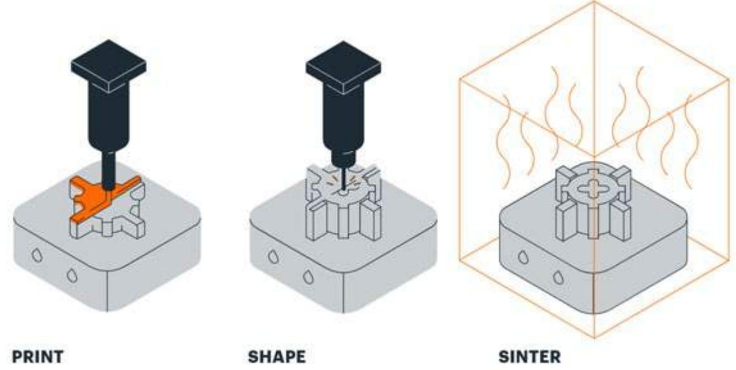
Using a Mantle tool insert, a global appliance manufacturer has already produced over 200,000 washing machine parts. The Mantle mould component cost 67% less than the cost from traditional methods and was produced in 70% less time. Similarly, a leading medical device manufacturer reduced the lead time for its tool by 80%. The built tool is reported to have performed just as well as tools made with traditional methods.

"Mantle is taking on the overlooked $45 billion tooling market that is a bottleneck for innovation because it is a slow process that has not changed significantly in seventy years," stated Steve Vassallo, General Partner at Foundation Capital. "Until Mantle, no one has been able to develop tooling tech that is disruptive in either time or cost, let alone both, which made backing Mantle an easy decision for us."

Mantle's TrueShape technology includes multiple tool steel materials, custom printing hardware, and a user-friendly software suite to deliver toolmakers a complete production-grade tooling solution. Further solutions are expected for a wide range of applications in the $300 billion precision parts market, including jigs and fixtures, low-volume industrial machinery and spare parts and high-volume part production.

"Mantle gives you the superpowers to make Apple-quality mechanical parts in days, not months, and lowers your cost by orders of magnitude," added Tony Fadell, Principal at Future Shape. "That speed and affordability lets you iterate to get your parts to perfection and still lets you launch much earlier. I wish we had these Mantle tooling breakthroughs for our Nest, iPod and iPhone projects!"

www.mantle3d.com



During the TrueShape process, tools are built, then shaped before a final sintering stage (Courtesy Mantle)

Incus Hammer Lab35 metal AM machine in production

Incus GmbH, Vienna, Austria, has begun production of its Hammer Lab35 metal Additive Manufacturing machine. The lithography-based metal manufacturing (LMM) process, defined as a Vat Photopolymerisation process (VPP) by ISO/ASTM, has been developed by Incus to offer an economic method for developing prototypes and small-scale production of components in Metal Injection Moulding (MIM) quality.

The Hammer Lab35 was launched at Formnext 2019, shipping its first series Hammer Lab35 machine in March 2020 and continuing to grow its network of customers and partners throughout 2020.

With a build speed of up to 100 cm^3/h and a lateral resolution of 35 µm, the Hammer Lab35 is designed to deliver high-quality parts. The process can also be integrated into existing MIM production lines or research and development departments as an option for small-scale production and prototyping.

Two Hammer Lab35 machines are reported to already be in operation at the Institute for Precious and Technology Metals at Pforzheim University and its spin-off company, Metshape. Within this cooperation, the process and system are reviewed and tested, and new materials and applications are being developed.

"Despite this challenging year, we had great collaborations with customers and have proven that LMM has the potential to increase performance and to reduce costs for small and mid-scale production, as well as for manufacturing parts featuring complex geometries," stated Dr Gerald Mitteramskogler, Incus CEO.

Incus has begun production of its Hammer Lab35 metal Additive Manufacturing machine (Courtesy Incus GmbH)

"Our team is extremely proud to have added 3D printing of metals with lithography to the manufacturing landscape. We highly appreciate the trust and patience of our first customers that have been helping to develop our product and our company," he continued. "We still have a journey ahead to scale up to mass-production, but we are eager to continue this path in 2021."

www.incus3d.com

Solukon expands business activities in Turkey with HASMAK-T partnership

Solukon Maschinenbau GmbH, Augsburg, Germany, has entered into a partnership with HASMAK-T, Istanbul, Turkey, in order to expand business activities in Turkey's growing Additive Manufacturing industry.

Founded in 1988, HASMAK-T serves as a consultant for tech companies to optimise and speed up their customers' production lines and manufacturing processes. It is one of the largest distribution companies in Turkey.

Solukon explains that the demand for an automated and secure depowdering process for metal additively manufactured parts is rising in the Turkish market. HASMAK-T, with Managing Partner Ufuk Bozkaya, will help Turkish companies explore the Solukon Smart Powder Recuperation® technology and find the right depowdering solution for their application in order to respond to the increasing demand of efficiency and safety in industrial Additive Manufacturing.

Michael Sattler, Global Sales Director at Solukon, stated, "The demand for repeatable and reliable cleaning results has grown a lot in the last year all over the world. By establishing HASMAK-T as our trusted partner for the Turkish market, we take the next step to ensure our position as best-in-the-industry of depowdering solutions. All the best to Ufuk Bozkaya and his team."

www.solukon.de
www.hasmak-t.com

Solukon manufactures a range of depowdering solutions for metal Additive Manufacturing (Courtesy Solukon)

Sam O'Leary to replace Meddah Hadjar as CEO of SLM Solutions

SLM Solutions Group AG, Lübeck, Germany, reports that Meddah Hadjar, the company's CEO and member of the management board, informed the supervisory board that, due to personal circumstances, he would leave the company at the end of January 2021. The supervisory board unanimously approved the appointment of Sam O'Leary as its new CEO.

O'Leary joined the company in December 2019 as COO and his deep experience in the Additive Manufacturing industry has reportedly been instrumental to SLM Solutions significantly improving its product portfolio and all its production-related processes, as well as overseeing the successful development of SLM's NXG XII 600 Laser Beam Powder Bed Fusion (PBF-LB) machine.

Meddah Hadjar (left) has not extended his contract as CEO of SLM Solutions and has been replaced by Sam O'Leary (right) (Courtesy SLM Solutions Group AG)

"Sam has played an integral part in successfully rebuilding SLM Solutions since he joined the company," stated Thomas Schweppe, chairman of the supervisory board of SLM Solutions. "He is highly trusted among employees and customers alike and, as one of the global leaders in the industry, Sam is the best person to drive SLM Solutions' growth and excellence to the next level."

In 2020, O'Leary agreed to extend his management board contract until November 2024, and, in addition to his current portfolio, he will permanently take over the responsibilities for Corporate Development, Strategy and HR.

O'Leary commented, "I'm excited to take over the leadership at such an exciting time for the company. With the changes to the organisation and key processes we have made and the additional strong talent we brought into the company over the past eighteen months, we have been able to put SLM Solutions back on a path of success. Importantly, we were able to add the industry-defining NXG XII 600 to our product portfolio. The customer response we have received since its launch has exceeded even our high expectations."

SLM Solutions states that in terms of further additions to the management team, the supervisory board has started a process to find suitable candidates for the role of a Chief Commercial Officer to take over some of Hadjar's other responsibilities permanently.

André Witt has been appointed to the management board temporarily until another member has been appointed. Witt currently serves as the company's General Counsel.

Hadjar will remain connected to SLM Solutions by becoming an advisor to the company and, based on the support of SLM Solutions' largest shareholders and subject to the nomination by the nomination committee of the supervisory board and confirmation by the shareholders' meeting, it is considered that he will join the supervisory board of SLM Solutions Group AG.

www.slm-solutions.com

3D Systems completes sale of Cimatron and GibbsCAM businesses

3D Systems Corporation, Rock Hill, South Carolina, USA, completed the previously announced sale of its Cimatron and GibbsCAM software businesses to a subsidiary of ST Acquisition Co., an affiliate of Battery Ventures, on January 1, 2021. The resulting purchase price of approximately $64.2 million, after certain adjustments and excluding $8.9 million of cash amounts, were transferred to the buyer.

"The divestiture of Cimatron and GibbsCAM, which were businesses focused on subtractive technologies, was an important step in our plans to refocus our company on our core mission: To be the leader in enabling Additive Manufacturing solutions for applications in growing markets that demand high-reliability products. These divestitures strengthened our balance sheet, enabling us to both pay off our debt and terminate the ATM Program much earlier than originally planned," stated Dr Jeffrey Graves, president and CEO of 3D Systems.

Using a portion of the proceeds from the sale, the company reportedly paid off approximately $21 million of outstanding balances under its senior secured term loan facility. With the paydown of the term loan, the company is now free of any outstanding debt, but continues to have availability under its senior secured revolving credit facility, which remains fully undrawn. The company also terminated the previously announced at-the-market equity programme (ATM Program), under which no shares of common stock were sold during the fourth quarter of 2020.

www.3dsystems.com

ROSATOM opens its first Additive Technologies Center in Russia

RusAT LLC, Moscow, Russia, an enterprise of TVEL Fuel Company and ROSATOM's integrator for Additive Manufacturing, has opened its first Additive Technologies Center (ATC) at the site of the Moscow Polymetal Plant. The ATC has been created to showcase a facility combining development, engineering and manufacturing. It is said to be unique for its combination of shop floors for Additive Manufacturing machine assembling, manufacturing and post-processing, as well as the laboratory for product research and sample testing. With this, RusAT engineers will be able to check the adopted design and technological solutions immediately after equipment launch and promptly make adjustments to its design.

The ATC is equipped with AM machines of ROSATOM's own design and production, including a Rusmelt 300M, Rusmelt 600M and Rusmelt 600 RM for metal Additive Manufacturing using the Laser Beam Powder Bed Fusion (PBF-LB) process. The Rusmelt 600M machine has a 600 x 600 mm build area and all machines feature Russian software with parameters and characteristics that meet international standards.

The second stage of the ATC facility will house machines for metal and plastic Additive Manufacturing. The range of testing and auxiliary equipment will also be expanded.

"Opening of the first Additive Technologies Center underlines the role of ROSATOM in creating a new technological paradigm in our country," stated Alexey Likhachev, Director General of ROSATOM. "This is an extraordinary milestone not just for the nuclear industry, but on a national scale, as well. There is a lot of work ahead to create a whole network of such centres, primarily in the cities and regions of Rosatom enterprises operation."

"The next such centre will be established in Novouralsk on the basis of NPO Centrotech, another enterprise of TVEL Fuel Company," he continued. "Development and application of these technologies has a great meaning for the entire nuclear industry. We have solutions for using Additive Manufacturing, from separate elements of some products to essential supplies of equipment."

Natalia Nikipelova, president of TVEL JSC, added, "By introducing additive technologies in our own business, we show an example for other industries. In fact, we are creating another new industry in Russia with its own centres, expertise, staff and linked universities."

www.rusatom-additive.ru
www.tvel.ru/en/
www.rosatom.ru/en/

Digital Metal adds pure copper to its metals range

Digital Metal, part of Sweden's Höganäs group and a global supplier of high-precision metal Binder Jetting (BJT) Additive Manufacturing machines for industrial use has added pure copper, DM Cu, to its material offering.

The excellent thermal and electrical conductivity of pure copper make it perfect for a wide range of applications, from electronics to heat exchangers, heat sinks and engine parts. Additively manufacturing parts in copper also offers a new freedom for designers, allowing optimal functionality with few restrictions. Copper is also known for being antibacterial.

For its customers, Digital Metal believes it will see the benefit of additively manufacturing with 99.9% pure copper versus more traditional copper alloys used in laser-based machines.

"Printing with pure copper using Digital Metal's Binder Jetting technology is one of the most anticipated material launches ever, and totally new within Binder Jetting. Copper has been high up on our customers' wish list and timing is perfect with the demand for copper applications soaring in fast growth areas such as e-mobility and heat conductivity," stated Christian Lönne, CEO.

"We have been developing the process for some time internally, but I would really like to emphasise the value of the excellent cooperation with key customers in our fast-growing Digital Metal User Group," he continued. "It has been a great help and we are now very pleased to deliver a high-quality copper process for Digital Metal Binder Jetting."

Pure copper bullhorn antenna built using Digital Metal's BJT machine (Courtesy Digital Metal)

DM Cu pure copper is the latest addition to Digital Metal's BJT machine, other materials featured in the company's range include stainless steel 316L and 17-4PH, tool steel DM D2, superalloys DM 625 (equivalent to Inconel 625) and DM 247 (equivalent to MAR M247) and titanium Ti6Al4V.

www.digitalmetal.tech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www.materials-solutions.com

Desktop Metal launches Desktop Health for patient-specific AM applications

Michael Jafar has been appointed as president and CEO of Desktop Health (Courtesy Desktop Metal)

Desktop Metal, Inc, Burlington, Massachusetts, USA, has launched Desktop Health™, a new business line focused on accelerating the growth of Additive Manufacturing solutions for dental, orthodontic and otolaryngology applications, based in Newport Beach, California, USA.

Desktop Metal states that the combination of new AM technologies, including bioprinting, high-speed metal Binder Jetting, and the use of advanced biocompatible materials across polymers, ceramics and metals, puts Desktop Health in a strong position to develop advanced healthcare applications.

"Today the world manufactures more than $85 billion in medical and dental implants each year," commented Ric Fulop, CEO and co-founder of Desktop Metal. "We think a large percentage of these parts could be printed and made patient-specific before the end of the decade, making this market a key opportunity for Desktop Metal. We look forward to building a best-in-class team to work with our industry partners to bring patient-specific solutions to the market at scale."

To lead the new business initiative, Desktop Metal has appointed healthcare executive Michael Mazen Jafar as president and CEO of Desktop Health. Jafar brings nearly twenty years of experience creating and scaling breakthrough healthcare products.

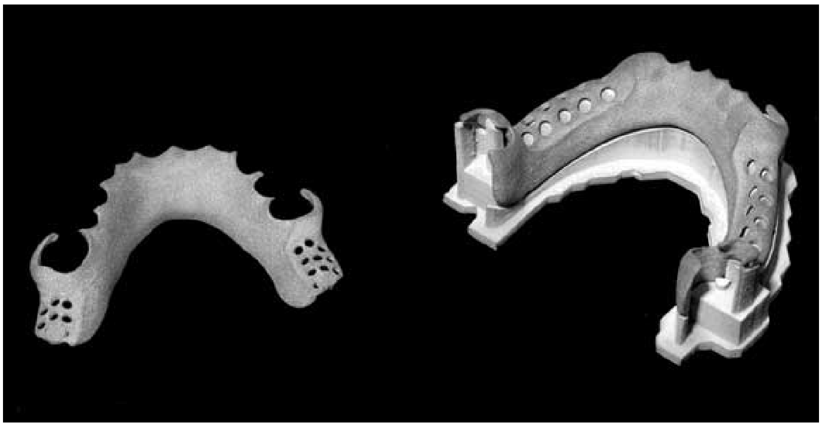
Jafar most recently served as Chief Commercial Officer of Evolus, a performance beauty company, where he oversaw the launch of its flagship product, Jeuveau®. For sixteen years, Jafar also led the ophthalmology and medical aesthetics division for Allergan, culminating as VP Marketing, U.S. Medical Aesthetics, and working on several of the company's marquee brands, including Botox® Cosmetic, JUVEDERM® Collection and CoolSculpting®.

"I am excited to join Desktop Metal at such an important time in medical technology," Jafar stated. "I want to build on years of the company's research and development to bring its core technology and advanced materials to many healthcare specialities. Desktop Health has a mission to change the way patients experience personalized healthcare, through innovation and science-based solutions."

Backed by twenty years of research, more than 1,400 published papers and 3D Bioplotter & Digital Light Processing (DLP) technology, coupled with high-speed metal Binder Jetting Additive Manufacturing solutions, Desktop Health plans to leverage proven technology to create patient-specific solutions in the medical field.

"It's a true privilege to work with leading technology alongside physicians, surgeons and dentists to advance personal care," added Jafar. "Our technology is widely used for customised in-office digital dentistry, makes customised metal implants possible, and has enabled exploration of applications such as bone regeneration, cartilage regeneration, and soft tissue biofabrication. We look forward to building on our success and ingenuity as we research extensions of our core technology across cardiology, orthopaedics, ophthalmology, dermatology and plastic surgery."

www.desktopmetal.com
www.desktophealth.com



Desktop Metal has launched new business line, Desktop Health which will offer AM solutions for dental applications. Technologies will include high-speed metal Binder Jetting for high-resolution, customised medical and dental applications (Courtesy Desktop Metal)

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Intech Additive Solutions expands its range of large-format metal AM machines

Intech Additive Solutions Pvt. Ltd., Bangalore, India, has announced the expansion of its range of metal Additive Manufacturing machines with the launch of the iFusion LF series, the company's large-format range of metal AM machines with a high build rate for cost-effective manufacturing.

The iFusion LF series, developed and built at Intech's facility in Bangalore, has a range that starts with a single 500 W system and is upgradeable to a quad laser configuration, with 700 W and 1000 W lasers if required. The LF series of machines are said to require the lowest initial investment to procure and install, compared to other similar-sized metal AM machines, along with locally available spares and support.

The company explains that its AM machines are a result of extensive research, development and innovation over a four-year period. The iFusion LF series, integrated with Intech's software suite, have a build volume of 450 x 450 x 450 mm, and aim to deliver robustness and productivity at a competitive cost per part (CPP).

"Indian companies have a huge interest in 3D printers that build parts larger than 400 mm," stated Pradeep Nair, vice president-Hardware Sales, Intech. "All these machines must be imported and are prohibitively expensive. There are other issues like long lead times for support and spares, making Indian companies ultimately settle for the less expensive mid-sized machines. The iFusion LF series amply fills this void."

He added, "The system supports a wide range of materials like aluminium, titanium, steel, Inconel and Cobalt Chrome addressing the needs of industries such as aerospace, automotive, general engineering, tool & die and medical market segments in India and abroad."

K S Swami, Director, Poeir Jets, commented, "The 3D printed parts from the iFusion series performed exceptionally well during the testing phases and proved to be of production quality. Intech's 3D printers helped us achieve the required scale for commercialising manufacturing and ensuring lower cost per part. We are now moving to printing parts on Intech's LF series of machines. The LF's larger build envelope suits our needs to print parts for our engine and Hybrid Drones. This, coupled with the lower costs compared to imported systems, local spares and support availability among other things, make it an automatic choice for us."

"The Ministry of Electronics and Information Technology has identified Additive Manufacturing as a critical focus area," noted Sridhar Balaram, CEO of Intech. "The lovernment plans to promote various AM sector verticals including machines, materials, software, and design methodologies to leverage new and untapped business opportunities. This initiative will prepare the Indian manufacturing sector for Industry 4.0 and evolve an integrated approach towards this emerging technology."

Intech Additive Solutions has expanded its iFusion LF series of metal Additive Manufacturing machines (Courtesy Intech Additive Solutions Pvt. Ltd)

"Intech's range of metal 3D printers is indigenously designed and manufactured for both the Indian and global markets. In this regard it is 'Made in India, Built for the World' and captures the essence of the Aatmanirbhar initiative of the Indian Government. We have an excellent team in place and are confident of enhancing and growing the Indian AM ecosystem with our range of metal 3D printers, and end-to-end metal AM solutions," concluded Balaram.

www.intechadditive.com

One Click Metal releases evolution of its AM machine with the MPRINT+

One Click Metal, Tamm, Germany, has released the latest evolution of its MPRINT metal Additive Manufacturing machine with the MPRINT+, part of its BOLDSERIES. Through the introduction of a fibre laser and a Galvo scanner, the MPRINT+ reportedly allows a wider field of application and increased productivity and precision.

With a focus diameter of 45 µm and a scanning speed of up to 3000 mm/s, the end part quality is said to be improved in terms of density and surface finish, whilst reducing cost by up to 40%. The MPRINT+ is reported to be similar in price to its previous iteration, and users will benefit from any past experience they will have gained with the MPRINT, with its familiar operation resulting in improved results.

"When introducing the fibre laser into our metal 3D printer, it was important to us that we retain the great advantages of the MPRINT, but, at the same time, additionally improve the existing modules of the new MPRINT+," stated Stefan Weber, CTO and co-founder.

The MPRINT+ is available with the MPREP data preparation software and the MPURE unpacking station with integrated automatic sieving unit is currently available at €100,000. The first machines have already sold, with deliveries scheduled from Q2 2021.

www.oneclickmetal.com

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Rusal America expands line of sustainable, high-performance aluminium powders

Rusal America, Rye Brook, New York, USA, has expanded its aluminium product offerings to include a range of aluminium powders suitable for Additive Manufacturing applications.

Its new powder portfolio is comprised of four traditional Al-Si based casting alloys and five speciality alloys designed for use in the aerospace and automotive industries, as well as more broadly in general industry.

The portfolio includes 100% pre-alloyed and fully metallic powders that exclude any ceramic- or nano-inclusions. Its RS-230 grade is a heat-crack resistant Al-Cu alloy with high-strength stability up to 250°C. The RS-553 grade is a novel aerospace Al-Mg-Sc alloy, with optimised scandium content, that delivers comparable properties at a lower cost than similar Al-Sc AM alloys.

The powders are atomised from the company's ALLOW aluminium feedstock, said to have a carbon footprint 75% lower than the global industry average (smelter scope 1 & 2 emissions). All powders come with a third-party certified carbon certificate to promote transparency and accountability.

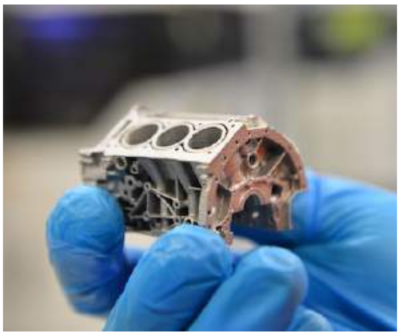
"From primary aluminium and foundry alloys to billets and wire rod, Rusal America is a trusted supplier with a reputation for delivering unmatched high-quality, low-carbon aluminium products backed by customer and technical support that is second to none," stated C Brian Hesse, president and CEO of Rusal America.

"We are excited to deliver the same to customers new and existing through our new line of innovative AM powder alloys," added Hesse.

www.rusalofamerica.com

ExOne and Ford collaborate to achieve high-speed, high-density aluminium Binder Jetting process

In a project co-funded by The ExOne Company, North Huntingdon, Pennsylvania, USA, and Ford Motor Company, a team of engineers, material scientists and manufacturing experts has developed a new patent-pending process for binder jet Additive Manufacturing and sintering of aluminium, which reportedly results in components with properties comparable to those found in die casting.



This aluminium 6061 engine block model demonstrates the high resolution and geometric control that can be produced in a new patent-pending binder jet AM process developed by ExOne and Ford Motor Company (Courtesy ExOne)

Although some aluminium alloys can be additively manufactured currently using lasers, the process developed by Ford and ExOne is reported to offer greater speed. The resulting process is expected to increase Ford's efficiency, allowing the company to affordably manufacture complex parts designed for AM, which will enable size and weight reductions, part consolidation and performance improvements.

"Developing a fast, affordable, and easy way to 3D print aluminium with traditional material properties is a critical step toward light-weighting more products and delivering a more sustainable future," stated John Hartner, CEO, ExOne. "Our world-class engineers and scientists are focused on solving the toughest problems with 3D printing technology, and this achievement is a real win for all of us."

While the Binder Jetting process for sintering stainless steels was well understood, ExOne states that achieving densities higher than 99% for aluminium represents a significant achievement for the industry.

"This is a breakthrough in making 3D printed and sintered parts for the auto industry," commented Harold Sears, Technical Leader for Additive Manufacturing, Ford. "While the 3D printing process is very different than stamping body panels, we understand the behaviour of aluminium better today, as well as its value in light weighting vehicles. High-speed aluminium 3D printing paves the way for other opportunities that we're just now starting to take a look at because of the ability to do complex parts with aluminium that previously weren't possible. It's really opening doors for other opportunities."

The relationship between ExOne and Ford dates back to the early 2000s, when Ford purchased several of ExOne's first industrial sand AM machines in the US in order to create sand moulds and cores for metal casting. The joint development process of this aluminium process began in 2019, with Ford leading the final material and repeatability testing to verify accuracy. The Ford/ExOne team is actively working on designs to further utilise the process and resulting materials.

www.exone.com
www.ford.com

Solukon launches Digital Factory Tool to bring depowdering into AM process chain

Solukon Maschinenbau GmbH, Augsburg, Germany, has launched the Solukon Digital Factory Tool, a fine-tuned sensor and interface management kit to enable its depowdering systems to fit into holistic Additive Manufacturing process chains. The company states that this launch is a crucial step towards fully integrated automation and quality assurance in AM.

Since releasing its automated depowdering system, the SFM-AT800 in 2015, Solukon has become a leader in powder removal systems. The company's Smart Powder Recuperation (SPR®) technology is used to overcome a number of potential issues with depowdering, such as the risk of explosion, occupational health, labour costs, powder recovery, cleaning quality and process repeatability.

The Solukon Digital Factory Tool reportedly now allows easy integration of automated powder removal into an overall digital AM process and includes the following features:

Production control
Since 2017, Solukon has equipped the SFM-AT800 with an OPC-UA interface to enable central controlling and monitoring. The Solukon Digital Factory Tool enables the operator to integrate all information into the dashboard of the machinery app. Data and parameters referring to cleaning programs, such as running time and batch number, can easily be assigned via the network. Regarding the cleaning process, the OPC-UA interface enables the operator to start, monitor and modify the cleaning program as desired. Machine state and process progress are accessible in real time.

Maintenance management
The new sensor system monitors all sensitive machine components and processes referring to lifetime of the machine. The operator, therefore, can immediately recognise unwanted changes in consumption of inert gas, compressed air, chamber atmosphere or energy to get an overview of the performance of the individual machine components. In addition, the system informs the operator in time, when maintenance is required or when to procure wear parts.

Integration of automation
Flagship projects like HyProCell and NextGenAm provide an outlook of

how automated AM production works, where the integration of downstream processes, in particular, are expected to play an increasingly important role. The SFM-AT800 is constantly communicating with a control centre while being loaded by a robot. For this purpose, the SFM-AT800 has been equipped with a special loading door and an automatic clamping system.

Process validation and quality management

The extended quality feature is said to be the key element of the Solukon Digital Factory Tool. Certification is a mandatory challenge for manufacturers of sensitive industries like medical or aerospace, and each step of production is supposed to be clearly reproducible. The more process data is recorded and logged, the easier the certification. The Solukon Digital Factory Tool provides a fine-tuned sensor package to record relevant conditions in the process chamber, such as residual oxygen, humidity, pressure, temperature and frequency of the vibrator, in a protocol file for quality assurance. Effective evaluation of the recorded data helps to validate the process in an overall quality certificate and simplifies process optimisation. The operator may set limits to sensible values in advance so that deviations are noticed and considered immediately and quality defects are avoided in time. Besides process data, even information referring to the cleaning program itself are recorded automatically. To create a certification document for each project, the user has the opportunity to fill out a large and individual composable input mask. The user can then collect data referring to their build job in a flexible dialogue box. This includes for example type, batch and used material. In the end, the user is provided with a final protocol as PDF, CSV or XML file to be stored centrally or printed on paper.

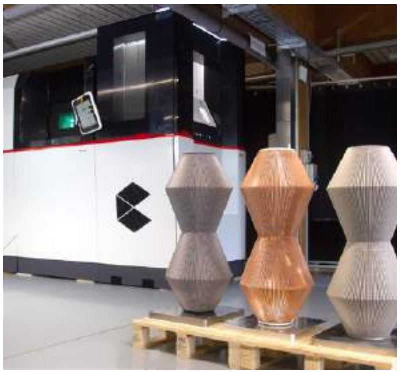
"The Solukon Digital Factory Tool marks a significant step towards automation in postprocessing and therefore towards integration into a holistic AM process chain," stated Alexander Bauer, Applications Manager at Solukon. "Especially through process validation in one comprehensive protocol, our customers achieve an even faster, more accurate and easier certification. The Solukon Digital Factory Tool is especially applicable to sensitive industries like Aerospace and Medical."

Solukon will offer the Digital Factory Tool as a new option for the SFM-AT800 and the SFM-AT1000-S. Existing SFM-AT800-S systems can also be retrofitted upon request. Solukon is currently cooperating with two leading manufacturers concerning process integration. Results of these projects will be presented soon.

www.solukon.de

Sintavia expands rocket capability with two M4K-4 AM machines from AMCM

Sintavia LLC, Hollywood, Florida, USA, has acquired two new M4K-4 metal Additive Manufacturing machines from AMCM GmbH, an EOS Group company based in Starnberg, Germany. As one of the leading AM rocket parts producers in North America, Sintavia will use the new machines to expand its portfolio of rocket thrust chamber design and manufacturing for the rapidly growing commercial space industry.



Sintavia's new M4K-4 machines from AMCM will process Cu and Ni alloys (Courtesy AMCM/Sintavia)

The M4K-4 is described as a stretched version of the EOS M400-4 machine, a Laser Beam Powder Bed Fusion (PBF-LB) machine offering more powerful lasers and an upgraded cooling system. Its four 1 kW lasers can build single-unit components with dimensions of 450 mm x 450 mm x 1 m.

"Since the acquisition of our first M400-4 three years ago, Sintavia has devoted tremendous resources to developing successful and repeatable operating procedures for the quad laser printing of extremely thin walls, such as those found in the thrust chamber of a rocket," stated Brian Neff, Sintavia's Chief Executive Officer.

"We now have eight M400-4 quad laser printers, and we expect that the successful strategies employed on the M400-4 will likewise work on these new M4K-4 units. We are pleased that we will be the first rocket printer in North America to offer the expanded footprint of the M4K-4 to our commercial space customers," added Neff.

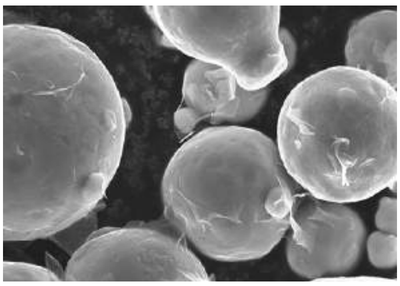
The design of the M4K-4 is said to have been driven largely by demand from commercial space launch customers looking to optimise thrust chamber assemblies with fewer traditional joining steps. For most existing commercial rocketry currently in production today, the M4K-4 is able to manufacture the entire thrust chamber assembly as a single unit, including optimised regenerative cooling passages, thereby dramatically reducing manufacturing complexity and time.

The two new machines are scheduled for delivery in June and July this year and will be set up to use high-performance copper and nickel alloys.

www.sintavia.com
www.amcm.com

Graphmatech's graphene technology increases the potential of copper AM

Researchers at Uppsala University, Sweden, in collaboration with Graphmatech, also based in Uppsala, have demonstrated a potential breakthrough in the use of copper in Laser Beam Powder Bed Fusion Additive Manufacturing (PBF-LB), said to significantly lower the reflectivity of copper powder to achieve denser AM parts.



Copper powder coated using Graphmatech's patented graphene technology (Courtesy Simon Tiden / Uppsala University)

In the Additive Manufacturing process, some metals, including pure copper, can present a challenge due to their high reflectivity. At the wavelengths commonly used in PBF-LB process, only a small part of the energy is said to be absorbed by the material, which can result in low-density parts.

To overcome the challenges in PBF-LB processing of pure copper, the researchers have identified graphene technology as a solution. "By modifying the surface of the copper powder using Graphmatech's patented graphene technology, we successfully reduced the reflectance by up to 67%," stated Dr Mamoun Taher, Graphmatech's CEO.

The graphene was also reported to survive the build process, positively affecting the density of the as-built copper-graphene parts by significantly reducing porosity.

The research is being undertaken by Professor Ulf Jansson's research group at Angstrom Laboratory, Uppsala University, with PhD student Simon Tiden having recently been awarded a poster prize at the Swedish Arena for Additive Manufacturing of Metals Conference for the work.

"The new process developed to coat metal powder with graphene opens up very interesting perspectives for the design of new materials in various applications," stated Professor Jansson.

Having already made significant advances in other graphene/metal composites and coated powders for Additive Manufacturing, Graphmatech is now actively scaling up this technology due to the potential for graphene in enhancing the processability of powders and the properties of AM parts. "This 3D printable hybrid material has the potential to add value in a range of sectors such as e-mobility, electronics and defence," Dr Taher concluded.

www.graphmatech.com

Lockheed Martin to acquire Aerojet Rocketdyne in $4.4 billion deal

Lockheed Martin Corporation, Bethesda, Maryland, USA, has entered into a definitive agreement to acquire Aerojet Rocketdyne Holdings, Inc., El Segundo, California, USA, for a total transaction value of $4.4 billion. Aerojet Rocketdyne's propulsion systems are already a key component of Lockheed Martin's supply chain and several advanced systems across its Aeronautics, Missiles and Fire Control and Space business areas.

The proposed acquisition adds substantial expertise in propulsion to Lockheed Martin's portfolio, and is said to expand on the foundation built by Lockheed Martin and Aerojet Rocketdyne over many years.

In partnership and separately, Lockheed Martin and Aerojet Rocketdyne have both utilised metal Additive Manufacturing in part development and production. Lockheed Martin was the first organisation to be certified for Additive Manufacturing safety by global safety science company UL in October 2018, and in June 2019, collaborated with Aerojet Rocketdyne on a project to identify candidate parts in the F-35 fighter jet that could be produced by Additive Manufacturing.

In 2020, Aerojet Rocketdyne produced the RS-25 engines used to propel NASA's Space Launch System (SLS) rocket, a critical element of the Artemis programme, which seeks to land a man and woman on the moon. The RS-25 engines used on the SLS are reported to contain multiple metal AM components.

"Acquiring Aerojet Rocketdyne will preserve and strengthen an essential component of the domestic defence industrial base and reduce costs for our customers and the American taxpayer," stated James Taiclet, Lockheed Martin's president and CEO. "This transaction enhances Lockheed Martin's support of critical US and allied security missions and retains national leadership in space and hypersonic technology. We look forward to welcoming their talented team and expanding Lockheed Martin's position as the leading provider of 21st century warfare solutions."

The transaction is expected to close in the second half of 2021 and is subject to the satisfaction of customary closing conditions, including regulatory approvals and approval by Aerojet Rocketdyne's stockholders. A transition team will be formed to allow for seamless integration and ensure continuity for customers, employees and other stakeholders.

www.lockheedmartin.com

www.aerojetrocketdyne.com

TBGA appoints Jennifer Coyne Associate Director of Programs

The Barnes Global Advisors (TBGA), headquartered in Pittsburgh, Pennsylvania, USA, has announced the addition of Jennifer Coyne as the Associate Director of Programs. Coyne is a long-time collaborator of TBGA and will oversee project development and execution.

"Jen is a tremendously valuable addition to our ADDvisor® team," commented John Barnes, TGBA founder and Managing Director. "Her depth of experience in heavy transportation, multiple forms of AM and service minded leadership aligns perfectly with our core mission to industrialise Additive Manufacturing on a global scale."

Coyne previously led the Global Additive Manufacturing Team for Wabtec Corp and oversaw Additive Engineering Design, Prototyping, and Parts Production Wabtec's global AM efforts. She formed the original AM team at GE Transport (now Wabtec) and led the launch of over fifty production additive parts and opened four global labs in the US and India with a range of metal polymer AM capabilities. Throughout her career, she has also been the recipient of seven US patents.

Currently, Coyne acts as an SME Additive Manufacturing Community Advisor. She has also received multiple awards, including one of Railway Age's Top Women in Rail 2020, 2017 GE Transportation's Women in Technology Award and the 2013 GE Transportation Innovation Engineering Award.

Prior to starting in Additive Manufacturing, Coyne led the PLM launch, held roles in Systems Engineering specialising in Locomotive Traction, Propulsion Systems and Energy Storage Reliability. She holds a BS in Mechanical Engineering from Grove City College, Pennsylvania, and an MS in Mechanical Engineering from the Georgia Institute of Technology. She is a graduate of GE's Edison Engineering Development Program and received intense technical training and business-focused assignments, including On-Shore Wind and Diesel Engine Emissions Designs Engineering Roles.

www.barnesglobaladvisors.com

Jennifer Coyne will oversee project development and execution in her new role at The Barnes Global Advisors (Courtesy The Barnes Global Advisors)

Rösler's AM Solutions adopts PostProcess Technologies' metal AM surface finishing system

PostProcess Technologies Inc., Buffalo, New York, USA has reported that its automated metal Additive Manufacturing surface finishing system has been adopted by AM Solutions SRI, Concorezzo, Italy, the Additive Manufacturing brand of Rösler Oberflächentechnik GmbH, Untermerzbach, Germany. The new post-build solution will expand the current portfolio of solutions used for finishing complex metal geometries, increasing the number of possible finishing options for customer parts and enabling the set up of hybrid and tailor-made processes, explains AM Solutions.

PostProcess Technlogies' DECI Duo metal surface finishing system for AM (Courtesy PostProcess Technologies)

The automated PostProcess™ DECI Duo™ is said to be in line with AM Solutions' objective to develop more replicable and high-quality finishes on treated parts. The solution's defining feature is its Thermal Atomised Fusillade (TAF) technology. Directed by Post-Process's proprietary AUTOMAT3D® software, TAF combines exclusive chemistries and suspended solid media to direct three axes of motion while precisely controlling flow, heat, liquid, and air pressure. This technology will expand AM Solutions' options of methods to treat parts, and finish metal surfaces, particularly in honeycomb structures, fine-feature details and through channels.

Ubaldo Concilio, General Manager of AM Solutions stated, "With the DECI Duo, we have an additional innovative solution to develop tailor-made and hybrid processes, delivering high-quality finishing results for complex metal parts to our customers. It is our main goal to deliver the top-tier results that meet the unique needs of our customers, and the new finishing technology will help us to achieve these goals."

"We truly consider the DECI Duo to be a game-changer for consistent additive metal surface finishing, and are thrilled to see AM Solutions – Manufacturing service partner leverage its full power for its newly opened service bureau in Italy," added Bruno Bourguet, Managing Director at PostProcess Technologies. "Together, we look forward to helping customers scale their metal AM operations."

www.solutions-for-am.com
www.postprocess.com

3D Systems and Huntington Ingalls Industries to develop CuNi and NiCu alloys for marine applications

3D Systems, Rock Hill, South Carolina, USA, is collaborating with Huntington Ingalls Industries' Newport News Shipbuilding division to develop copper-nickel (CuNi) and nickel-copper (NiCu) alloys for Powder Bed Fusion (PBF) Additive Manufacturing. These new materials could allow Newport News Shipbuilding to additively manufacture parts that are traditionally cast, reducing lead times by up to 75% and improving supply chain efficiency.

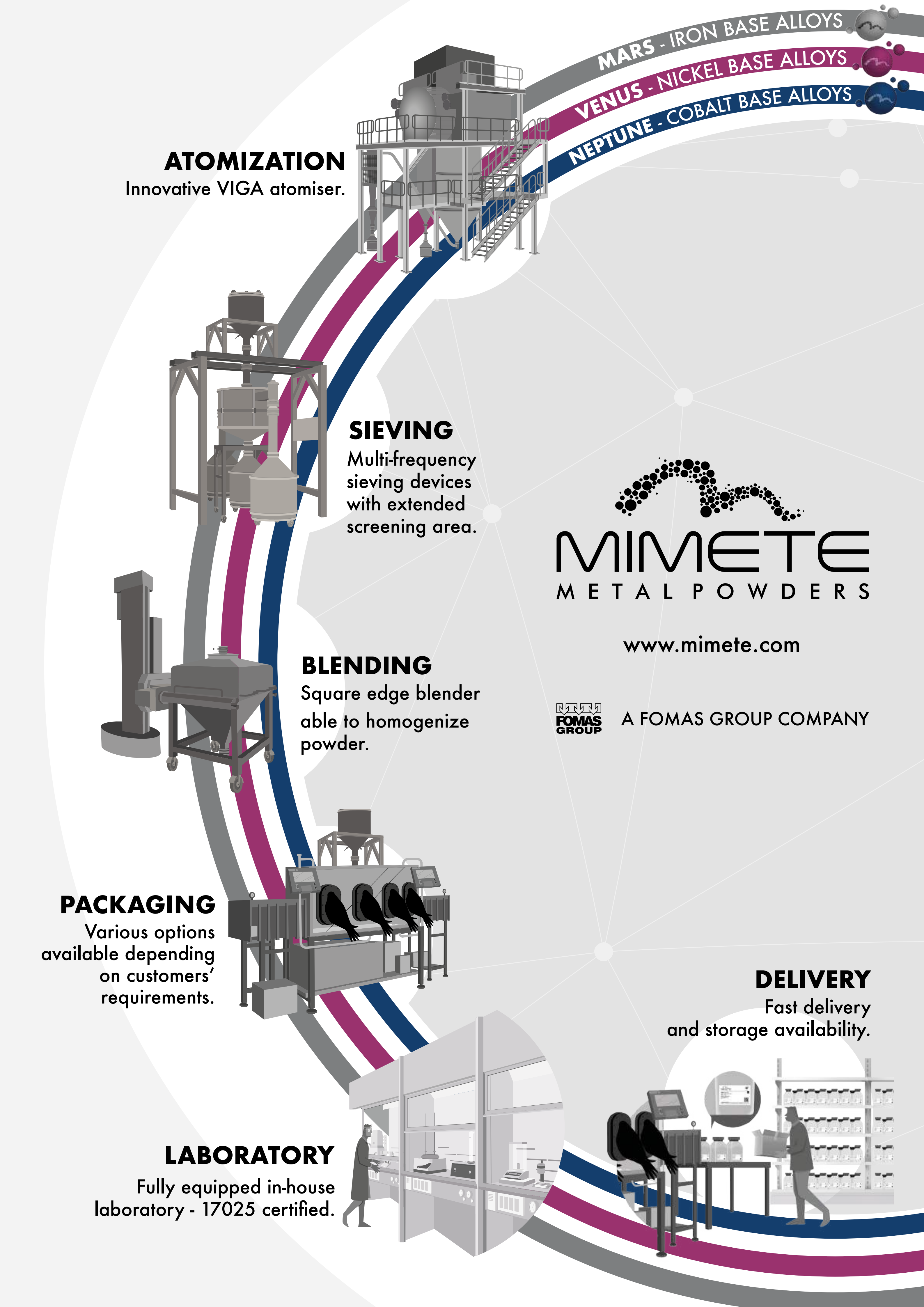
CuNi and NiCu alloys are ideal for marine applications due to their corrosion resistance. While marine parts produced with these metals possess high strength and toughness over a variety of temperatures, they are currently produced by traditional casting methods. This requires significantly long lead times, sometimes in excess of twelve months. If these alloys were to be formulated for use with metal AM technologies, lead times for some of these parts could be reduced to a fraction of the traditional procurement time.

"These new materials have the potential to redefine Newport News Shipbuilding's innovation pipeline enabling them to more efficiently deliver high-quality parts," stated Chuck Hull, co-founder, EVP, Chief Technology Officer, 3D Systems.

Through this material development effort, 3D Systems is working with Newport News Shipbuilding to select the alloy composition, design the process parameter experiments, and qualify parts that include tensile and other material testing. Newport News Shipbuilding will then use metal AM to produce replacement parts for castings, as well as valves, housings, and brackets.

"We're excited to continue our partnership with 3D Systems on these important shipbuilding alloys," commented Dave Bolcar, vice president of engineering and design for Newport News Shipbuilding, a division of Huntington Ingalls Industries. "We're looking forward to expanding on these efforts by developing parameters that will allow us to further expand the use of Additive Manufacturing into our platforms, in order to improve both product quality, schedule, and performance for the fleet."

www.3dsystems.com
www.huntingtoningalls.com


MARS - IRON BASE ALLOYS
VENUS - NICKEL BASE ALLOYS
NEPTUNE - COBALT BASE ALLOYS
ATOMIZATION
Innovative VIGA atomiser.
SIEVING
Multi-frequency sieving devices with extended screening area.
BLENDING
Square edge blender able to homogenize powder.
PACKAGING
Various options available depending on customers' requirements.
LABORATORY
Fully equipped in-house laboratory - 17025 certified.
DELIVERY
Fast delivery and storage availability.
MIMETE
METAL POWDERS
www.mimete.com
FOMAS GROUP
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GM opens Additive Industrialization Center dedicated to AM for auto sector

General Motors (GM), Detroit, Michigan, USA, has announced the opening of its Additive Industrialization Center (AIC), a new 1,400 m^2 (15,000 ft^2) facility dedicated to Additive Manufacturing for the automotive industry located at the GM Tech Center in Warren, Michigan.

The facility houses twenty-four AM machines that provide metal and polymer solutions for a number of processes, including Laser Beam Powder Bed Fusion (PBF-LB) and Material Extrusion (MEX)-based process Fused Filament Fabrication (FFF).

The AIC aims to validate AM technologies and applications, focusing on evolving AM machinery and equipment. GM Ventures and GM R&D are collaborative partners with the AIC, supporting an integrated, enterprising approach to adopting accelerated product development and tooling.

"The core component of GM's transformation is becoming a more agile, innovative company, and 3D printing will play a critical role in that mission," stated Audley Brown, GM director of Additive Design and Materials Engineering. "Compared to traditional processes, 3D printing can produce parts in a matter of days versus weeks or months, at a significantly lower cost."

Ron Daul, GM director of Additive Manufacturing and Polymer Centers, added, "GM is increasingly applying the benefits of 3D printing, from prototype development to manufacturing tooling and production vehicles. With the opening of the AIC, we'll continue to accelerate adoption of this technology across the organisation."

www.gm.com

The General Motors Additive Industrialization Center at the GM Tech Center (Courtesy Steve Fecht / General Motors)

nTopology launches new software to automate design of AM jigs and fixtures

nTopology, New York City, USA, has released the newest feature of its FDM™ Fixture Generator, a collaboration between the company and Stratasys, headquartered in Eden Prairie, Minnesota. The new Masking Fixture Module is said to be able to automate 90% of the design work required for additively manufactured jigs and fixtures.

Engineers can use this tool to keep parts safe and clean throughout the manufacturing process without the hassle of designing one-off jigs and fixtures. Early customer feedback reported several applications in which this had proven useful: protecting critical faces, gaskets, holes or mating surfaces with tight tolerances during a painting, coating, or bead blasting post-processing, for example.

Jigs and fixtures make up around 10% of all end-use parts being additively manufactured today, yet less than 1% of fixtures used in factories around the world are produced via AM. nTopology believes that this isn't because manufacturers couldn't benefit from them, but, rather, that the industry needs automated Design for AM tools that can simplify the design of fixtures, making them more accessible to the factory floor.

Additively manufactured masking fixtures remove the need for manual masking techniques regardless of model complexity; the Masking Fixture Module automates the design of these fixtures and saves CAD work.

Users in the aerospace and defence industries are said to see a potential in reducing scrap rate and increase throughput; a machine shop creating medical devices and aerospace is said to plan on using this to protect faces during deburring and abrasive processes.

The Masking Fixture Module is the second output of the ongoing collaboration with Stratasys; a few months back, the Assembly Fixture Module, a workflow that automates the design of kitting trays, storage cases, and other simple fixtures to support manufacturing operations, was released.

www.ntopology.com
www.stratasys.com

Fraunhofer IFAM installs Tritone's MoldJet AM system, Europe's first

The Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM), Dresden, Germany, is expanding its range of sinter-based Additive Manufacturing technologies with a new MoldJet® system from Israel's Tritone Technologies, Ltd. IFAM, the first European user of the MoldJet process, has installed the new machine at its Innovation Center Additive Manufacturing (ICAM).

The MoldJet process is described as a synergy of two manufacturing processes, allowing for the flexible production of customer-specific parts. Firstly, a mould is produced as a negative of the component geometry from a wax-like polymer with inkjet-like print heads. This additively manufactured 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.

Due to the nature of the mould, surface quality is said to compare favourably to typical laser-based AM machines, and components can be made from any sinterable material – such as stainless steel, pure copper, nickel-base alloys, titanium and refractories, or ceramics. The most significant advantage however, is reported to be the high productivity of the process. With six manufacturing trays and six autonomous workstations, up to 1,600 cm^3/h may be achieved.

Fraunhofer IFAM's ICAM brings together a wide range of AM processes and develops solutions for materials and component geometries. Alongside the MoldJet, the centre also hosts capabilities for Electron Beam Powder Bed Fusion (PBF-EB), 3D Screen Printing, metal-based Fused Filament Fabrication and Gel Casting.

www.ifam.fraunhofer.de
www.tritoneam.com

The new MoldJet printing system from Tritone Technologies at Fraunhofer IFAM, Dresden (Courtesy and Fraunhofer IFAM Dresden)

MELD's titanium certified to meet ASTM & AMS standards

MELD Manufacturing Corporation, Christiansburg, Virginia, USA, has released data confirming that its MELD metal Additive Manufacturing machines produce titanium meeting the ASTM and AMS standards for forged materials, as built.

The data was said to have been generated through a programme with the National Center for Manufacturing Sciences (NCMS), the Army Research Laboratory (ARL) and the Advanced Manufacturing, Materials, and Processes (AMMP) using Ti6Al4V material (ASTM Grade 5) for the testing.

Data has shown that the as-built material exceeds minimum requirements for yield strength, ultimate tensile strength and elongation as specified in ASTM B265, ASTM B381, and AMS 4911 in all axes, including through the build layers.

ASTM B265 is the ASTM standard specification for Titanium and Titanium Alloy Strip, Sheet, and Plate. ASTM B381 is the ASTM standard specification for Titanium and Titanium Alloy Forgings. AMS 4911 is the AMS specification for Titanium Alloy, Sheet, Strip, and Plate, 6Al – 4V, Annealed. Chemistry analysis shows that MELD Ti6-4 is consistent with the feedstock material and conforming to the requirements of ASTM B265, ASTM B381, and AMS 4911.

"Optical microscopy and SEM investigations produced images which revealed clean, defect-free material. The MELD deposited Ti6-4 is monolithic, as individual layers are not visible during evaluations," stated Ryan Henderson, Process Engineer.

Ti6-4 is desirable because of its high strength to weight ratio and favourable balance of properties, but its prohibitive cost can prevent use in components that require a large amount of material to be machined away. MELD enables use of this alloy by manufacturing only what is needed.

www.meldmanufacturing.com

Protolabs launches digital quoting and design analysis platform for US customers

Protolabs, Maple Plain, Minnesota, USA, has launched a new digital quoting and design analysis platform for its US-based customers, following a successful European launch last year. The company explains that the new platform has a modern, user-friendly interface that enables engineers to better manage their project requirements, collaborate easier with colleagues and identify new levels of transparency into their orders. Like the previous platform, its flagship feature – interactive design for manufacturability (DFM) analysis – remains, but is said to now be more intuitive.

"Protolabs was founded on a digital manufacturing model that would dramatically reduce the time it took to get parts – and it was a success," stated Rob Bodor, Protolabs' incoming CEO and current VP and GM of Americas. "Twenty years later we've reinvented manufacturing once again with the launch of an all-new digital experience to our customers that reaffirms our position as the global leader in digital manufacturing services."

Mark Flannery, global product director for e-commerce at Protolabs, commented, "We listened to hundreds of our customers to learn about their design analysis and quoting needs, and then built our new quoting platform around those needs. We then thoroughly tested the platform with our customer base to refine it even further. The result is a digital quoting system designed entirely around an elevated user experience that accelerates their product development cycle every step of the way."

With the launch Protolabs' moulding, machining, and AM services united in a single platform, users are offered easier quoting and ordering experiences. Injection moulding users can now view and discuss gate and ejector pin layout before ordering tooling and parts. With CNC machining, threading assignments have been simplified to let users quickly assign required threads. AM customers can now see per-part pricing with itemised costs as well as self-select their desired delivery date for each part within order at checkout.

"Unprecedented changes in many of our markets are underway due to customer demand and the ongoing pandemic, but technological advancement in manufacturing are throwing the doors of innovation wide open to allow suppliers and their customers to pivot quickly," stated Rich Baker, the CTO who led the platform's launch. "That agility is often the difference between success and failure."

www.protolabs.com

Levil, Virtual Foundry and Sapphire3D offer complete metal AM lab

Levil Technology, Oviedo, Florida, USA, has partnered with The Virtual Foundry, Stoughton, Wisconsin, and Sapphire3D, Chicago, Illinois, to provide an all-inclusive solution to set up a complete metal Additive Manufacturing Lab.The complete kit on offer includes the Levil EDU-Mill, with its industry-grade dual-head AM machine and a selection of Levil, FANUC, or Mitsubishi control options; The Virtual Foundry's proprietary metal AM filaments, which come in a variety of materials; and Sapphire3D's furnace.

"Levil Technology could not have asked for better partners when it came to creating a metal 3D printing solution for our customers," stated Andres Leon, Levil's General Manager. "We wanted local partners that would provide expertise and support to our users and not only did they deliver but also exceeded our expectations. Their products fit seamlessly with our space-conscious, low inertia machines. We cannot wait to see what our end users create when they have all these tools at their disposal."

www.leviltechnology.com
www.thevirtualfoundry.com
www.sapphire3d.com

ExOne to offer controlled atmosphere X1 160Pro for reactive metal powders in 2022

The ExOne Company, North Huntingdon, Pennsylvania, USA, reports that it will offer a controlled atmosphere model of its X1 160Pro™ extra-large production metal Binder Jetting (BJT) Additive Manufacturing machine in the second half of 2022. The controlled atmosphere update will enable high-volume production of aluminium, titanium, copper, and several other materials using BJT.

The X1 160Pro features a build box of 800 x 500 x 400 mm (160 litres) and is the company's tenth and largest production-ready metal BJT system to date. The company explains that a controlled atmosphere is essential for the Additive Manufacturing of reactive fine metal powders, but it also offers other benefits, such as reduction of powder oxidation and enhanced powder dispensing and spreading through control of humidity.

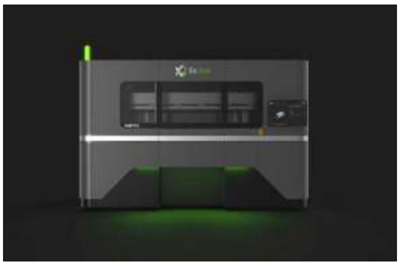
ExOne has successfully been Binder Jetting reactive powders in controlled atmospheres, also referred to as inert or chemically inactive, for some years. On December 1, 2020, ExOne was issued a patent on binder jet 3D printing in a controlled atmosphere.

The controlled-atmosphere X1 160Pro model can reportedly be used with nitrogen or argon and will be paired with accessories and ancillary equipment also equipped with inert atmosphere features. These include a curing oven, powder conditioning system, depowdering station, and transport device for moving the build-box between process stages to ensure complete atmosphere control throughout the process.

ExOne will continue to offer the original model of the X1 160Pro for customers who don't require a controlled atmosphere system to process metal powders such as stainless steels. The company's BJT AM technology is capable of processing twenty-three metal, ceramic, and composite materials, including a dozen single-alloy metals such as aluminium and titanium.

The current model is available to be shipped from ExOne's European headquarters and production facility in Gersthofen, Germany.

www.exone.com



ExOne will offer a controlled-atmosphere model of its X1 160Pro extra-large production metal Binder Jetting machine in 2022 (Courtesy The ExOne Company)

Xerox installs first ElemX Liquid Metal machine at US Naval Postgrad School

Xerox, headquartered in Norwalk, Connecticut, USA, has announced the installation of its first ElemX Liquid Metal Additive Manufacturing machine at the Naval Postgraduate School (NPS), Monterey, California, USA. As part of a collaborative research and development agreement, NPS aims to explore new ways the technology can deliver on-demand metal parts and equipment, with the potential to dramatically transform the way the military supplies its forces.

"The military supply chain is among the most complex in the world, and NPS understands first-hand the challenges manufacturers must address," stated Naresh Shanker, Xerox's Chief Technology Officer. "This collaboration will aid NPS in pushing adoption of 3D printing throughout the US Navy, and will provide Xerox valuable information to help deliver supply chain flexibility and resiliency to future customers."

Xerox entered the AM market for the first time in February 2019, when it acquired metal AM company Vader Systems. With the acquisition of Vader, the company gained its liquid metal process along with additional Additive Manufacturing technology.

With access to the latest AM equipment, NPS faculty and students will use the ElemX machine to conduct thesis research to develop new capabilities for the Navy and Marine Corps.

"As the Department of the Navy's applied research university, NPS combines student operational experience with education and research to deliver innovative capabilities and develop innovative leaders with the knowhow to use them," added Ann Rondeau, NPS president retired Vice Admiral. "This partnership is about the strategic ability of the Navy to have sailors on ships with the capability through creativity and technology to advance their operations at sea. Through collaboration, NPS and Xerox are helping build a Navy for the 21st Century."

"Global supply chains leave industries like aerospace, automotive, heavy equipment, and oil and gas vulnerable to external risks," said Tali Rosman, vice president and General Manager, 3D Printing, Xerox. "Our goal is to integrate localised 3D printing into their operations, and the real-time feedback from NPS gives us actionable data to continuously improve the ElemX."

www.nps.edu
www.xerox.com

Xerox has installed its first ElemX Liquid Metal Additive Manufacturing machine at the Naval Postgraduate School (Courtesy Xerox)

Burloak Technologies awarded Boeing approval for AM aluminium parts

Burloak Technologies, Oakville, Ontario, Canada, a division of Samuel, Son & Co., Ltd., has been approved by The Boeing Company to additively manufacture aluminium AlSi10Mg components to the Boeing BAC 5673 specification. Burloak Technologies is reported to be the world's first additive manufacturer to achieve this qualification. Burloak and Boeing are now working to apply the BAC 5673 specification to several programmes for existing and future components.

"This approval marks the completion of a qualification process that included a rigorous evaluation of Burloak's capabilities by Boeing. We would like to thank Boeing's additive manufacturing team for its collaborative approach," stated Peter Adams, Burloak's founder and Chief Innovation Officer. "Together, we developed a well-defined specification that has demonstrated robust, repeatable processes to produce flight components using Additive Manufacturing."

Colin Osborne, Samuel's president and CEO, commented, "Achieving this qualification further validates Burloak's position as a global leader in the Additive Manufacturing space, and clearly demonstrates our ability to commercialise this transformational technology. This milestone also signals the increasing importance of Additive Manufacturing within aerospace and represents a step forward on the path to a greener future for aviation."

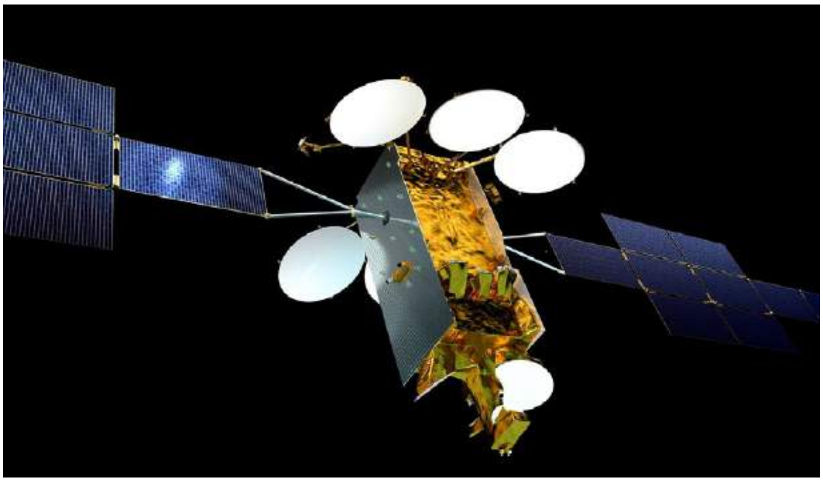
www.burloaktech.com
www.samuel.com

Airbus additively manufactures 500 radio frequency parts for two Eurostar Neo satellites

Airbus has additively manufactured a total of 500 radio frequency (RF) components, composed of multi-waveguide blocks and switch assembly networks, at its Airbus Defence and Space site in Portsmouth, UK, for two of its Eurostar Neo spacecraft that will join the in-orbit fleet of Eutelsat, a leading provider of satellite communications services headquartered in Paris, France.

The two satellites, EUTELSAT HOTBIRD 13F and 13G, are expected to reinforce and enhance Eutelsat's TV broadcasting services over Europe, the Middle East, and North Africa. By utilising Additive Manufacturing for the satellites, Airbus stated there were major labour savings and a significant reduction in the number of individual required parts.

Gareth Penlington, the HOTBIRD Payload Manager at Airbus, commented, "This is recognised as the first large-scale deployment of RF products using the ALM process, and it puts us in an industry-leading position for the technology's application in producing radio frequency components."



Airbus has additively manufactured 500 RF parts for two of its Eurostar Neo series satellites (Courtesy Airbus)

Airbus' manufacturing team in Portsmouth developed innovative designs for the Eurostar Neo's multi-waveguide blocks and switch assembly networks to be additively manufactured, taking them from initial concept and patenting through industrialisation and the completion of a successful qualification programme. The first EUTELSAT HOTBIRD satellite's communications module was transferred in early February from Portsmouth to the Airbus Defence and Space facility in Toulouse, France, where the spacecraft's full build-up will be completed. Assembly of the second HOTBIRD communications module is now underway in Portsmouth, with its testing scheduled this quarter.

Penlington added, "This is recognised as the first large-scale deployment of RF products using the ALM process, and it puts us in an industry-leading position for the technology's application in producing radio frequency components."

www.airbus.com

www.eutelsat.com

Kanthal and Swerim invest in atomising equipment for PM, AM and HIP applications

Swedish heating technology company Kanthal, part of the Sandvik Group, and metals research institute Swerim, Luleå, Sweden, is to invest €2 million in ultra-modern atomising equipment designed for research and development of both materials and the atomising process.

The new equipment will allow the atomising of powder batches up to approximately 85 kg, both for Additive Manufacturing and Hot Isostatic Pressing (HIP) applications. It will be installed in Swerim's site in Kista, outside of Stockholm and is expected to be operational by Q4 2021.

The joint investment lays the foundations for a long-term partnership in which Kanthal receives access to Swerim's sixty years of experience in Powder Metallurgy, metal AM, advanced structural analysis, testing and modelling.

"The investment will enable unique possibilities for us to develop materials for AM and to get new products out on the market, faster," stated Dilip Chandrasekaran, Head of R&D at Kanthal. "The cooperation with Swerim will also allow for world-class research within this field which is strategic both for Kanthal and for Sweden."

Jesper Vang, research leader in AM and Powder Metallurgy at Swerim, commented, "Sweden is world-leading in the area of powder metals thanks to our long experience of in-depth research and continuous development of materials, processes and products."

"The investment is a direct result of increased demand for research possibilities," added Vang. "To keep the leading position, Swedish companies have to be in the forefront when it comes to development of new materials and technologies."

www.kanthal.com

www.swerim.se

Freemelt announces multiple orders for its AM machines from Swedish research institute

The orders for two PBF-EB machines will allow further study of advanced materials and synchrotron radiation studies of PBF-EB processes (Courtesy Freemelt)

Freemelt, Mölndal, Sweden has received two separate orders from KTH Royal Institute of Technology, Stockholm, Sweden, for its Electron Beam Powder Bed Fusion (PBF-EB) Additive Manufacturing machines.

A Freemelt ONE system will be housed at KTH in Stockholm for use in the study of advanced materials. A modified PBF-EB system, based on the Freemelt ONE technology, will be placed alongside the PETRA III at the DESY research facility in Hamburg, Germany, and used for synchrotron radiation studies of PBF-EB processes in a joint Swedish-German project.

"These orders confirm our position as a prime supplier of 3D printers for cutting edge material research," stated Ulric Ljunblad, CEO of Freemelt. "We are very pleased to see that our products will be used at one of the world's leading synchrotron radiation facilities, as well as at Sweden's largest technical research and learning institution. We look forward to supporting KTH in their exciting research endeavours."

Greta Lindwall, Assistant Professor at KTH, commented, "These E-PBF systems will strengthen our 3D printing research at KTH and we look forward to the collaboration with Freemelt. The access to a Freemelt ONE system will support our Research Initiative on Sustainable Industry and Society (IRIS) with focus on integrated mechanics, components and materials design for 3D printing. The modified system will enable in-situ synchrotron X-ray studies to provide fundamental insights in the E-PBF process."

Both machines are scheduled to be delivered during 2021.

www.freemelt.com

Rio Tinto and Amaero collaborate on aluminium-scandium alloy for AM

Rio Tinto, headquartered in London, UK, has signed an agreement to provide aluminium-scandium alloy from its North American operations to Amaero, a producer of additively manufactured parts and AM service provider based in Notting Hill, Victoria, Australia.

Under the agreement, Rio Tinto will deliver alloy billets made of responsibly-produced, low-carbon aluminium from its hydro-powered Canadian smelters and high-purity scandium oxide from its Rio Tinto Fer et Titane (RTFT) metallurgical complex in Sorel-Tracy, Quebec, Canada. The billets will be processed by Amaero into powder for Additive Manufacturing and offered to the market for high temperature applications.

The scandium oxide will be supplied from a new plant in Sorel-Tracy, reportedly the first North American supply source. The plant will use an innovative recovery process developed by Rio Tinto scientists to extract high-purity scandium oxide from the waste streams of titanium dioxide production, without the need for any additional mining.

The companies will also collaborate in the development of the supply chain and commercialisation of Amaero's high-performance, high operating temperature aluminium alloy, Amaero HOT Al.

Rio Tinto Aluminium Sales and Marketing vice president, Tolga Egrilmezer stated, "As a global leader in aluminium, and the first producer of high-quality scandium oxide in North America, Rio Tinto is uniquely positioned to provide a secure source of aluminium-scandium alloy to the market."

"Aluminium-scandium alloy is the material of choice where a lightweight, high-strength material with thermal resistance and good welding properties is needed, such as for defence and aerospace applications. This first sale demonstrates our ability to develop products that meet our customers' needs, drawing on our technical expertise and world class assets," Egrilmezer added.

"We are very pleased to enter this agreement with Rio Tinto to purchase the first commercial batch of aluminium scandium alloy from a North American source," commented Barrie Finnin, Amaero CEO. "This is an important step in the commercialisation of this high-performance alloy that will be used in our breakthrough 3D metal printing technology. We look forward to working with Rio Tinto to progress the production of the alloy so we can commence the qualification process with key customers in the aerospace sector and other industries."

www.riotinto.com
www.amaero.com.au

MELD awarded $1.5M from US Navy for metal AM and legacy repairs

Developer and provider of metal Additive Manufacturing machines, MELD Manufacturing Corporation, Christiansburg, Virginia, USA, has been awarded a $1.5 million contract from the United States Navy following the successful demonstration of its MELD AM process. The current contract will build upon naval investments, including those by the National Shipbuilding Research Program for 'Scaling Up 3D Printed Steel Castings'.

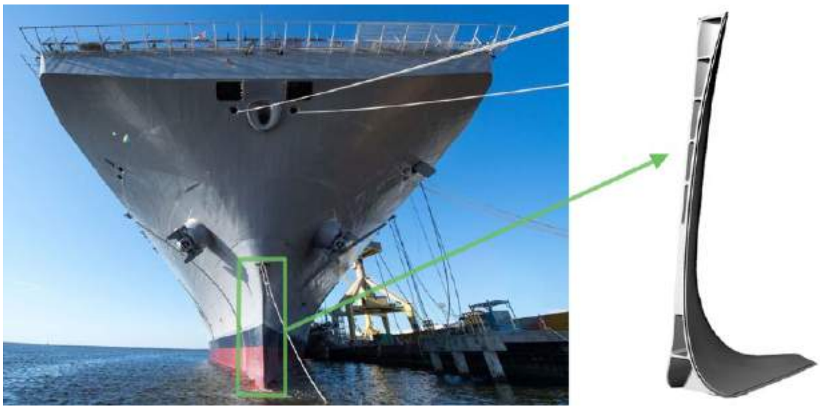
The programme will support the development of qualification data for parts manufactured by MELD, guiding naval use of the company's equipment. The contract includes the purchase of a MELD L3 model, planned to be housed in the Navy's Center of Excellence for Additive Manufacturing at the Norfolk Naval Shipyard in Virginia. The programme is intended to further the Navy's support of critical operations by delivering instructions for repair and manufacturing of naval metal parts on-site at the shipyard.

"We've received requests for a number of parts in a wide range of metal alloys from the Navy and ship-builders that are not able to be printed with any other technology," stated Dr Chase Cox, Director of Technology. "The range of need expressed to us really highlights the value of a MELD machine, because unlike other metal printers, MELD can print metals the Navy truly needs at a size that is not otherwise possible."

The programme will repair legacy and obsolete parts, as well as additively manufacturing new parts critical to the modernisation of the Navy's fleet, where both repair and manufacture will help to overcome long lead times for forged and cast products. The L3 machine will provide flexibility to use multiple materials whilst preserving the ability to create and repair parts with newly-designed alloys.

"MELD solves the global problem of long lead times for forged and cast metal products and provides large scale components in all metals," commented CEO Nanci Hardwick.

www.meldmanufacturing.com



The MELD solid-state Additive Manufacturing process was chosen by the National Shipbuilding Research Program to reduce the lead times and efficiency of large steel castings like this ship stem bar (Courtesy MELD)

ExOne adds USC Solutions to sales network to support growth in Singapore, Malaysia and Indonesia

The ExOne Company, North Huntingdon, Pennsylvania, USA, has announced that USC Solutions is now an authorised channel partner to sell ExOne industrial solutions in Singapore, Malaysia and Indonesia.

"We're excited to have the experienced team from USC Solutions represent us. We look forward to leveraging their reputation of providing solutions in the local manufacturing market," stated Ben Leung, ExOne, vice president, Asia. "ExOne continues to grow in Asia and we expect USC Solutions to play a key role in strengthening our network for this ongoing expansion."

USC Solutions is the latest to join a growing number of distribution partners in the ExOne network across Asia. ExOne has qualified more than twenty metal, ceramic and composite materials for its Binder Jetting (BJT) process. More than half of those materials are single-alloy metals, such as 17-4PH, 316L, 304L, M2 Tool Steel, Inconel 718 and others. High-demand materials, such as aluminium and titanium, are also being fast-tracked for qualification, whilst binder developments include inorganic binder systems tailored for aluminium castings.

"We believe Binder Jetting complements our customers' portfolios well because of its unique properties allowing for material and application flexibility as well as safety and cost benefits," added Riyaz Vehmi, General Manager of USC Solutions Pte Ltd.

"USC Solutions is introducing ExOne's binder jet technology to our existing Additive Manufacturing customers to complement their current systems. The wide variety of metal and ceramic materials address key application needs within their portfolios and it will be a useful addition for them to increase their capabilities in both research and manufacturing," Vehmi concluded.

www.exone.com
www.uscsolns.com

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Latest Alfa Romeo F1 car doubles the amount of AM components

The newly-launched 2021 Alfa Romeo Racing Orlen F1 race car, the C41, manufactured in partnership with Additive Industries, Eindhoven, the Netherlands, will take to the track with 304 additively manufactured metal parts, more than doubling the number from 2020's C39 race car.

The parts for the C41 were produced on the MetalFAB1 AM machine from Additive Industries, with some 22% of the 304 parts made from Ti64Gd23, 36% from Scalmalloy, 40% built from AlSi10Mg and 2% in stainless steel. The total combined weight accounts for approximately 14.86 kg, a comparatively small increase over last year's 13.14 kg considering the 113% parts increase.

Cost savings of up to 90% per part, in comparison with traditionally-manufactured parts, has also been a major benefit for Sauber Motorsport AG, the Swiss company which manages and operates the Alfa Romeo Racing Orlen team. These savings come not only from lighter parts and higher productivity, but also from having direct access to MetalFAB1 machines.

"By having the MetalFAB1 systems in house, and not outsourcing externally, it helps us to achieve an important element of the cost cap," commented Jan Monchaux, Technical Director.

Sauber began its collaboration with Additive Industries with the plan to establish a metal AM competence centre within three years. However, the collaboration is entering its fourth year with four machines already in operation, instead of the intended two machines within three years.

www.sauber-group.com/motor-sport/formula-1

www.additiveindustries.com

The C41 has an increase of 113% of AM parts from the previous year's 143 (Courtesy Sauber Group)

European Patent Office intends to grant PyroGenesis plasma atomisation patent

PyroGenesis Canada Inc., Montreal, Quebec, Canada, reports that the European Patent Office has issued its intent to grant the company a patent based on its prosecuted application for a 'Plasma Apparatus for the Production of High Quality Powders at High Capacity'. This patent relates to the production of high-purity spheroidal powders for use in Additive Manufacturing, but can also be used in Hot Isostatic Pressing (HIP).

The company explains that the patent aims to provide a simplified device geared to increasing productivity while at the same time allowing for further control over particle size distribution, thereby reducing overall costs. This patent has reportedly been filed for patent protection in an additional six different jurisdictions.

"European patents provide protection not only in the thirty-eight member states of the European Patent Organization, but also in two extension states plus four validation states," commented Pierre Carabin, Chief Technology Officer of PyroGenesis. "This represents an area with approximately 700 million inhabitants. This new addition to our intellectual property portfolio brings the total number of issued and pending patents held by the company to 124, which is a historical high. We currently have 100 patent applications in progress, covering nineteen families of invention. When combined with our significant know-how and trade secrets, we are continuing to create a formidable barrier to entry in the markets we serve."

P Peter Pascali, CEO and Chair of PyroGenesis, stated, "This European patent will further strengthen our position as a leader in powder production not only in Europe, but worldwide. We have seen a steady increase in demand for plasma atomised powders and not only with respect to titanium alloys. With an increased production rate and a higher yield, we can now open up new markets where materials, that would normally have been too expensive to consider in additive manufacturing, can now be used economically."

"This type of innovation not only secures PyroGenesis' position as a powder producer but, in management's opinion, significantly increases the overall market potential for PyroGenesis' powder offerings," concluded Pascali.

www.pyrogenesis.com

Safina offers range of metal powders for Additive Manufacturing

Safina has developed its own master alloys to meet the standards for AM production (Courtesy Safina)

With beginnings in the mid-19th century, Czech company Safina has a long tradition in the complex processing and manufacture of products from precious and nonferrous metals such as thermocouple wires, PGM wires, plates and tubing, sputtering targets, labware, chemicals, powders and others. For many years, the company produced silver powders – prepared by reduction from silver nitrate solution in a large range of particle sizes with dendritic shape. These powders are commonly used in the fields of sintered contacts, carbon brushes and EMI/RFI shielding. However, chemically-precipitated powders, such as these, are not suitable for technologies like Additive Manufacturing or cold spraying.

Safina initially invested in cold spray technology in 2012 for the production of rotary targets for the flat glass industry. Rotary sputtering targets produced from gas atomised powder by cold spraying ensure superior properties like low porosity, gas content, high purity – 4N, fine and homogeneous grain size. In line with this development, the company invested in a gas atomiser suitable for the production of silver powder for cold spray technology.

Safina soon became aware that its uniquely-developed processed powders have properties for cold spray and AM which the standard powders did not. With this in mind, it started the external production of gas atomised powder for partners, which is currently a keystone of the company's portfolio.

Powders from Safina

Safina's powder range extends to three main types: gas atomised; chemically precipitated; and its newly-developed coated powders, which are manufactured by hydrometallurgy. To maintain the quality of its powders, Safina uses inspection methods such sieving analysis, laser diffraction granulometry, dynamic image particle analysis, Scanning Electron Microscopy (SEM), chemical analysis by ICP-OES or EDX, gas content measurement, tap and apparent density/flowability measurements.

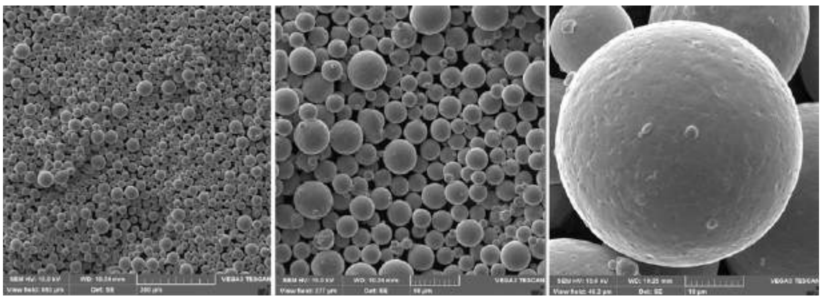
The company recently added gas atomised powders from ternary copper-based alloys to its range, meeting the needs of high-end applications like the combustion chambers in rocket engines or heat sinks in nuclear fusion reactors. While pure copper has good thermal conductivity, its strength, especially at higher temperatures, falls short. With the introduction of some other elements like NB, Cr, Ag or Zr, there is an improvement in that strength while still preserving the high thermal conductivity at temperatures around 700K. Generally, Cr and Ag nano precipitates offer higher strength, while Zr acts as a grain refiner, blocking coalescences of nano precipitates, meaning precipitates have to be as small as possible to maintain high mechanical properties.

Alloys like CuCr1Zr are common, widely available as rolled semi-finished products (rods, plates and sheets). However, Safina found that it had to overcome several obstacles to produce higher quality powder, as the quality of raw material was found to be insufficient for AM production, either Laser Beam Powder Bed Fusion (PBF-LB) or Cold Spraying.

To ensure high, replicable quality of production powders, Safina developed its own high-purity master alloys, as even several tens of ppm impurities are detrimental and can cause Intermediate Temperature Embrittlement (ITE). The most important elements to watch are O_2, H, Bi, Sn, Sb, Pb, Te, Se, P and Fe.

Safina has also altered the entire process, from melt atomisation to packing, in order to prevent oxygen contamination and reach optimal particle size distribution. This is especially important for its copper alloys, as copper powder is very sensitive to oxygen exposure and rapid oxidisation can influence its mechanical properties, meaning a proper handling procedure is vital at both sides of the supply chain.

www.safina.cz



SEM images of CuCr1Zr powder (mag: 200x/500x/4500x) (Courtesy Safina)

Uniformity Labs and Desktop Metal announce new aluminium powder

Through a collaboration between Desktop Metal, Burlington, Massachusetts, USA, and Uniformity Labs, Fremont, California, USA, a new powder enabling aluminium sintering for Binder Jetting (BJT) AM technology has been discovered. This comes after a multi-year effort between the companies to develop a low-cost raw material that yields fully dense, sinterable 6061 aluminium with greater than 10% elongation, as well as improved yield strength and ultimate tensile strength versus wrought 6061 aluminium undergoing comparable heat treatments.

"This breakthrough represents a major milestone in the development of aluminium for Binder Jetting and a significant step forward for the AM industry, as it is one of the most sought-after materials for use in automotive, aerospace and consumer electronics," stated Ric Fulop, CEO and co-founder of Desktop Metal. "The global aluminium castings market is more than $50 billion per year, and it is ripe for disruption with Binder Jetting AM solutions."

"The introduction of lightweight metals to Binder Jetting opens the door to a wide variety of thermal and structural applications across industries," added Adam Hopkins, founder and CEO of Uniformity Labs. "This innovation is a key step towards the adoption of mass-produced printed aluminium parts."

The Uniformity 6061 powder enables the sintering of unadulterated 6061 aluminium, said to be a significant improvement over prior aluminium sintering techniques, which required coating powder particles, mixing sintering aids into the powders, using binders containing expensive nanoparticles or diluting the aluminium with metals such as lead, tin or magnesium. Most importantly, Uniformity 6061 also allows for the use of water-based binders and has a higher minimum energy relative to other commercially-available 6061 aluminium powders, resulting in an improved safety profile.

Over the coming year, Desktop Metal and Uniformity Labs will continue their partnership to qualify the powder and scale production for commercial release. Once qualified, Uniformity 6061 will be available for use with Desktop Metal's Production System. "These are the best reported properties we are aware of for a sintered 6061 aluminium powder, and we are excited to make this material available exclusively to Desktop Metal customers as part of our ongoing partnership with Uniformity Labs," Fulop concluded.

www.desktopmetal.com
www.uniformitylabs.com

AML3D to supply industrial components to key 3DPC client

AML3D Limited, Edinburgh, Australia, has announced that it will supply a series of industrial components for evaluation and testing to a key client of Japan's 3D Printing Corporation (3DPC). As an Additive Manufacturing service, 3DPC, headquartered in Yokohama, focusses on enhancing the manufacturing capabilities of its clients with its unique AM supply chain solutions.

"We are excited to work with 3DPC with this purchase order, highlighting the exposure we receive in the Asia Pacific region. We are confident that the successful validation of the WAM [Wire Arc AM] technology will lead to greater commercial opportunities in the future," commented Andrew Sales, AML3D Managing Director.

AML3D has reportedly received substantial interest from 3DPC clients hoping to overcome traditional manufacturing constraints. In one such case, a client's wait time for traditional components is sixth months, whereas AML3D components can be delivered in less than two weeks. This client has submitted a purchase order for sample components, to test the suitability of AML3D's technology for its needs. The trial, if successful, will result in a switch to the AM components, which is expected to lead to business development in industrial and energy sectors.

"By building a supply chain for 3D printed industrial components, we are able to drastically reduce lead time and inventory costs for our industrial clients," stated Alexander S DeVore, 3DPC CEO. "This first phase is qualifying a component that frequently requires replacement due to harsh conditions and we expect a cost savings of approximately 700,000 USD per annum when AML3D's WAM technology is fully integrated."

www.3dpc.co.jp
www.aml3d.com

ALM3D is using its Wire Arc Additive Manufacturing technology to support manufacturers hoping to overcome problems presented by traditional manufacturing (Courtesy AML3D)

ESPRIT CAM successfully tested for Binder Jetting Additive Manufacturing

DP Technology, Camarillo, California, USA, developer of the ESPRIT CAM system, a computer-aided manufacturing software that supports a variety of CNC machines, reports that, through its existing partnership with France's Technical Centre for Mechanical Industry (Cetim), it has successfully tested the ESPRIT CAM system with Binder Jetting (BJT) Additive Manufacturing.

In 2020, teams from ESPRIT continued to develop products to enhance the support of AM technologies and released a new feature that adds support to several new slice formats such as 3MF and Binary CLI, further improving interoperability between software and machines.

ESPRIT already supports both Direct Energy Deposition (DED) and Powder Bed Fusion (PBF) Additive Manufacturing with products that have been tested and validated by industrial partners. Relying on an established collaboration with Cetim, ESPRIT teams validated the support of Binder Jetting.

As built (left) and sintered (right) 40 mm impeller designed by Cetim, prepared with ESPRIT CAM and additively manufactured on Digital Metal equipment (Courtesy Cetim/ESPRIT CAM)

By preparing data in ESPRIT Additive Suite products, Cetim was able to build a job made of six impeller parts with a BJT machine from Digital Metal, part of Sweden's Höganäs group. Although ESPRIT additive support for BJT technology is not yet commercially available, the company states that this success demonstrates what's possible when both teams collaborate closely.

"We used the ESPRIT Additive PBF product to slice the 3D model and produce a compatible file format that would be readable by Digital Metal's machine," stated Clement Girard, ESPRIT's Additive Product Manager. "All data preparation was done using a version of ESPRIT Additive PBF that's still in development."

www.cetim.fr

www.espritcam.com

Relequa launches Moisture Profiling software update for metal AM powder moisture testing

Relequa Analytical Systems, a developer of moisture analysis instruments headquartered in Dungarvan, Co Waterford, Ireland, has announced an update to the Moisture Profiling™ software in its MP-1000 system to test for the presence of moisture in metal Additive Manufacturing powders, and to research their behaviour in the environment of AM processes.

Founded in 2009, Relequa is committed to researching moisture behaviour to provide its customers with innovative products for moisture analysis. It specialises in moisture problem-solving systems for the pharmaceutical industry, moisture profiling analytical systems, moisture ingress studies for packaging, rapid moisture test and moisture testing of AM metal powders.

The company states that its technology does not use heat or sample weight as proxy measurements of moisture. Instead, based fundamentally on Water Activity the technology measures moisture being directly released from the metal powder. No sample preparation is needed, the test is non-destructive and powders are tested directly within the AM process area avoiding sample handling and storage issues.

Dr Peter Moir, moisture expert consultant and CEO of Relequa, recently presented at the INVIRTA workshop: 'Special Insight in Metallic Powder Characterisation'. Data was delivered showing how unique metal powders are in their moisture interaction behaviour. Relequa's updated Moisture Profiling protocol was shown to distinguish between different metal AM alloy powders.

Relequa has updated the Moisture Profiling software in its MP-1000 system for running in Additive Manufacturing moisture testing mode (Courtesy Relequa Analytical Systems)

Further information about the updated Moisture Profiling software is available via the company website.

www.relequa.com

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- Part Feasibility Evaluation
- Design for Manufacturing
- Support/Setter design

Process:
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- Molding parameters - MIM
- Feedstock formulation and analysis - MIM/AM
- Printing parameter analysis - AM
- Depowder process review - AM
- Powder management - MIM/AM
- Curing Process review - AM
- Part Handling and Care

Debind:
- TGA process and report reveiew
- Debind process analysis
- Primary Binder Removal
- Secondary Binder Removal
- Binder removal analysis

Sinter:
- Sinter process review
- Temperature analysis
- DSC process and analysis

Quality:
- Equipment needs analysis
- Molding Defects analysis - MIM
- Print Defects Analysis - AM
- Feedstock Quality Analysis - MIM/AM
- Metallurgy review
  - Chemistry
  - Density
  - Mechanical properties

Total Process Management:
- Step by Step Analysis
- Economics review
- Production Process Work Flow review
- Equipment selection and analysis
- Facility Layout review and analysis
- Lean Manufacturing Applications
- Material Storage
- Individual Process Audits
- Process Innovation
- Packaging and Delivery
- Customer/Supplier Relationship
- Development
- Post Process Step Review
  - Rework
  - Heat Treatment
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DSH TECHNOLOGIES

GE researchers developing portable water-producing prototype using AM

The Defense Advanced Research Projects Agency (DARPA), an R&D agency of the US Department of Defense (DoD), has selected a team from GE Research, GE's tech development arm based in Niskayuna, New York, USA, to lead a new four-year, $14.3 million Atmospheric Water Extraction (AWE) project. Called AIR2WATER (Additively Manufactured, Integrated Reservoir to Extract Water using Adsorbents and Thermally-Enhanced Recovery), the programme will work to simplify the transport of potable water to troops in the field, while addressing water scarcity around the world.

According to the World Wildlife Fund, more than 1.1 billion people do not have access to water; approximately 2.7 billion experience water scarcity. The selected team of GE researchers, together with scientists and engineers from the University of California at Berkeley, University of Chicago, and University of South Alabama, will develop and design a highly compact, portable device that can produce clean, safe water out of air.

As stated in an Army Environmental Policy Institute report, 10–12% of United States Marine Core casualties in Iraq and Afghanistan were brought about in the delivery of fuel and water. The prototype that GE researchers are developing could prove a transformational development, drastically reducing, even potentially eliminating, the need for the distribution of water by providing a ready source of clean water directly where troops are stationed.

The AIR2WATER device will be a compact, lightweight system that is able to be lifted by four people and produce enough daily water for around 150 troops. The key technologies being used to produce potable water are sorbent materials to absorb the air and an additively manufactured heat exchanger that effectively draws in heat over the sorbent materials to release water.

The team from UC Berkeley, led by Omar Yaghi, Professor of Chemistry, will focus on the development of sorbent materials. To help predict and inform the selection of the best materials, the University of South Alabama, led by Prof Grant Glover, will model the mass transfer and measure the adsorption kinetics, while AI experts from the University of Chicago, led by Prof Laura Gagliardi, will utilise AI-guided molecular screening tools.

GE researchers will oversee these developments and lead the overall system integration, including the AM design of and sorbent integration into the heat exchange, drawing from decades of experience producing heat exchangers for aerospace applications and power generation turbines.

Test samples of different additively manufactured heat exchangers built in the Additive Manufacturing Lab at GE Research in Niskayuna, New York, USA (Courtesy GE Research)

David Moore, Principal Investigator and Technology Manager for Material Physics and Chemistry at GE Research, stated, "By creating a highly portable, compact device that efficiently extracts water from the atmosphere, we can save lives."

www.ge.com/research
www.berkeley.edu
www.southalabama.edu
www.uchicago.edu

Norsk Titanium supplies titanium AM components for Boeing Dreamliner

Norsk Titanium US Inc, Plattsburgh, New York, USA, has announced production deliveries of new Boeing 787 Dreamliner components to Leonardo's Grottaglie Plant, part of Leonardo's Aerostructures Division, based in southern Italy.

Built using Norsk's Rapid Plasma Deposition (RPD) process, a form of plasma-based Directed Energy Deposition (DED), Norsk engineers designed Ti6Al4V preforms that reduced raw material needs by over 40%. The Additive Manufacturing process enabled Norsk to create a near-net-shape design, while maintaining the stringent process control and material properties needed for structural applications in Boeing aircraft.

"We are pleased to be Leonardo's supplier," said Karl Fossum, director of customer programs for Norsk. "This delivery marks a significant increase in the number of additively manufactured parts previously manufactured from titanium plate. It also is an important step towards our mission to provide an alternative to titanium forgings in aerospace applications."

The delivery is reported to add a third production customer to Norsk's commercial aerostructures customer base, and represents Norsk's first recurring production order from a European Union-based aerospace company.

www.norsktitanium.com

Equispheres adds systems from Aconity3D and Granutools for developing its metal AM powder

Equispheres, Ottawa, Ontario, Canada, has added systems from both Aconity3D and Granutools as part of the Equispheres' lab expansion project. Last year, the company closed a C$30 million investment round to support the lab expansion, increase powder production and continue research and product development of high-performance metal powders for Additive Manufacturing.

The company has selected an Aconity3D AM machine equipped with a 1000 W laser to further research processes and techniques for faster part production. The company also acquired a Granutools' GranuCharge system, which measures the electrostatic charge created within flowing powder.

Explaining the rationale behind each investment, Evan Butler-Jones, Director of Applications Engineering at Equispheres, stated, "Normally the GranuCharge system is used to conduct basic research at academic institutions. However, we use the tool as part of our QA process. Quality parts require quality powder, and that requires precise instrumentation and measurement systems. The Aconity3D printer was chosen because of its increased precision, high configurability and powerful 1000 W laser. This printer enables us to conduct high-speed production parameter optimisation research and testing."

Kevin Nicholds, CEO of Equispheres, commented, "We pride ourselves on our innovative metal powder solutions, and continued innovation relies on research, testing and data. We are providing our team of skilled engineers, materials scientists and metallurgists with the best tools and systems to ensure Equispheres and our customers are set for success."


The Aconity3D AM machine at Equispheres (Courtesy Equispheres)

www.equispheres.com
www.aconity3d.com
www.granutools.com

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Titanium spinal fusion cage produced on Farsoon AM machine receives China's NMPA clearance

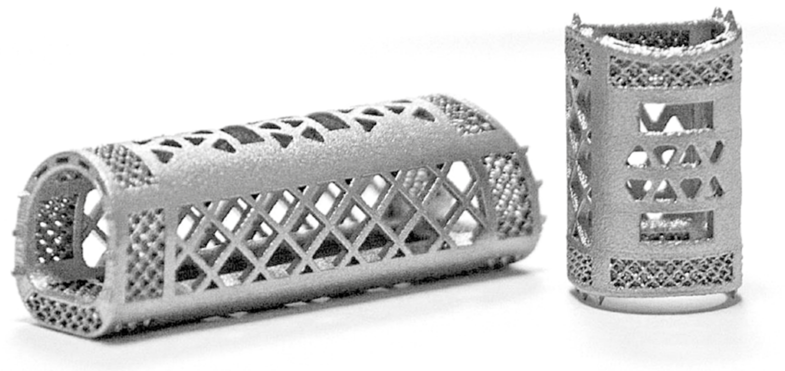
Huaxiang Group, a leading China-based medical Additive Manufacturing provider and Dr Wang Wenjun's Spinal Surgery team from First Affiliated Hospital of University of South China, have received Category 3 medical device clearance from China's National Medical Products Administration (NMPA) for their titanium porous spinal fusion cages produced on Farsoon metal AM machines. Farsoon Technologies, headquartered in Changsha, Hunan, China, reports that the spinal cage is the first approved orthopaedic implant to be additively manufactured by Laser Beam Powder Bed Fusion (PBF-LB) in China.

Compared to traditional cages, the additively manufactured porous spinal fusion cage offers an advanced solution for spinal conditions, including degeneration, fractures, deformities and tuberculosis. Being one of the key medical implant products identified by the '3D Printing Technology Application of Personalized Implant Device' project, the NMPA recognised that the implant showcased a combined knowledge in medical-grade material, AM, design software and medical device development & clinical application.

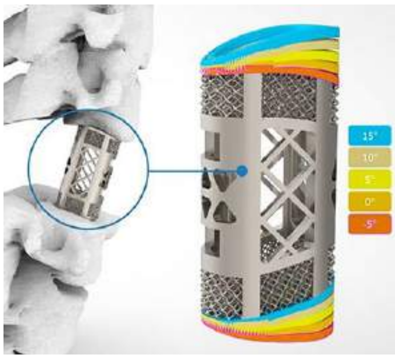
The 3D Printing Technology Application of Personalized Implant Device project is an initiative supported by the Ministry of Science and Technology in the '13th Five-Year Plan' led by Shanghai Jiaotong University's Ninth People's Hospital, with a team consisting of members from the Chinese Academy of Sciences Institute of Metal Research, South China University of Technology, Sichuan University, Xi'an Jiaotong University, Shanghai Institute of Ceramics, Hubei University, Central South University, Farsoon Technologies and Huaxiang Group.

The goal of the project is to establish and extend the application of Additive Manufacturing solutions for advanced medical devices including medical-grade material, AM machines, design software, medical device development & clinical verification and medical supply chains.

The spinal fusion cage portfolio is developed with a patient-tailored process from Dr Wang Wenjun's Spinal Surgery team for customised volume batches. The development has taken multiple iterations of structural optimisation throughout the years, with comprehensive research into over thirty mechanical properties, physical & chemical performance, biological evaluation and cytotoxicity, etc. During the clinical study phase, Dr Wang's team conducted 108 cases in five Tertiary A hospitals across the country, before it received clearance from NMPA.



The NMPA approved porous spinal fusion cage additively manufactured on a Farsoon metal AM machine (Courtesy Huaxiang Group)



The additively manufactured porous spinal fusion cage portfolio featured with a variety of geometries structures (Courtesy Huaxiang Group)

With the advanced capabilities of metal AM, Dr Wang's team together with the Huaxiang Group, are able to create a unique lattice design similar to the trabecular micro surface structure featuring customisable pore size, porosity and elastic modulus that are close to that of human bones. It reportedly helps to reduce the tension of stress, promote bone in growth rate and long-term stability.

With substantial input from surgical design and metal Additive Manufacturing, unique geometric structures with fully-customised anatomical endplates which feature curved angles and expanded contact surface topology are able to deliver the perfect anatomical match for a wide range of complex surgical conditions. The surgeons are also said to benefit from significantly faster 'on-demand' development to the production cycle for a high-quality, precise product by using Farsoon Technologies' PBF-LB machines, whereas the conventional multiple-use device usually takes months to manufacture.

"This is a ground-breaking day for metal 3D printing in the Chinese medical market," stated Li Xinghua, Head of Marketing from Huaxiang Group. "I'm grateful for joining such a strong team with Dr Wang and industry Additive Manufacturing leader Farsoon Technologies for this journey. We are very proud to contribute our effort to future patient-tailored spinal implant surgeries with the application of SLM technology."

www.farsoon.com

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Kurtz Ersa enters into metal AM market with the Alpha 140

Kurtz Ersa, a producer of components, systems and equipment for the optimisation of manufacturing processes, headquartered in Kreuzwertheim, Germany, has entered the Additive Manufacturing equipment market with the release of its Alpha 140 Laser Beam Powder Bed Fusion (PBF-LB) metal AM machine.

Said to combine innovative Additive Manufacturing technology with simple operation and lower system costs, the Alpha 140 is aimed at small and medium-size companies, particularly those in the moulding and tooling industries where the Alpha 140 is ideal for complex geometric structures such as moulds with internal, near-contour cooling. The company believes the Alpha 140 particularly shines with small batch sizes, allowing users to save on tooling, something which may also prove attractive to universities and research institutes.

During the machine's development, engineers worked to meet the desire for a simple, economical, and open architecture, as well as allowing the user to process special materials, produce customisable designs and provide geometric freedom. With these specifications, and the comparatively low costs in mind, Kurtz Ersa states that the Alpha 140 is an ideal entry point into metal Additive Manufacturing.

The Alpha 140 is a result of a partnership between Kurtz Ersa and Laser Melting Innovations (Courtesy Kurtz Ersa)

Optimised production process

The Alpha 140 utilises a 140 W fibre-coupled diode laser, enabling the production of fine details and thin wall depths, while the laser's gantry mounting enables a constant focus diameter throughout the entire installation space. Layer thicknesses between 30 μm and 90 μm allow for a component- and material-dependent optimised manufacturing process. The spindle-driven axis system allows high positioning and repeatability of the laser system, while a laminar-shielding gas flow creates optimised processing conditions for both protecting the laser optics and for the inert welding process.

The round build envelope of the machine measures 140 mm in diameter with a maximum build height of 200 mm. With a footprint of just 170 x 95 cm, and an optional integrated nitrogen generator enabling self sufficiency without an external gas supply, the 'plug and produce' machine is ideal for space-saving use in production environments and research labs alike, where connection by means of a cold appliance plug and optional air cooling enables simple installation.

The components manufactured on the Alpha 140 are said to reach strengths comparable to traditional PBF-LB machines with densities greater than 99.5%. Being up to 80% more economical, Kurtz Ersa states the Alpha 140 can offer a worthy industry contribution to the European Green Deal's goal of climate neutrality by 2050.

Available materials and parameter sets for the Alpha 140 include stainless steels (such as 1.4404), nickel-base superalloys (IN625 and IN718), tool steel and aluminium alloys (AlSi7Mg), with more materials upon request. The open system design also enables in-house material qualifications and the development of new types of materials. Because the Alpha 140 is designed as a complete AM system, it also has its own software for data preparation (either via preset parameters or extensive manual input), from component design to simulation and generation of support structures to data preparation, allowing the mapping of the entire AM workflow.

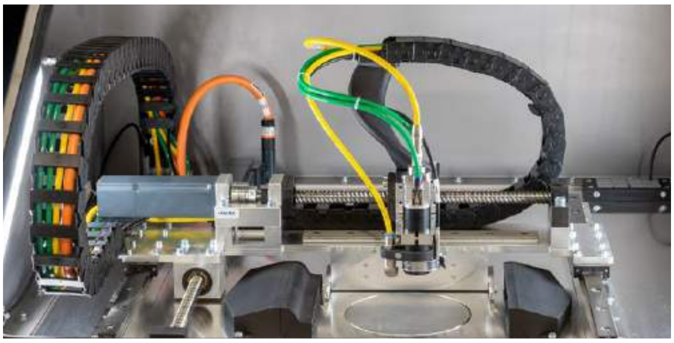
Cooperation with LMI

The Alpha 140 was developed by Laser Melting Innovations GmbH & Co. KG (LMI), a spin-off from the RWTH Aachen University, where Additive Manufacturing has been an essential part of development activities for over twenty years. The cooperation with Kurtz Ersa, with its access to a worldwide sales and service network, enabled the machine's rapid market launch.

"In Aachen, the cradle of metal Additive Manufacturing, more than 200 top developers, specialists and young talents are continuously working on the topic of Additive Manufacturing," commented Professor Johannes Henrich Schleifenbaum, one of LMI's founders. "In addition to processes and machines, we have a particular focus on the benefits for industrial users, from component design through 3D printing and post-processing to the ready-to-use component. Here, we have direct access to a wealth of experience of more than 1,000 man-years. We make this available to our partners."

After signing a cooperation agreement in August 2020, the assembly of the initial AM machine began just ten weeks later, with the first delivery taking place in December 2020. Further machines have been installed and are already in production – such as those at the German Aerospace Centre (DLR) and the Fraunhofer IWKS (Research Institution for Materials Recycling and Resource Strategies). Orders for other Alpha 140's have been confirmed, including one for the Technical University of Cologne, or are close to completion directly with industrial companies.

"3D metal printing complements our relationships in the manufacturing



The interior of the Alpha 140 shows the inert gas and axis systems. The spindle-driven axis system allows high positioning and repeatability of the laser system (Courtesy Kurtz Ersa)

An example of the particularly high degree of geometric freedom offered by AM (Courtesy Hans Erlenbach Entwicklungen GmbH)

scene and fits perfectly with our strategy 'Global. Ahead. Sustainable.', with which we present ourselves as technology leaders in our respective markets," added Rainer Kurtz, CEO of Kurtz Ersa. Together with Managing Director Uwe Rothaug, Kurtz was also pleased with the "fantastically short time to market" of the Alpha 140.

The cooperation between the companies is a classic win-win scenario. For Kurtz Ersa, the process knowledge of the LMI team in the field of Additive Manufacturing was the key to entering this new business field. For its part, LMI, as a young company, was able to utilise the sales and service channels of the more established Kurtz Ersa as a perfect complement to the roll-out of its metal AM technology.

The Alpha 140 is manufactured at the Kurtz Ersa production site in Kreuzwertheim. A 24-hour service is offered thanks to a global presence, with live presentations being available in the the Kurtz Ersa Corporation's demo centres. An Alpha 140 specific showroom is also planned for LMI in Aachen.

www.kurtzersa.com

AML3D and Austal Australia's maritime AM crane receives verification from DNV

AML3D Limited, Edinburgh, Australia, reports that maritime AM parts developed in conjunction with global shipbuilder Austal Australia, Henderson, Australia, have received formal verification from DNV, a risk management and quality assurance provider based in Oslo, Norway. AML3D produced an aluminium personnel recovery davit (crane), intended for naval applications with its proprietary WAM® Additive Manufacturing technology (a wire-based DED process also known as WAAM), on behalf of Austal.

As part of the qualification process, a three-metre long personnel recovery davit was designed and additively manufactured to meet international and naval specifications. The assembly was then function tested to more than twice its design working load. Following the successful load test, as well as non-destructive and destructive testing, the results were reviewed by all parties before the final verification statement was issued.

The additively manufactured material (davit) was subjected to extensive testing by the John de Laeter Centre and the Curtin Corrosion Centre at Curtin University, Australia. Researchers utilised advanced microanalysis instrumentation to generate high-quality microstructural information and images. In addition, the mechanical and corrosion characteristics were assessed and compared against established marine grade metals.

Andy Sales, AML3D Chief Executive Officer, stated, "We're proud to have been able to partner with Austal and demonstrate the advantages of our proprietary Wire Additive Manufacturing capabilities in the creation of the Davit Arm. Additionally, we are equally as excited to see this WAM printed component receive an official verification statement by DNV. This now offers a verification pathway for a much wider range of components that can now follow a similar validation process."

"This is a fantastic achievement by the AML3D team, Austal and our other partners in this project," Sales continued. "Working with Austal's vision for implementing Additive Manufacturing has been a further endorsement for our own business model and we're excited for the future."

Andrew Malcolm, Austal Chief Digital Officer, added that the successful collaboration with AML3D and Curtin University on the AM project highlights the many opportunities to pursue emerging technologies with the Australian industry. "Austal Australia has been working with AML3D since 2019 on the development of hybrid manufacturing approaches that put robotics side by side with our highly skilled tradesmen and women to fabricate large complex structures."

"Wire Arc Additive Manufacturing, or WAAM, has the potential to enable a productivity step change in shipbuilding, able to 3D print marine grade metal structures at a scale well beyond other commercially available metal 3D printing technologies. This DNV verification statement for the AM-produced personnel recovery davit shows that these Additive Manufacturing processes can meet our specification(s), which have been developed to fulfil the requirements to fit components to naval vessels, and we are certainly encouraged by the verification to pursue future opportunities," Malcolm stated.

AML3D sees this successful collaboration with Austal as a conduit to utilise the company's WAM technology across a wide range of marine applications. Interest in AM has reportedly grown strongly in the sector due to inherently low production runs and the specialised nature of many marine parts. It is expected that additional 'proof of concept' and accreditation processes will be completed with the wider industry during 2021 that have the potential to result in a significant order pipeline for AML3D.

www.aml3d.com

Left to right: Austal Technology Project Manager Jeffrey Poon; DNV Representative Jude Stanislaus; and AML3D Chief Executive Officer Andy Sales with a sample of the davit produced during the AM project (Courtesy Austal Australia/AML3D)

Headmade Materials enables high-end titanium pedals for bikes

Headmade Materials GmbH, Würzberg, Germany, has collaborated with Titanum GmbH, Hamburg, to produce lightweight titanium clipless bike pedals. Through the use of Headmade Materials' Cold Metal Fusion Additive Manufacturing process, the journey from initial contact between businesses to final design has taken only six months.

Rico de Wert, co-founder of Titanum, had been working on the design for the clipless pedals for a number of years, but technical feasibility and high-cost manufacturing have held the project back. Matthias Sharvogel, CEO of titanium specialists Element 22 GmbH, based in Kiel, Germany, brought Titanum and Headmade Materials together in mid-2020, a successful partnership that has resulted in bringing the new MyTi clipless pedals to market.

The sinter-based Cold Metal Fusion technology, developed at Headmade Materials, uses a titanium feedstock that can be processed on widely available standard polymer PBF-LB machines. Once the green part is built, it is debound and sintered to obtain a fully-dense metal part.

Following the production of the first prototype, where the performance was said to be outstanding, only a few details were changed before the patent was filed. The pedals have since been tested and found suitable for both mountain bike and road use by bike specialists such as Ralf Holleis at Huhn Cycles and Tom Sturdy from Sturdy Cycles.

www.headmade-materials.de
www.titanum.bike
www.element-22.com

The MyTi titanium clipless pedals will be available from summer 2021 (Courtesy Headmade Materials GmbH)

Many thousands of the clipless pedals will be additively manufactured each year (Courtesy Headmade Materials GmbH)

Orbex commissions largest industrial AM machine in Europe for rapid rocket building

Orbex, a UK-based spaceflight company with headquarters, production and testing facilities in Scotland, and design and testing facilities in Denmark, has commissioned AMCM to build the largest industrial Additive Manufacturing machine in Europe, allowing the company to rapidly build complex rocket engines. The custom-made, large-volume system will allow Orbex to build more than thirty-five large-scale rocket engine and main stage turbopump systems annually, as the company scales up its production capabilities for launches.

The multi-million pound deal was signed with AMCM, an EOS Group company that offers customised, modified and enhanced EOS machines tailored to customer requirements, following a series of successful trials building various large-scale rocket components over a number of months. AMCM will deliver a complete AM suite, with post-processing machinery and 'Machine Vision' systems, providing automatic imaging-based inspection of AM components. To accommodate the new machinery, Orbex is expanding its factory floor space by an additional 1,000 m².

The new AM machine will build rocket parts using a custom blend of metals, including titanium and aluminium, to create a lightweight system designed to withstand the temperature and pressure extremes of spaceflight. Orbex will build components such as rocket engines as a single piece, eliminating the weaknesses which can arise from joining and welding.

The AM rocket components will be critical parts of Orbex's launch vehicle, a 19 m long 'microlauncher' rocket, designed to deliver small satellites into polar orbits around the Earth. Planning permission was granted for Orbex's home spaceport, Space Hub Sutherland, at the A'Mhoine peninsula in Sutherland, Scotland, in August 2020. The A'Mhoine site is currently the only UK spaceport to receive planning permission, with construction expected to begin in 2021 and the first orbital launch expected in 2022.

Uniquely for a commercial rocket, Prime is fuelled by bio-propane, a clean-burning, renewable fuel which reduces CO_2 emissions by 90% compared to kerosene-based fuels. The Prime rocket was designed to be re-usable, incorporating a novel recovery and reusability system. The rocket has also been designed to leave zero debris in orbit around the Earth.

"Although our rocket engines and other critical systems are already quite mature after years of testing, a large-scale in-house 3D printing system like this gives us far greater speed and agility as we ramp up production," stated Chris Larmour, CEO of Orbex. "It means we can continue to iterate and drive up performance even further. Longer term, as we get ready for multiple launches per year, it will give us greater control over our costs and supply chain. After exhaustive trials, the results we've seen from AMCM were very successful and we're confident that we've made the right choice of partner."

"Investing in a large-scale 3D printing system like this says a lot about Orbex's ambition in the European spaceflight sector," added Martin Bullemer, MD of AMCM. "If they are to lead the European market, they need the production reliability and speed that a large-scale 3D printing system like this will give them. And although this is a major purchase, it will allow for significant cost control for Orbex in the years to come."

Orbex recently announced that it had secured $24 million in a funding round led by BGF, said to be the UK's most active investment company, and Octopus Ventures, one of the largest VCs in Europe. The additional funding brings significant new investment in high technology employment opportunities and large-scale production facilities in the Highlands region of Scotland.

www.amcm.com
www.orbex.space

The new AM machine from AMCM will allow Orbex to build more than thirty-five large-scale rocket engine and main stage turbopump systems annually (Courtesy Orbex)

Tekna begins trading on Euronext Growth Oslo

Tekna Holding AS, Sherbrooke, Quebec, Canada, has begun trading on Euronext Growth Oslo, a multilateral trading facility operated by the Oslo Stock Exchange. The shares in the new issue were sold at NOK 27 (€2.7), corresponding to a pre-money market capitalisation of NOK 2.7 billion (€270 million) for the company.

The company explains that it wants to invest in further growth and, prior to the listing, Tekna conducted a private placement, raising NOK 750 million (€75 million) in new equity. The placement was said to be multiple times oversubscribed and attracted significant interest from domestic, Nordic and international investors including cornerstone investors such as Lugard Road Capital (managed by Luxor Capital Group), Norron, Andenæsgruppen, Blackcrane, together with Storebrand and Delphi funds.

"This IPO marks the start of a new and exciting chapter for Tekna as a publicly-traded company, and propels us forward in our vision of taking a leadership position in three multi-billion-dollar markets: Additive Manufacturing, printed electronics and energy storage," stated Luc Dionne, Chief Executive Officer, Tekna Canada. "Supported by a strong portfolio of plasma-based technologies, we have a proven track record of scalability, with over 80% recurring sales of advanced materials. Our business model serves as a solid platform for increased market shares and strong revenue growth. This listing on Euronext Growth, combined with the successful private placement, provides us with a strong financial platform to accelerate our value creation strategy."

Over the last thirty years, Tekna has developed industry technology and know-how to produce high-purity metal powders for applications such as Additive Manufacturing in the aerospace, medical and automotive sectors, as well as optimised induction plasma systems for industrial research and production.

Morten Henriksen, chairman of Tekna Canada and Chief Executive Officer of Tekna Holding AS, commented, "Built on three decades of delivering excellence, Tekna has proven and commercialised technology with a global network of over 200 blue-chip customers and an ambitious growth strategy towards 2030. The listing on Euronext Growth is an important part of this growth strategy and we look forward to continue the Tekna journey as a listed entity."

www.tekna.com

FAU invests in Civan's Dynamic Beam Laser for metal AM research

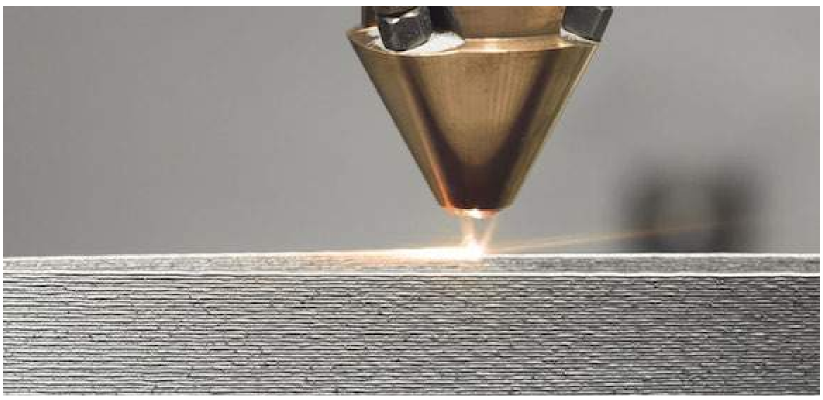
After being selected by the German Research Foundation to invest €2.25 million into the study of industrial metal Additive Manufacturing processes, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Germany, has selected Israel's Civan Advanced Technologies' OPA-20 Dynamic Beam Laser for its research into Directed Energy Deposition (DED).

Dr Eyal Shekel, Civan's CEO and founder, commented, "We are proud and honoured to have our laser placed in the leading institute under Prof Schmidt's management and become a part of such a unique and important journey. I would also like to thank the Israeli Innovation Authority for supporting the development of this technology and product."

Civan is reportedly the only company in the world offering the Dynamic Beam Laser technology, which allows manufacturers to control beam shape, frequency, sequence and focus steering to eliminate spatter, and increase welding power and speed. With these advanced beam-shaping capabilities, FAU sees this technology as a possible pathway to countless new applications.

"We strongly believe that Dynamic Beam Shaping will open new possibilities in material processing, and are very excited to start using this groundbreaking technology," stated Prof Dr-Ing Michael Schmidt, chair of the FAU's Institute for Photonics Technology. "Dynamic Beam Shaping brings novel capabilities that will allow us to achieve major progress creating never-before-seen capabilities for next generation 3D printers."

www.fau.eu
www.civanlasers.com



Fraunhofer IAPT and Fiat Chrysler's additively manufactured wheel carrier with integrated brake caliper (Courtesy Fraunhofer IAPT/ Fiat Chrysler Automobiles)

Mauro Antolotti and BEAMIT: The story of Italy's leading AM parts producer and its founder's view on the industry

From machine producers to part manufacturers and end-users, the Additive Manufacturing industry is rich in success stories that are the result of one person's vision of what the technology could deliver. In the case of BEAMIT, Italy's largest metal AM parts producer, it was the vision of the company's founder, Mauro Antolotti. Here, Luca van der Heide interviews Antolotti for *Metal Additive Manufacturing* magazine and explores the company's development, his view of the industry, and ambitions for the future.

BEAMIT, an Additive Manufacturing company founded in 1997 when AM technologies were in their nascency, is today the largest AM manufacturer in Italy and one of Europe's leading players. Born from the vision of its founder, Mauro Antolotti, and sustained by careful planning and a strategic vision, the company has not only been able to survive the coronavirus (COVID-19) crisis, but to more than double its revenues throughout the period, culminating in an increase of 130% in 2020.

At the root of BEAMIT's success is Antolotti, the 'heart and soul' of the company, who shared with *Metal Additive Manufacturing* magazine how the business's current situation is the result of many years of experience in the industry, careful timing, and well-planned choices. After recent acquisitions and a major international partnership, Antolotti and his team are now eager to face the challenges of a market which is anticipating an increasingly widespread use of AM technology in industry.

"There is no doubt that AM processes will very soon become more accessible to the wider public," stated Antolotti, "but, first, we will have to navigate a crucial transition, from a technology that is still a prerogative of the richer markets to one that is available to everyone." This vision is of a more affordable and automated AM value chain, leading to mass production and the replacement of more inefficient and restrictive industrial processes. But how will BEAMIT get there?

Fig. 1 Mauro Antolotti founded BEAMIT in 1997. Today the company is one of Europe's leading manufactuerers of metal AM components (Courtesy BEAMIT)

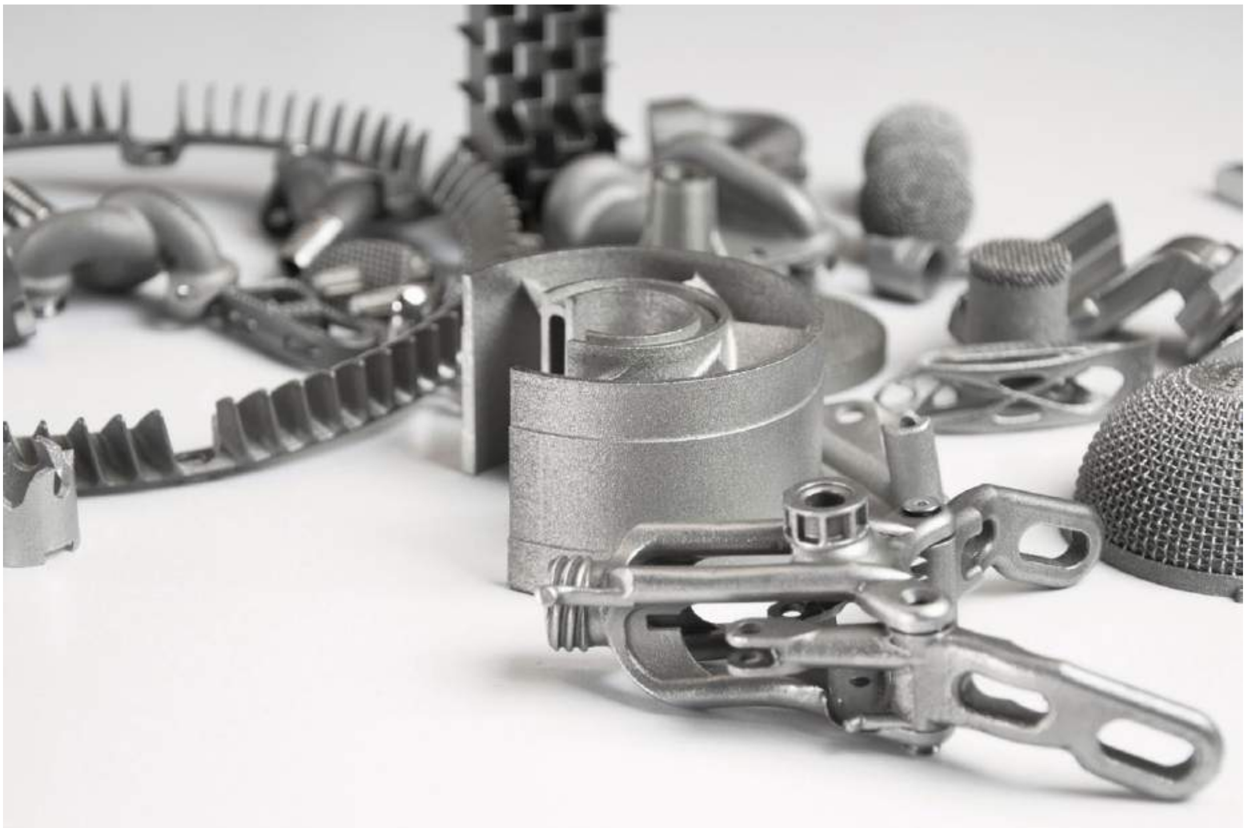


Fig. 2 A selection of metal additively manufactured parts produced by BEAMIT (Courtesy BEAMIT)

The BEAMIT story

Based in Emilia-Romagna, one of Italy's wealthiest regions and a globally recognised centre of industry, BEAMIT has grown from a startup with just a handful of employees to a company with more than a hundred employees distributed across five plants, as well as commercial offices in France, Germany, the United Kingdom and Japan.

Motivated by the commercial and technological opportunities in what is still a relatively new industry, BEAMIT opened its doors to international collaboration in 2019, when global engineering group Sandvik acquired a significant stake in the company. Sandvik has more than 150 years of advanced materials expertise and offers what is believed to be the widest material range for Additive Manufacturing on the market. By joining forces, the two companies now have leading expertise across the AM value chain, which is crucial to the industrialisation of the technology. In 2020, BEAMIT then acquired a share in the startup company Pres-X, which specialises in post-processing for metal AM, and the same year it fully acquired its main competitor in Italy, the AM service provider Zare.

The business has been built on solid foundations that are grounded in research and development. This has allowed it to focus on both its technical capabilities and quality management. Recently, it received its seventh NADCAP certification for its aerospace related activities. Financial stability has also been a consistently high priority, with the company having received CRIBIS Prime Company certification in recognition of the highest levels of stability and reliability in its business activities, something that has been granted to only 7% of six million candidate companies.

Such achievements are not the result of mere business acumen, but, rather, of Antolotti's near fifty years of expertise in the industry and a close familiarity with the processes he is involved with. Since his modest beginnings in the small town of Fornovo, Antolotti has spent much of his life in search of innovations that would allow him to differentiate himself from the competition. When ground-breaking surface coating and heat treatment technologies first arrived in Italy from the USA, making it possible to extend component durability and improve quality, he seized the opportunity and became an expert in these special processes, quickly extending his experience in the following years to a range of sectors, including aerospace.

In 1997 Antolotti recognised the potential of Additive Manufacturing and invested. "BEAMIT has reached where it has today because it benefitted from strategies learned over many years of special processes and application development," Antolotti commented. "My experience in special processes taught me that, with technologies such as AM, it is crucial to have every variable under control, at

Fig. 3 Kristian Egeberg, president of Sandvik Additive Manufacturing, and Mauro Antolotti at the signing of the partnership between the two companies in 2019 (Courtesy BEAMIT)

every stage of the value chain, and to recognise that, in this market, only those who innovate and keep innovating can survive the fierce competition."

These words seem to encompass the whole of Antolotti's philosophy and entrepreneurial agenda: Innovation. In 1997, BEAMIT was in a research phase and could only work with polymeric products. However, as soon as the Additive Manufacturing of metals became possible, around 2004–2005, BEAMIT did not hesitate to set up its first metal AM facility. This was not for the purpose of doing business, since there was no business to be made, but rather to develop the technology and get it ready for market. "The market was only going to open its doors to the technology if we could demonstrate that its mechanical characteristics were reliable and repeatable. To achieve this goal, we worked in close contact with universities and research centres for ten years," explained Antolotti.

It wasn't until around 2014–2015 that the technology was finally accepted into the market, stated Antolotti. That's when BEAMIT's consistent efforts to innovate proved to be a winning strategy. "You can have as much capital as you need," said Antolotti, "but, if you do not spend it on innovating, you will be out in no time. Important international customers see a reliable partner as one who continues to offer the latest available materials and technology, because they know it will give them the edge they need to differentiate themselves from their competitors. This is especially true in times of crisis."

As 2019 approached, a year that would turn out to be pivotal for the company, BEAMIT realised that the objective of becoming one of the leading AM manufacturers in Europe was close, but that a leap of faith was needed. Antolotti knew that to reach the next level required more than just capital: he needed to pair up with a strong industrial partner with an international reputation, which had a strong metallurgical background, a shared ethos, and that could bring longevity and credibility to the business.

Sandvik, which already had a world renowned metal powder manufacturing business as well as advanced metal AM research activities, proved to be an ideal match, and acquired a 30% stake in BEAMIT in July 2019. "Sandvik came to us spontaneously," said Antolotti. "They came to visit our facilities and it was love at first sight. They are honest, respectful people and, after one year and a half, we are as committed as ever."

Partnering with Sandvik was the qualitative leap they were looking for. "Many doors opened at a global level and, by assimilating our market strategy to that of a business with a 150 year-long history of successes, we know we have consolidated a future for our company. In this sector, you are chosen not only

Fig. 4 A motorsport exhaust system component designed for AM and built from a nickel-base superalloy (Courtesy BEAMIT)

on the basis of your technical resources, but also of financial stability and the guarantee to still be around in twenty, thirty years."

With the capital provided by Sandvik, BEAMIT proceeded to acquire its main competitor, Zare, and the startup Pres-X. With these two acquisitions, the company boosted every aspect of the AM workflow, maximising customer care and value through a fully-integrated value chain and optimised post-processing solutions.

Although these developments stem from the same drive to provide all-round customer support and the highest product quality that was established many years ago, they are also part of a master plan to push the boundaries of AM processes and overcome the compartmentalisation of expertise that, according to Antolotti, is currently preventing the technology from expanding into true industrialisation.

The state of the AM industry and its biggest challenges

Despite recent major technological advances and the success of companies such as BEAMIT, Antolotti believes that the overall AM sector has also been under serious financial stress for the past year and a half. "Since many of the industry's gurus sang the praises of this market five or six years ago, predicting extremely positive growth rates and future trends, it has been a gold rush. After years of continued growth, 2019 saw a deceleration for everybody: small, medium-sized and large enterprises. This tecnology is, still today, a technology for rich markets so, after years of economic boom, this was just the logical consequence. Impressive production capacity was created, but since the market was not yet large enough to justify such capacity, many companies found themselves with idle machines, especially the small- and medium-sized companies that did not have enough capital to spend on innovation. Some manufacturers started struggling to draw efficiency and profitability from the machines they had invested in and, as a consequence, machine suppliers aren't selling so many machines."

Reducing costs is, therefore, the number one priority. "There are technological barriers," stated Antolotti, "but the world today has all the resources necessary to overcome them. We at BEAMIT have run and keep running simulations of mass production projects. However, mass production is not sustainable in the long run at today's technology costs. There is sometimes a gap between what the client wants to spend and the actual cost of production. The technology, therefore, must become more cost efficient if industrialisation can be possible in other industries than, for example, aerospace and medical."

Hindrances to the wider adoption of AM in the industry do not seem to be related to misconceptions of the technology itself, but rather the lower costs of the main competitor, the foundry. Casting processes are today completely automated and cost much less. "Unlike casting, the process that is most widely used in industry," Antolotti explained, "AM is heavily dependent on human operators, and there are a number of tasks that cannot be automated today. This is the next crucial innovation: to design machines that are self-sufficient and independent of human monitoring, that can operate day and night, with the same degree of reliability, but much faster and, most importantly, that can be cheaper to purchase and operate. In other words, the smart AM factory. This means that the machines should be entirely re-designed in the direction of automation and given many more lasers per machine so as to dramatically reduce build times. The whole range of post-additive processes should also be industrialised. Right now, they are far too disjointed."

Antolotti believes that automating AM processes would considerably lower overall costs, with the result that the companies that are still forced to use casting processes because of their low cost could make the move from the more wasteful, environmentally polluting and high-CO_2 emitting foundry to a more efficient and cleaner technology.

Major markets and applications

It should come as no surprise that the markets that profit most from AM technologies are those that particularly benefit from its unique potentialities and are resourceful enough to absorb the costs. These are, for the most part, rich markets where time savings in development, sustainability and efficiency concerns are absolute priorities.

For the gas turbine and aerospace markets, AM processes have the two-fold advantage of curbing the environmental impact of turbines and aircraft engines, while allowing companies to reduce costs. "Where, with old processes, a turbine burned as much as 300 litres of oil," explained Antolotti, "by utilising AM technology they consume around 260 litres, producing the same energy with about 15% reduced waste. Financial advantages also come into play, as aircraft burn less fuel and, in turn, airlines see considerable cost savings. This proves that, even though the technology is expensive, the companies that can afford it end up saving money in the long term, while reducing carbon emissions at the same time."

Another crucial contribution to sustainability in the aerospace sector is weight reduction. "The aerospace sector is constantly searching for ways to reduce the weight of aeroplane components. We have produced components via AM whose final weight is up to 60% lighter than production via conventional technologies, and this, of course, represents a massive difference."

Fig. 5 A heat exchanger, originally developed in partnership with Politecnico di Milano, produced as a single piece in an aluminium alloy for high-performance motorsport applications (Courtesy BEAMIT)

Fig. 6 Some of the first metal AM applications were in the area of medical implants. This tibial implant is produced in Ti6Al4V and CNC machined (Courtesy BEAMIT)

Fig. 7 Additive Manufacturing can be used for complex geometries with extremely small and intricate internal channels that would be difficult, if not impossible, to obtain with traditional technologies. This AM aerospace component has been cut open to show such internal channels (Courtesy BEAMIT)

Fig. 8 EOS M 400-4 Laser Beam Powder Bed Fusion machines at BEAMIT (Courtesy BEAMIT)

In comparison with conventional manufacturing technologies, AM also represents a huge step forward for both design freedom and time efficiency. The possibility for engineers to create complex designs through the use of specialist software means that there are virtually no limitations for designers when coming up with innovative products. At the same time, no tools or moulds are needed, saving a lot of money and time. "AM machines allow our customers to obtain very complex components in very little time," said Antolotti. "Let's take, for example, the world of motor racing. Before Additive Manufacturing, a team had to design a component for the following season, and it would take around ten months to end up with the part. Now, they can have the same part available in two to three weeks; development times are drastically shortened."

"Let's take, for example, the world of motor racing. Before AM, a team had to design a component for the following season, and it would take around ten months to end up with the part. Now, they can have the same part available in two to three weeks..."

Smaller markets and the Italian manufacturing landscape

Whilst the majority of BEAMIT's larger customers are the industrial gas turbine, space, aerospace and defence, motor racing, biomedical and general industrial sectors, they are not the only markets that benefit from AM. There are a multitude of small and medium-sized companies that also use the technology, albeit in a more occasional, selective way.

"If there were doubts on whether AM is a technology worth investing in, they remain in the past," said Antolotti. "Today, everyone seems convinced of the advantages of Additive Manufacturing and every major company now appears to have an AM expert. However, AM is utilised, for the most part, in an extremely selective way: only for small and special components, and only when a company has the funds to invest in higher-quality products. At BEAMIT we have more than 350 active customers, many of which could be categorised simply as industrial businesses. Individually, such businesses take up a relatively small percentage of our workload but, collectively, their output adds up to an impressive quantity of 'niche' AM applications. An example is the packaging sector, a very important sector in Italy and one of the strongest industries here in the Emilia-Romagna region."

The Italian market has grown considerably in recent years, becoming an important market for big OEMs, as well as maintaining its historic reputation for excellence in small and medium-sized industry. Antolotti notes that BEAMIT's success hasn't been by chance, but has, instead, been greatly affected by its position in the very active and innovation-thirsty Italian manufacturing landscape. "In Italy, we have a proliferation of curious entrepreneurs with a strong drive to innovate and to be major creators of technological breakthroughs. Unfortunately, despite the recent success of leading manufacturing companies like us, Italy is still greatly undervalued. However, I do hope that, in the light of the evident fast expansion of major Italian capabilities, as well as the recent mergers and acquisitions, Europe will finally recognise the importance of Italy in the international marketplace."

Fig. 9 SLM Solutions PBF-LB machines at BEAMIT (Courtesy BEAMIT)

Fig. 10 View of the AM production area at BEAMIT (Courtesy BEAMIT)

Machines and manufacturing

To grow the recognition of Italian industry in the global AM market is even more relevant as 2021 begins, with BEAMIT now showcasing one of the largest AM machine installations in Europe. The company has nurtured relationships with a number of AM machine makers since the technology first became available. In 2017, the company signed multi-machine, long-term deals to purchase an increasing number of state-of-the-art machines in the following years. Last year, BEAMIT signed a letter of intent to purchase fifteen more AM machines, bringing its total capacity to around fifty.

Today, the company offers both Laser Beam Powder Bed Fusion (PBF-LB) and Electron Beam Powder Bed Fusion (PBF-EB) Additive Manufacturing. Antolotti explained that whilst there are fundamental technical differences between PBF-LB and PBF-EB processes, from a customer perspective the main relevance is the type of materials they can be used to process. Whilst both can be used to produce nearly 100% fully dense metal components, PBF-EB is able to process alloys such as titanium-aluminides that simply cannot be manufactured using laser-based AM.

The company's operations are designed to be highly efficient, operating around the clock with advanced process monitoring. Extensive post-production services

Fig. 11 A large format Concept Laser X Line 2000R PBF-LB machine (Courtesy BEAMIT)

and quality systems ensure that the company manufactures products that are always flawless and faithful to the customer's vision.

It is worth stating that, as well as enabling applications that offer improved efficiency and sustainability, Additive Manufacturing is also a clean technology in itself. AM machines consume significantly lower levels of electricity than conventional manufacturing processes. As opposed to casting and other subtractive industrial processes, AM machines obtain finished products not by removing, but by adding material, dramatically minimising waste. PBF-LB machines consume relatively low amounts of electricity, around 4–5 kW per hour.

Antolotti could not stress enough how, in order to ensure the correct functioning of the machines and maximise the potential of the AM process, it is fundamental to keep every variable of the process under control and to guide and support the customer from start to finish. BEAMIT's experts work side by side with the customer on an application's design, providing ongoing support every step of the way to ensure that a final product is as optimised as possible, and according to the client's specifications.

"Our responsibility is to make sure the machines are constantly calibrated by highly-specialised personnel," he stated. "This calibration is certified, registered and archived, always at hand in case of need. We have to keep traceability of everything: from powder production to laboratory tests, every process that happened in the last thirty years is documented. This is a necessary safety measure to make sure that, if a problem arises, we can immediately call the technicians and solve it. If

"Antolotti could not stress enough how, in order to ensure the correct functioning of the machines and maximise the potential of the AM process, it is fundamental to keep every variable of the process under control and to guide and support the customer from start to finish."

something is slightly off, the quality system of the company notices right away, and intervenes."

"This is why it is not just important, but decisive, to be involved in the complete process, from machine development to post-processing," continued Antolotti. "BEAMIT has the most integrated value chain, and this will be further expanded in the coming years. This is the only way that we can guarantee complete reliability to the customer. We want to have the entire process in house, so that security can be further improved, and customer care elevated to the highest possible standards."

The present and future

It is thanks to this resilient and advanced value chain that BEAMIT was able to face the coronavirus pandemic and come out of it stronger. While the effects of the pandemic have made, and are still making, many companies suffer, the AM sector has been impacted only indirectly: many companies had to shut down not for a reduction in demand, but because it was impossible for them to react quickly to the crisis. If BEAMIT was able to see constant growth and even an increase on its profitability, it was in large part thanks to careful planning and its consolidated position as a leader in the industry.

"When the pandemic struck," said Antolotti, "we were seen as a positive example of how to survive such a crisis thanks to our integrated value chain, and we were therefore asked to contribute in a more substantial way to the biomedical sector. For this reason, in January 2021, we launched a new brand, Proxera®, with a dedicated facility specialised in highly-advanced biomedical and dental applications. When the demand came, we were able to respond quickly, because we were already equipped to do so and had already proved to have a credible, sustainable solution. At the same time, we were greatly helped by the fact that, at the end of 2019,

Carboni e Metalli: BEAMIT and Bercella explore combining metal AM and carbon fibre composites

As part of the 'Carboni e Metalli' venture of Bercella SRL and BEAMIT, The Lunar Project, created to celebrate the 50th anniversary of the first steps taken on the moon, explores the potential of combining carbon fibre composites and metal Additive Manufacturing.

Behind this project are two friends: Massimo Bercella, CEO at Bercella, and Michele Antolotti, son of Mauro Antolotti and Head of Engineering and R&D at BEAMIT Group. The Lunar Project represents not only their common passion for design, but also their interest in promoting and exploring the use of composites and Additive Manufacturing outside the traditional niches of the aerospace and motorsport industries.

The Lunar Project is based on a reimagining of an old KTM 250 GS motorbike with a futuristic approach, combining vintage details such as a steel frame and a massive 2-stroke engine with the most advanced current technologies: a carbon fibre sub-frame, carbon fibre/AM titanium rear swingarm, and AM aluminium front fork mounts, to name a few. The bike has been presented at bike festivals around the world.

More information: www.bercella.it/en/stories-en/a-story-of-ordinary-technology-the-lunar-project/

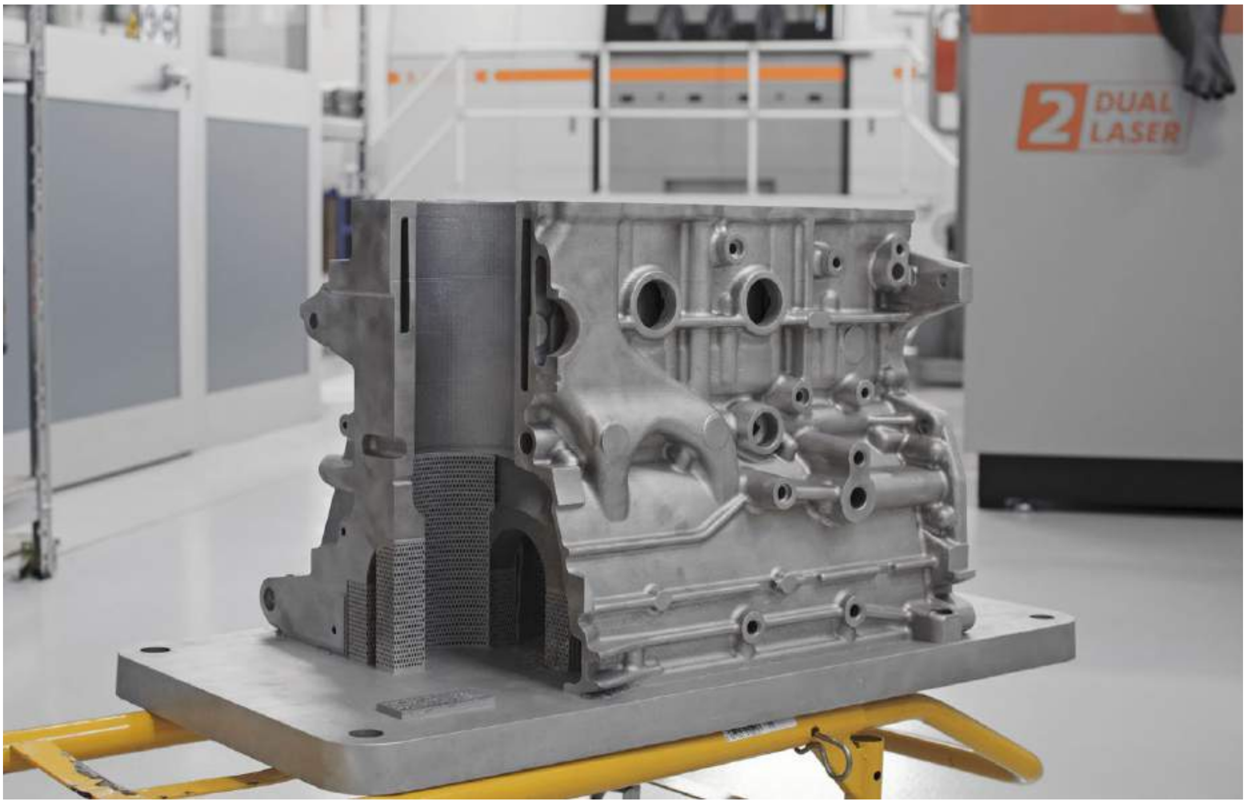


Fig. 12 Light alloys such as aluminium are ideally suited to single-piece AM engine blocks for motorsport (Courtesy BEAMIT)

we already had orders planned for the whole of 2020. So, even though the flow of incoming orders did slow down, our turnover has kept growing dramatically in the last year."

Thanks to its position in the market, BEAMIT benefits from an important competitive advantage, and Antolotti predicts another year of growth for 2021. "As soon as the marketplace returns to a normal and steady pace, there will be many opportunities to seize. The future is full of potential for organic and inorganic growth, as well as global market expansion."

Together with Sandvik, the BEAMIT Group already offers an end-to-end process covering the full AM value chain, as one of very few specialist AM service providers. "We now continue to build for a future where we will add increased customer value and productivity through further factory automation and digital integration, thereby taking the lead in terms of helping the AM industry reach the plateau of productivity it needs to reach."

Although Antolotti remains discreet when it comes to future projects for the company, he has open and clear ideas on the future of the technology. "The goal of achieving a completely automated, smart AM factory is not that far away – but in order to unlock the technology's true potential, it is necessary to bring together the areas of expertise that remain, at this moment, disjointed. Today, there is no company that has all the expertise needed. We are aware of this and vouch to act as a promoter and facilitator of this process in the coming years. Everyone has a part to play. Now, we have to continue our journey to put all the pieces together."

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In our fast moving industry...

As this issue of *Metal AM* magazine was going to press, news broke of BEAMIT's purchase of UK-based metal AM parts producer 3T Additive Manufacturing. Read the full story on page 9 of this issue.

Why do we need Women in 3D Printing? The what, the who, and the why of the blog that became a movement

Since 2014, Women in 3D Printing has grown to become a highly visible and influential international organisation. But what does the movement stand for, why is it proving to be so popular, and where does it go from here? *Metal AM* magazine's Emily-Jo Hopson-VandenBos spoke with the group's founder, Nore Toure, and fifteen members about their views of the organisation and the current status of women in the industry. These conversations reveal not only the challenges that we face to improve diversity in its broadest sense, but also the tangible benefits that members are seeing at both the personal and organisational level.

Between January 27–28, 2021, the TIPE Women in 3D Printing conference hosted 147 women speakers on its programme of over forty presentations, and was attended by 1,600 participants. Across the two-day programme, supported by 120+ participating companies, could be found a who's who of AM industry talent: from the five women appearing on the 'Being a CEO in AM' panel on day one (Fig. 1), to leading figures in aerospace and automotive AM, to a crop of high-level global researchers. It would be fair to say that, for the first conference held by non-profit organisation Women in 3D Printing (Wi3DP), the scale of success and surrounding industry buzz was a surprise to many.

Since the spread of coronavirus (COVID-19) early in 2020, leading to widespread travel bans and industry disruption, the vast majority of industry events have moved online, with mixed results. While the energy and willingness to attend events from home was high in the early months of the pandemic, twelve months on, 'Zoom fatigue' and a rather jaded view of the content offered at some digital events has, to some extent, diminished collective enthusiasm.

The TIPE conference, however, saw a renewed level of enthusiasm for all involved, speakers and attendees alike. Why? Perhaps this can be put down to the speaker list: In an industry made up, according to the most recent statistics held by Women in 3D Printing, of only 13% women, and with only 11% of businesses owned or managed by women, the organisers of TIPE filled two days of high-level presentations with a 100% female speaker list. Compare this to the programmes of the majority of industry events and it becomes clear where TIPE found the novelty factor to engage a somewhat fatigued AM community.

Fig. 1 Screenshot from TIPE Women in 3D Printing conference panel Being a CEO in AM. From left to right: Moderator Debbie Holton (Managing Director, Industry Events, ASME), Melanie Lang (CEO, FormAlloy), Christina Perla (CEO, Makelab), Ellen Kullman (President and CEO, Carbon) and Kay Matin (President, AlphaSTAR) (Courtesy Women in 3D Printing)

Fig. 2 Screenshot from TIPE Women in 3D Printing Conference panel Power Women, featuring, from left to right: Moderator Sarah Goehrke (Founder, Additive Integrity), Marie Langer (CEO, EOS), Sonita Lontoh (Global Head of Marketing/CMO, 3D Printing & Digital Manufacturing, HP), Michelle Bockman (CEO, 3D Control Systems) and Vicki Holt (CEO, Protolabs) (Courtesy Women in 3D Printing)

This is not to criticise those other events in the calendar: AM as an industry consistently produces some of the most engaging technical and business conferences in the manufacturing space, with high-level speakers and content in no short supply. The availability of 147 women speakers at TIPE, however, the majority of whom had never appeared on the same programme, represented a groundbreaking moment for the industry, and women in AM in particular. By nature of the industry's gender make-up, on a typical conference programme of approximately 150 speakers, comparatively few women are featured – indeed, the existence of a single all-woman panel at a typical industry conference is notable. It is clear that the shake-up offered by TIPE didn't appeal only to the industry's women; of the attendees, a large portion were male, and feedback from all genders was overwhelmingly positive and receptive to the change that the event represented.

> *"By nature of the industry's gender make-up, on a typical conference programme of approximately 150 speakers, comparatively few women are featured – indeed, the existence of a single all-woman panel at a typical industry conference is notable."*

Though TIPE entered the calendar as a brand new feature, Women in 3D Printing has been around, and growing, since December 2014. The organisation was founded by Nora Toure, at the time General Manager & Director of Business Development at Sculpteo and now serving as Director, Sales and Service Factory Operations at Fast Radius, Inc., a global manufacturing services company based in Chicago, USA.

Toure founded Women in 3D Printing, initially, to share the stories of the women shaping the space, many of whom had come from outside the AM industry and brought with them diverse, cross-industry experience. This aim is still central to Women in 3D Printing: each week since its founding, the organisation has highlighted one woman in AM, building an extensive library of female leaders in the industry – including engineers, business professionals, teachers, researchers, artists, designers and others – in interviews which highlight their achievements and offer them the opportunity to share their viewpoints, ideas and advice on AM.

Since 2014, Women in 3D Printing has branched out into eighty global chapters, with regional chairs and ambassadors worldwide hosting regular chapter meetups which range from networking socials, in-person and via Zoom, to discussion panels and company tours. Women in 3D Printing further aims to facilitate a more inclusive and diverse AM workforce by hosting a packed job board and female industry speakers database on its website, and monitors gender diversity in AM through industry surveys and an annual statistical report. More recently, its efforts have expanded to focus on filling the oft-spoken of talent gap in AM through the establishment of a youth initiative, Wi3DP Next Gen, headed by Janet Kar, Head of Marketing at Wi3DP and SVP Digital Transformation at Link3D.

Criticisms faced by Wi3DP

As with almost any social or political movement, the sharp growth in the visibility of Wi3DP from its inception to the present has exposed its founders, ambassadors and proponents to criticism from certain spheres of the Additive Manufacturing community, typically in the realm of social media. The strongest criticism Toure and her ambassadors face is the accusation of 'reverse sexism', with some questioning, for example, why there is no 'Men in 3D Printing', and noting that the existence of such an organisation would be seen as outdated and sexist.

Other critics might dismiss the need for the movement, believing that women are well-enough represented in the industry as it stands, or that a lack of female visibility is due either to a lack of merit or interest in careers in AM, as opposed to a lack of opportunity. Some may even brush the organisation off as little more than a social club: a chance for women to drink wine and have a chat once a month on the company expense account!

In the period from January to April 2021, I interviewed Nora Toure and fifteen other members of Women in 3D Printing, who shared how they would respond to those critics, their respective experience of the organisation's benefits, their perception of the number and status of women in the industry, and how Women in 3D Printing is helping to promote AM to a new generation of talent. The women interviewed here are employed in a range of positions in the AM industry, and include the presidents and CEOs of major businesses; sales and marketing professionals; academics; application engineers; research and development professionals; recruitment specialists and private consultants.

As a woman in AM myself, I can't claim an unbiased view of this debate; the experiences related by the interviewees in this article reflect experiences that I have shared, and the discussions which Wi3DP's founder, members and ambassadors have had with the group's detractors closely echo conversations I have had with people both in- and outside of the industry on the same issues.

It is my hope that, in sharing the insight gained from these interviews, I can offer a space for the organisation's members to explain and, perhaps, justify the group's existence to those who remain dubious of its value or place in the industry.

The story of Women in 3D Printing

I spoke to Nora Toure on a Zoom call shortly after International Women's Day 2021, as the latest in a barrage of interviews which had kept her busy leading up to, through and after the occasion. Calling in from her home in Denver, USA, Toure spoke to me about the experiences which drove her to establish Women in 3D Printing, the current status of the organisation and the AM industry, and her plans and hopes for the future.

Like many in this industry, Toure did not pursue AM as a career, but found her way into the field somewhat by chance in 2010. "It was mostly luck. I had no idea what 3D printing was," she explained. In fact, French-born Toure had recently graduated law school in Paris when her interest shifted to a career in sales and business. After returning to school for a master's degree in business management, she was offered the option of pursuing end-of-year internships at a number of companies, one of which was Sculpteo, the online Additive Manufacturing service platform, now a brand of BASF. "When I saw the printer, it was really appealing to me," she recalled. "I thought, 'woah, I think I get that – that's pretty cool.' I wanted to do that."

While some of the other companies at which internships were offered were far more established, Toure followed her gut, took the risk, and joined Sculpteo, where she set about getting to grips with a new technology and industry. "I was lucky to have a really good team around me who helped me, and whose engineers were patient with me and taught me everything I knew about 3D printing in my early days. Customers, too, were really generous in sharing about their projects, and I absorbed it all."

Though her experience at Sculpteo in France was overwhelmingly positive, it was on moving to the USA in 2012 to open the company's first North American facility that the seed of Women in 3D Printing was planted. "The first two years I was in the US, it was basically just me – we had a

Fig. 3 Nora Toure, founder and principal of Women in 3D Printing (Courtesy Women in 3D Printing)

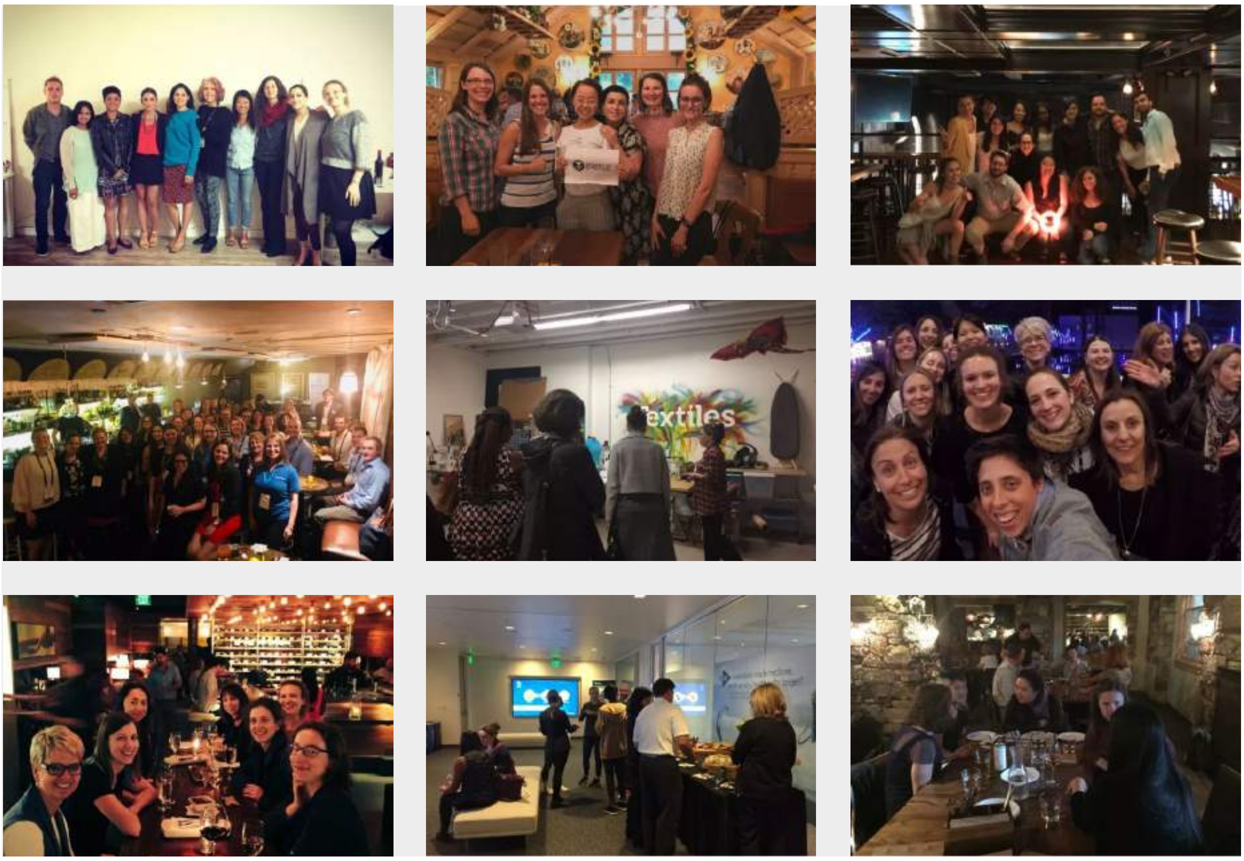

Fig. 4 Pictures from just nine of eighty Women in 3D Printing chapters around the world (Courtesy Women in 3D Printing)

few people coming in and out to help us, and I had the support of the team in France, but physically, it was me, in San Francisco, working from a co-working space," she explained. "Developing my personal network so that I could be representative of the company and develop the business was harder than I thought it would be; being twenty-four and coming from Europe, I thought I knew everything about the USA and would just have to do everything I'd done in Europe, but I had no clue."

As she sought to build her network, Toure attended every conference she could think of, and was surprised to find it an often-uncomfortable experience. "I didn't necessarily feel welcome," she stated. "I believe there were a number of reasons for this: I was a foreigner, I was young, I was a little bit shy and unsure of my place, I was not an engineer and could not necessarily pick up on some of the engineering-level conversations you can have at conferences, and I was a woman." While she was unsure which of these factors was predominant in making her feel unwelcome, Toure explained that, *as* a woman, "I had a few awkward situations – really awkward situations – which were not necessarily pleasant."

While she is quick to clarify that none of these situations were "particularly dramatic," Toure recalls the overwhelming impression she received. "You don't feel in your right place. You think, 'I'm not sure I belong here.'" A recurring trade show experience Toure recalls will be all too familiar for many women reading this article: "A number of times, I had a male intern with me and found that when I tried to engage with men and women, they would say, 'no, it's ok, I'll talk to the engineer over there.' He wasn't an engineer, he was my sales intern. This was really frustrating then, and though it happens a little less than it used to, it's still really frustrating now."

It was almost too much. "I told my husband I wanted to quit the entire industry – not because of my company, I loved working for Sculpteo, but I didn't know what I was doing here, I had no idea it would be so hard, and I felt like nobody was helping me." Toure's husband's response was simple – "He told me, 'you're not a quitter, you're going to find a solution, you just have to think about it.'"

Toure thought about it, stopped trying to build a network in places where she felt unwelcome, and began to build a network on her own terms. "I started talking to the few people I had in my network, even in competing companies, who were feeling the same as I did and talking about it. It hit me that we were mostly women, who shared the feeling of being the only woman in the meeting room, or the experience of being at a trade show where visitors want to talk to the male you are attending with."

From discussing these shared experiences and recognising the odd, sometimes alienating experience of being a woman in AM – or any STEM field – emerged the idea of Women in 3D Printing. Initially, Toure's ambition was small: she started a blog on which to share the stories of women who had come to the AM industry from non-engineering backgrounds, with the aim of encouraging other women from outside the industry to consider roles in AM as an option. "I wanted to show that AM isn't as opaque as it seems from the outside," she explained.

While much more than a blog now, Women in 3D Printing still shares the stories of women in AM, and encourages women from all backgrounds to consider joining the industry. But how exactly did a blog started in 2014 grow into the global organisation, boasting a 23,000 strong membership, that we see today?

To begin with, Toure planned on writing one interview a month. Her original network of women in the industry comprised only twelve members; by interviewing one a month, she would treat the blog as a one-year project, wrap things up with the twelfth, and move on. But interest quickly grew: "Before I knew it, I had women from all over the world coming to me to say, 'this is awesome, I want to share my story.' I soon had a waiting list of over 300 names." Now, Women in 3D Printing publishes new interviews every week, and the waiting list is still growing.

As Toure came into contact with more women in AM, she began to meet with some of the individuals she had interviewed and who were part of her network in San Francisco; these informal meetups eventually evolved into official Women in 3D Printing gatherings for women who wanted to invite their own industry connections, enabling yet more women to build their networks. "Before I knew it, I had someone in Paris telling me 'hey, I want to do the same here, is it ok if we say it's a Women in 3D Printing gathering?' Months later, London was doing the same. Now, we have something like eighty chapters across the world; of course, now it's a bit more organised, and we have official ambassadors, but this is how it started – purely organically."


WOMEN IN 3D PRINTING

DIVERSITY FOR ADDITIVE MANUFACTURING 2020 REPORT: Special Edition #DfAM2020

Approach to "Diversity & Inclusion" and actionable takeaways that can be leveraged to create a more diverse and inclusive additive manufacturing industry.

Lead author: Kety Sindze
Supported by and Produced for Women in 3D Printing
Published on August 2020

Fig. 5 Women in 3D Printing's Diversity for Additive Manufacturing 2020 Report, a special edition on racial diversity and the representation of minority groups in the industry (Courtesy Women in 3D Printing)

Drawing on Wi3DP's talent pool: Past, present and future

Many of Women in 3D Printing's current activities are drawn directly from the volunteered expertise of its members. On the board of directors, industry journalist Sarah Goehrke, with a background as a research analyst, is behind the organisation's semi-annual *Diversity for AM* report, which seeks to expand beyond the basic employment figures provided in the majority of industry reports to more closely study diversity in the AM industry, initially via discussion of gender parity, but, more recently, in a special edition on racial diversity in the industry (Fig. 5).

Wi3DP Next Gen, the youth initiative which Toure described as "almost a subsidiary" of Women in 3D Printing due to its rapidly growing size and ambition, was developed based on repeated requests for information on how the organisation was supporting the youth population in AM. "We had nothing in place until Janet [Kar] came in," Toure explained. "Janet said, 'I want to do something for youths, let's try to put things together,' and, before I knew it, she was putting a plan together; we now have a team of more than twenty young men and women volunteering for that specific part of Wi3DP. Now it has more than four different programmes. It's becoming huge." Toure added that she is "pretty hands off" with Wi3DP NextGen, preferring to leave it in Kar's capable hands (Fig. 6).

"Everything we've done so far has grown like this, from requests from volunteers who say 'hey, I want to join,

Fig. 6 Janet Kar, Head of Marketing at Wi3DP and SVP Digital Transformation at Link3D (Courtesy Janet Kar)

"It's really a community built for, and by, the community. Of course, we have some roadmaps now that we are becoming bigger and more structured – we know what we want to work on and prioritise for the year, but we will always keep a level of flexibility for anything new..."

and this is an idea I have, what do you think?'" she explained. "Most of the time, we say 'bingo, let's try' – sometimes it's successful, sometimes we fail and do something else or reshape it, but this is how we grow." This is an ethos Toure is keen to maintain going forward. "It's really a community built for, and by, the community," she stated. "Of course, we have some roadmaps now that we are becoming bigger and more structured – we know what we want to work on and prioritise for the year, but we will always keep a level of flexibility for anything new that comes from the community. I want us to make sure we keep this bandwidth and open-mindedness about things that we aren't thinking of now or the real needs from the community that we need to tackle."

TIPE's success makes the establishment of further Wi3DP-led conferences something of a no-brainer, though Toure is clear that an event on the scale of TIPE 2021 will only be held once annually. She is conscious of the need to let Wi3DP's global chapters 'breathe' in the meantime, making sure that the chapter events held every month have enough visibility and are well supported.

On the roadmap for the future of Women in 3D Printing, Toure has an immediate goal of developing a number of new programmes to respond to the changes she is seeing in the AM industry.

"The last year has been interesting for everyone, even more for our community," Toure commented. "Up to now, I was mostly talking to marketing departments at all company sizes. More and more, I am now dealing with the HR department, and seeing new titles emerge in the industry like VP of People, Chief Transformation Officer, Diversity and Inclusiveness Officer. These are new titles that did not exist even a year ago. This is awesome, but makes me realise that what we are offering as a community to those companies might need to differ a little bit from what they expect; we know what we want to offer for marketing managers and for marketing efforts, but we still need to figure out how we can help companies who have those kinds of people in place and are really making [diversity] a priority."

In the coming year, this is the work that Wi3DP will focus on; growing the number of companies it works with that make diverse hiring practices a priority, aiding in the development of their diversity-focused programmes and policies, and encouraging more companies to adopt this attitude.

Wi3DP is also expanding its focus increasingly from gender diversity to encompass racial and sexual diversity. Toure is clear that she does not only want to see the industry achieve a gender balance in future, but also a colour balance, from meeting rooms to conference programmes. Due to a lack of reporting within companies, statistics on diversity in Additive Manufacturing are hard to come by, but, as an example, Toure noted that while only 13% of individuals employed in AM are women, it is estimated that fewer than 5% of industry employees of any gender are Black.

In one of its first race-focused events, on April 20, 2021, the organisation hosted a panel titled Wi3DP Against Asian Hate, tackling anti-Asian harassment. "We want to make a statement that we're supportive of all communities, because we want our community to be diverse."

Women in AM on the benefits of Wi3DP

So, what are the key benefits offered by Women in 3D Printing to its members, both new and established in the AM industry? For Toure, the first thing that comes to mind is the immediate professional network Wi3DP offers. "We are a very welcoming community: membership is free and as simple as getting our newsletter. As a member, you have access to the network, and are able to get to know the women and men [who make up approximately 30% of the membership globally] in the community, and be part of an organisation which shares the same values."

As a developing industry, AM often involves a degree of collaboration that can be global, or at least cross-organisational. Wi3DP also functions as an enabler of innovation and knowledge transfer by connecting industry professionals across all levels of AM, at various stages of the workflow. "We have panels on aerospace, on healthcare, on fashion – we tackle every sort of industry we can think of, so, as well as the network, you also have access to the knowledge shared there," Toure stated. As founder, she also noted that she receives daily requests for introductions and recommendations from members keen to leverage the global network they are part of. "This can lead to new opportunities for both of them; I don't need to know what, it's none of my business."

I asked the women I interviewed what they identified as the key benefit of their association with Wi3DP.

Fig. 7 Melanie Lang, CEO and co-founder of FormAlloy (Courtesy FormAlloy)

Fig. 8 Marie Langer, CEO of EOS GmbH (Courtesy Ritsch/EOS)

Melanie Lang
Co-Founder & CEO of FormAlloy Melanie Lang recalled how Wi3DP supported her transition into AM. "Several years ago at a RAPID event, I was new to the scene. I was in the aerospace industry and a hobbyist, so I didn't have many relationships in AM. I met Nora and she instantly invited me to join the (much-smaller at the time) Wi3DP, which introduced me to some of my first contacts, now friends."

This sentiment was echoed universally by every industry professional I spoke to, in all sectors: Wi3DP offers a gateway to an invaluable community and network in an industry to which many come as newcomers, and which can easily overwhelm. "I was instantly empowered with a network," Lang remembered, "and the confidence that I had a support system to embark on my AM journey." But Wi3DP did not only provide Lang's initial points of contact; it remains a valuable tool for her and for FormAlloy to the present. "My network and the amazing people that surround me are my greatest asset," she stated. "Wi3DP has enabled many of my connections and relationships, including suppliers, customers and dear friends."

Marie Langer
CEO of EOS GmbH, Marie Langer, has also found that the greatest benefit of membership is the network offered by Wi3DP. "I truly enjoy participating and engaging with the Wi3DP community as it is a great way to connect with a wonderful community, committed and excited about the prospects of 3D printing," she stated.

Fig. 9 Tali Rosman, vice president and General Manager of 3D Printing at Xerox (Courtesy Xerox)

Fig. 10 Stacey DelVecchio, a long-time champion of gender equality in STEM who began her engineering career in 1989 (Courtesy Stacey DelVecchio)

Fig. 11 Lynda McKinney, VP of Communications at Desktop Metal (Courtesy Lynda McKinney)

Fig. 12 Alison Wyrick Mendoza, Senior Product Manager & Product Marketing at GE Additive (Courtesy GE Additive)

Tali Rosman

As vice president and General Manager of 3D Printing at Xerox, Tali Rosman explained, "Being involved with Women in 3D Printing has been an excellent experience for me so far. Being exposed to the incredible network of women in this industry has facilitated some important networking that will hopefully lead to some interesting partnerships down the road for us."

Stacey DelVecchio

Long-time gender equality champion Stacey DelVecchio began her career in 1989 and served in various roles in her time in manufacturing before taking on the role of AM Product Manager at Caterpillar Inc. from 2014–2019. She is a former president of the Society of Women Engineers, and currently serves as a member of the SME Additive Manufacturing Advisory Committee and president of her AM consultancy, StaceyD Consulting. Her book, *Women in 3D Printing: From Bones to Bridges and Everything in Between*, will be published by Springer as part of its Women in Science and Engineering series in June this year. "Personally, Wi3DP is a place for me to stay connected in a safe and supportive environment," she stated. "Yes, there's good programming, but the environment of a supportive group of like-minded women in the same industry is where I see the most advantage. I have connections through Wi3DP that I would not have made previously; I feel like I have an 'in' through our mutual engagement with the organisation."

Lynda McKinney

McKinney, VP of Communications at Desktop Metal and co-ambassador for Wi3DP's Boston, Massachusetts chapter, shared her views on the benefits of membership in Wi3DP at both a corporate and personal level: "I chose to join Wi3DP as both a member and co-ambassador to help change the face of the industry as well as foster the fact that women can and do make a difference across all disciplines – engineering, software, marketing, HR," she stated. "While there's a huge lack of diversity in the tech industry, there is also a huge need for talent. By joining the tech industry at this critical time, women can make a lasting impact on the future of the industry and the technology we use every day. Not only can women change the industry, but we can change what the industry produces and ensure that the technology being developed today is created with both men and women in mind."

"More than just an organisation, Wi3DP has become a global movement of members who share the same values and same mission of striving for an inclusive technology industry," she continued. "We will succeed by tackling it as a global community together. Much like the way the Additive Manufacturing industry is changing the way parts and products are manufactured, so too is this same community joining together to make a lasting change in our collective work cultures. While we may compete in the market, as members of Wi3DP we are colleagues, not competitors, working together for a common purpose – to educate, empower and celebrate women. For companies to recruit top talent, it's important that they show the importance of inclusion and a true commitment to closing the gender gap in the workplace. One way to do that is to join Wi3DP, where they are showing they, too, embrace and celebrate this movement."

Fig. 13 A meeting of the Boston Chapter of Women in 3D Printing, of which Lynda McKinney is co-ambassador, at Desktop Metal HQ (Courtesy Desktop Metal)

"More than just an organisation, Wi3DP has become a global movement of members who share the same values and same mission of striving for an inclusive technology industry."

Alison Wyrick Mendoza

Mendoza, Senior Product Manager & Product Marketing at GE Additive, and one of the most recognisable faces in Additive Manufacturing on social media under the handle Additive Alison, expanded on this sense of a community working toward a common goal, saying, "I really enjoy the networking aspect, of course. But the ability to be part of an organisation that influences – through action – opportunities for young women to pursue and succeed in STEM roles is, perhaps, the greatest benefit."

Jennifer Killingback

Additive Manufacturing recruitment specialist Jennifer Killingback, Director North America of Alexander Daniels Global, stated, "Wi3DP is a great resource for the Additive Manufacturing industry as a whole. A wealth of knowledge, different backgrounds and experiences to share. For me personally, I have been able to make connections with women who are interested in advancing their careers within the industry. It is exciting to see more women become involved at all levels and disciplines within Additive Manufacturing."

Dr Laura Cordova

Dr Cordova, a researcher in metal AM who previously served as Project Manager Additive Manufacturing at the Fraunhofer Project Center, University of Twente, the Netherlands, before joining Chalmers University of Technology in Sweden as a

Fig. 14 Dr Laura Cordova, a researcher in metal AM (Courtesy Chalmers University of Technology)

researcher in March 2021, recalled: "I came across Women in 3D Printing online events such as happy hour which were fun and inspiring; a great opportunity to meet women with similar and relatable backgrounds from all over the world. Having relocated several times around Europe and worked in many industrial fields and academia, these connections were very valuable. In one of the first events, I met Valeria Tirelli and Elvira Leon. They are truly an inspiration to me, their spirit and passion for 3D printing is contagious."

Of the members I interviewed for this article, it was, unsurprisingly, those employed in research and development and those new to AM who had benefitted the most from the knowledge-sharing facet of Wi3DP. As Dr Cordova explained, "The connection of R&D with industry is vital to maintain an innovative and fast-growing ecosystem. I think the Wi3DP network plays an important role in this. The last four years I have worked with the influence of powder handling activities such as reuse, reconditioning, rejuvenating and storage on the process development and quality of metal parts. This is key for metal AM users to control the process repeatability and part reliability. In fact, understanding very well all the powder-process interactions helps to take decisions towards a more cost-efficient and sustainable process," she noted. "In one of the international events, I met Sherry Handel, Executive Director at the Additive Manufacturer Green Trade Association (AMGTA). She was interested in my research, we connected on the importance of having more control on the material life cycle. This has been positive in the later development of my projects on this topic."

"In my previous job at the University of Twente, I worked on projects with materials typically used in aerospace such as Inconel 718, Ti6Al4V and Scalmalloy," she continued. "My experience in this industry was key to my participation as a panellist at the first TIPE conference; I could exchange experiences on the topic with industry experts. My participation in this event, with plenty of networking opportunities, resulted in contacts and collaboration for future R&D projects."

"In my current position at Chalmers University of Technology I focus on the sustainability component of AM," she continued. "Here, I research aspects of the powder life cycle for AM processes: from powder production, to the efficiency of powder utilisation during AM, powder rheological characterisation, and material recycling. The Wi3DP network provides great opportunities to connect with professionals at organisations both in Europe and worldwide with an interest in improving their process cost-efficiency while reducing the ecological footprint."

Lisa D Block

Director of Global Sales and Marketing at Hybrid Manufacturing Technologies, Lisa D Block is a newcomer to Wi3DP and has found the knowledge-sharing aspect the organisation's most useful offering to both her and the company she represents. "I have only been a member of Wi3DP for a short time, but I believe it has absolutely been a benefit to my company," she stated. "I gained a client at the [TIPE] conference and have personally benefitted from all the knowledge and personal experiences shared via the various speakers and events."

Maddie Frank

An Additive Manufacturing professional and recent graduate from the Electrical Engineering programme at UW-Milwaukee, as well as owner of AM consulting firm W1 Consulting, LLC, Maddie Frank explained that prior to becoming familiar with Wi3DP, she hadn't previously taken an interest in other 'Women in...' organisations due to less-than positive experiences with university-level groups. "In my university, a lot of 'Women in...' groups didn't do a lot, or what they did was based on saying 'these are all the horrible things you can expect when you get into the workplace: men are going to do X, Y, Z and you're going to have no choice but to take it," she explained. "For me, I've always been in a male-dominated field of study in sports, so even in work now it's like – yeah, you get this every once in a while, but for me it hasn't been fully systemic."

However, once she began to take an active part in Wi3DP, with access to the network of contacts the organisation offers, Frank quickly saw the benefit of membership. "I will say that [before joining Wi3DP] I did not know very many women in this industry. I can show you my Rolodex up until July, and it was pretty much just fifty-five-year-old men – who I love, they're absolutely fantastic – but I pretty much only interacted with men in this industry, and Wi3DP, just by nature, brings together a lot of women who work in the industry that you might not necessarily know about, or who maybe you see on LinkedIn and think, 'who are you and what do you do?' So it really provides a great way where you can speak and connect with women."

Fig. 15 Lisa D Block, Director of Global Sales and Marketing at Hybrid Manufacturing Technologies (Courtesy Lisa D Block)

Fig. 16 Maddie Frank, Additive Manufacturing professional and recent graduate of Electrical Engineering at UW-Milwaukee (Courtesy Maddie Frank)

Fig. 17 SJ Jones, Additive Manufacturing Application Engineer at Siemens Energy (Courtesy SJ Jones)

Frank cited another benefit which she noted might 'get her some flack.' "A lot of times, when you're the single woman in the engineering field, you have your niche and you're good at it, and then another woman comes in and 'encroaches' on your space, and you feel like – 'Oh, shoot.' [...] Not many people admit it, especially if you're a woman, but I will: I initially didn't like women that came into my space, but Wi3DP has allowed me to go out there and really get to know these women, see that they're actually just really cool people, and understand and start training myself against that initial knee-jerk reaction."

SJ Jones

A full-time Additive Manufacturing Application Engineer at Siemens Energy and another well-known face in the AM Twittersphere, where she tweets under the handle @inconelle, SJ Jones joined Wi3DP roughly a year into her Additive Manufacturing career. Jones shared how the connections she has made through the organisation have impacted her on both a personal and professional level:

"I've hugely benefitted from meeting women not only at all levels, but also across different industries. Christina Perla has been amazing in opening my eyes to being an immigrant and a small business owner in the US. On another hand, Amy Alexander has brought up discussions with me about the role of 3D printing in patient-specific care and its direct impact outside of just surgical metal implants. I've also been fortunate to meet women from all over the world. Alex Kingsbury, from Australia, gives a different perspective to how she approaches AM by getting companies competitive in innovation with newer AM applications."

"Success isn't linear, and I think that 'success' in AM is multi-faceted. Being able to hear the stories of these women and the different journeys that they have taken is inspiring."

"Success isn't linear, and I think that 'success' in AM is multi-faceted," she added. "Being able to hear the stories of these women and the different journeys that they have taken is inspiring. Failing is easy, but getting back up and finding the courage to try again? That's the hard part. But hearing their stories makes that hard part just a tad bit easier because it's a burden we all share. In our group, we all want to see each other succeed and there's a stronger sense of camaraderie."

Filling the talent gap: How the AM industry can benefit from a wider talent pool

As a rapidly-developing new field, Additive Manufacturing's growth and industrialisation is, to an extent, reliant on the recruitment of new talent into the industry, whether from other fields or education. But, as SJ Jones pointed out to me, "there's a leaky pipeline in getting more women into the talent pool. We comprise 50% of the population. As a whole [taking into account all subjects], more women are earning PhDs than men – outpacing them in education by 137 to 100 (Table 1, [1]). This means that there are vastly more qualified female candidates than male candidates, right? Unfortunately, in a microscopic world like AM, you see the industry has yet to catch up to the reality. I think I saw a statistic in the Alexander's Global survey last year that stated only 11% of the industry was female – that's barely one in ten" (Fig. 18).

To some extent, this may be because AM shares the image problem of most STEM fields in that it appears, from the outside, to be a male-dominated field – whether this is true or not.

"The image problem definitely exists," stated Nora Toure, "and it's the product of a representation problem that is not just related to gender diversity, but diversity in general – if you don't see someone who looks like you doing something, it's really hard to put yourself in that person's shoes, or skin. This has been a problem forever; it was a problem when I was younger and choosing my career path, and it's a problem now."

I asked the women I connected with to what extent they believe this image might be damaging the industry's ability to recruit new talent, why we need diversity in AM, and how far they think Wi3DP, and the industry, have already come in terms of addressing the image problem and promoting the hiring of more women.

Highlighting a potential lack of awareness, at an industry level, of the damage done by the misconception

Doctoral degrees, by field and gender, 2016–2017			
Field	**Male**	**Female**	**Females per 100 males**
Arts and humanities	46.8%	53.2%	113.7
Biological, agricultural sciences	47.4%	52.6%	111.0
Business	51.1%	48.9%	95.7
Education	31.2%	68.8%	220.5
Engineering	76.6%	23.4%	30.5
Health and medical sciences	29.7%	70.3%	236.7
Mathematics and computer sciences	74.9%	25.1%	33.5
Physical and Earth sciences	65.9%	34.1%	51.7
Public administration	24.4%	75.6%	309.8
Social and behavioural sciences	38.9%	61.1%	157.1
Other fields	47.6%	52.4%	110.1
Total	**47.0%**	**53.0%**	**112.8**

Master's degrees, by field and gender, 2016–2017			
Field	**Male**	**Female**	**Females per 100 males**
Arts and humanities	41.2%	58.8%	142.7
Biological, agricultural sciences	43.9%	56.1%	127.8
Business	56.2%	43.8%	77.9
Education	23.1%	76.9%	332.9
Engineering	74.6%	25.4%	34.0
Health and medical sciences	20.0%	80.0%	400.0
Mathematics and computer sciences	66.8%	33.2%	49.7
Physical and Earth sciences	57.6%	42.4%	73.6
Public administration	21.8%	78.2%	358.7
Social and behavioural sciences	37.4%	62.6%	167.4
Other fields	41.7%	58.3%	139.8
Total	**42.7%**	**57.3%**	**134.2**

Total graduate school enrolment, by field and gender, Autumn/Fall 2017			
Field	**Male**	**Female**	**Females per 100 males**
Arts and humanities	43.8%	56.2%	128.3
Biological, agricultural sciences	45.5%	54.5%	119.8
Business	54.2%	45.8%	84.5
Education	25.0%	75.0%	300.0
Engineering	74.8%	25.2%	33.7
Health and medical sciences	22.1%	77.9%	352.5
Mathematics and computer sciences	67.9%	32.1%	47.3
Physical and Earth sciences	62.3%	37.7%	60.5
Public administration	22.7%	77.3%	340.5
Social and behavioural sciences	37.0%	63.0%	170.3
Other fields	41.4%	58.6%	141.5
Total	**42.1%**	**57.9%**	**137.5**

Table 1 Enrolment and graduation from graduate studies at US universities by gender (Courtesy Council of Graduate Schools) [1]

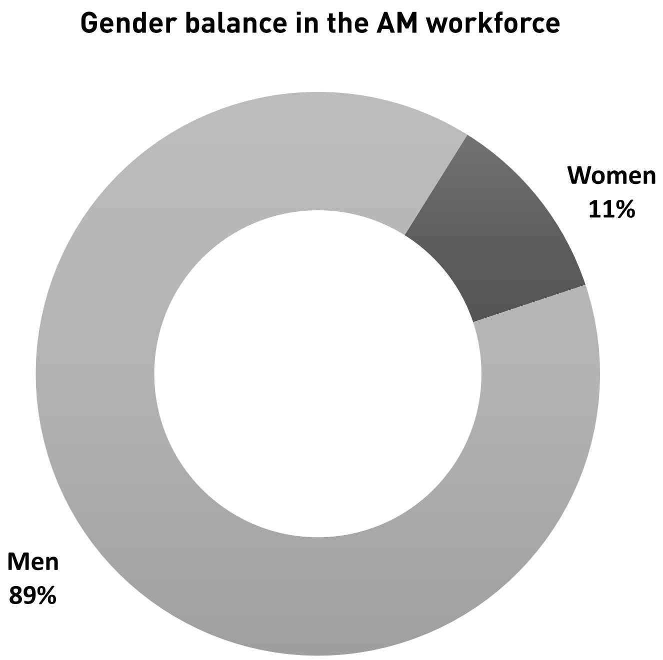

Fig. 18 Statistics vary, but a recent Alexander Daniels Global survey puts the percentage of women in the AM workforce as low as 11% [2]

of AM as a 'male field', SJ Jones observed, "I don't think that most see it as damaging. When you're part of the 'in' crowd or the overwhelming majority it's harder to notice who is 'missing' from the room. As a woman, it feels very isolating as you walk into a room and every face echoes how much you don't belong there. I think Wi3DP has come far in addressing this perception in giving women the space to be themselves and to be the majority in a room on a subject we are all incredibly passionate about: 3D printing."

"Prior to my experiences with Wi3DP, the women I interacted with were very few," stated Lisa D Block. "In fact, the TIPE conference was the first time I was able to see so many female engineers and executives in the same place, but it was so refreshing to see. I think that when there is any group that could appear to hold a monopoly on any industry, it makes people that don't fit the predetermined description less likely to apply for those positions, leaving the company to just select anyone versus the person that may be the most qualified for the job. Ultimately, the company and the industry will suffer as a result of people's hesitancy to apply."

> *"When you're part of the 'in' crowd or the overwhelming majority it's harder to notice who is 'missing' from the room. As a woman, it feels very isolating as you walk into a room and every face echoes how much you don't belong there. I think Wi3DP has come far in addressing this perception..."*

Dr Melissa Orme, Vice President Boeing Additive Manufacturing, added her perspective: "I think that there have been great advances in promoting diversity in STEM in general. That said, long-standing societal biases still exist that tend to guide many young girls away from STEM areas. I think these biases need to be addressed at the early ages of education and development, as they affect the choices that girls make in school that ultimately impact their professional direction. Once on a certain path, it is difficult to 'correct' without having the proper academic preparation. At Boeing, we are paying close attention to improving the representation and inclusion of women throughout the organisation – particularly in STEM careers and leadership. The underrepresentation of girls and women in STEM fields is a global challenge."

Melanie Lang sees great strides being made in improving the outside perception of AM among prospective talent. "Wi3DP has improved the perception that manufacturing in general is male dominated by creating a powerful and well-respected community of all genders that work together to solve some of the most impactful and interesting challenges of our time, and that's what it's really about – people working together to bring the best ideas and experiences to move the industry forward. The organisation has also removed the myth that the talent pool is male based and most of the experts are male; there is a large group of qualified, experienced experts that are not only male."

Alex Kingsbury, Additive Manufacturing Industry Fellow and Engagement Lead at RMIT University, and Women in 3D Printing's Regional Chair for Oceania, stated, "The great thing about AM is that it is a relatively new field that is less shackled to the traditional manufacturing image, which is seen as more male-dominated. Before Women in

3D Printing started, I only knew a handful of women who worked in the field, but now I know hundreds! And I only need to go to the Women in 3D Printing website to see a huge range of interviews with women who are in 3D printing from all over the world."

"One thing we know for sure is that diverse teams deliver better results, and this shows in the bottom line, so there are very good business reasons for creating and retaining diverse teams," she continued. "What we want is a diversity of viewpoints, experiences, approaches, and thinking styles. The way we control for that is through these diversity markers, or social indicators. When women consist of 50% of the population but only 13% of the workforce in AM, then we know we have a gender diversity issue that we should be addressing. There are plenty of reasons why and how we socialise girls and women to not choose certain career paths, but part of the solution is to promote and highlight women who are working in the industry – if she can see it, she can be it!"

This, of course, is where Wi3DP excels. "You only need to look at the recent TIPE 3D conference to see how much of a good job Wi3DP does in promoting and highlighting talented women in 3D printing," Kingsbury continued. "I was blown away by the depth and breadth of the speaker line-up!"

"From many stories I've heard, having access to the Wi3DP network has been just the encouragement that was needed to pursue 3D printing, or to remain in the field when things get tough," she noted. "Just seeing someone that looks like you in 3D printing can be a huge source of inspiration and encouragement for those coming through the ranks. It can be a little lonely and isolating when you're the only woman in a meeting room, or in your team, but having a strong network of women sitting outside of those teams, who are also often the only women in their meetings, is sometimes the only thing you need for the world to feel right again."

Fig. 19 Dr Melissa Orme, Vice President Boeing Additive Manufacturing (Courtesy Boeing Additive Manufacturing)

Fig. 20 Alex Kingsbury, Additive Manufacturing Industry Fellow and Engagement Lead at RMIT University, and Women in 3D Printing's Regional Chair for Oceania (Courtesy Women in 3D Printing)

Fig. 21 Jennifer Killingback, Director, North America, Alexander Daniels Global Inc. (Courtesy Jennifer Killingback)

Stacey DelVecchio echoed Kingsbury's perspective on the importance of diverse hiring practices in AM. "We care about gender diversity in additive as all the research shows that diverse teams come up with more innovative solutions. And innovation abounds in additive, so why wouldn't you want a diverse team? I like to think as gender diversity as 'Diversity 101'. Let's start with gender diversity so we can move on to some of the more complex facets of diversity."

"STEM fields, especially engineering and manufacturing, definitely have an image problem with being mostly male," she stated. "More often than not, it's the reality, not just an image. It's damaging, as young girls tend to opt out of these kinds of fields at a young age, simply because of the image. They don't see women going into the STEM careers, so they don't think it's for them. When I first entered the world of additive in 2014, I was shocked there weren't more women," she recalled. "I thought this new, rapidly-growing industry would be a natural fit for women. I was surprised it wasn't. While it's difficult to measure progress, there is no doubt in my mind that Wi3DP has made an impact on the visibility of the women in the industry. The organisation is very connected virtually, which means is easy to search for women in 3D printing and see role model after role model. Visibility is huge when you're talking about changing the public's perception, and Wi3DP has hit the mark here."

"Whether perception or reality, I believe this issue is prevalent in many industries, not just additive," stated Alison Wyrick Mendoza. "What the Wi3DP organisation does well is make it easy for those outside the circle to really see just how many women we do have in the industry currently, how many are joining every year, and demonstrate tangible results from all their many collective efforts to increase representation of women. It puts all those efforts in the spotlight, bringing validation and promoting continued proactive behaviours."

Tali Rosman echoed the general consensus. "The risk here when it comes to recruiting new, up-and-coming talent is that, because of this perception, women may be shy about applying for these roles or going after them. A key reason why we don't have more women in our team is because I get fewer CVs from women. Organisations like Women in 3D Printing serve a crucial role in helping to promote the AM industry to women. For women contemplating entering the AM industry, Wi3DP shows that it's possible to be a woman in this industry and reach very senior positions. Those of us involved can serve as role models for that next generation of women joining the industry, which is still often perceived as a male-dominated one."

Rosman further stated that she had not seen a significant increase in the number of women in the technical or manufacturing fields in the last few years, noting that there is still work to do in addressing the gender gap. "However, we are starting to see women take key leadership roles in the 3D printing industry; for example, the CEO of EOS being a woman is encouraging. But we still haven't seen the spike we were hoping for just yet."

From a recruitment point of view, however, Jennifer Killingback stated that she believes things are improving. "The presence of women with the Additive Manufacturing industry has definitely increased and improved since I began my career in January 2015. It is exciting to see more technical and senior level roles being achieved by women from all around the world in all areas of Additive Manufacturing. Many things have changed since I was first interviewed by Nora at Wi3DP in June 2017. From my experience, many in our industry have been very proactive in the selection and promotion of women within Additive Manufacturing. It is exciting to see more women move into STEM-focused roles as well."

Melanie Lang agreed that there has been a positive increase in the number of women employed in AM in recent years. "From my first experiences with AM several years ago to where we are today, I am glad to say I notice a more diverse community and am proud to be a part of an organisation that has truly helped drive this change. From business leadership and technical experts to speakers and attendees at conferences, there are more women participating and thriving."

Women in 3D Printing provides a valuable resource for Killingback's recruiting activities in AM. "Wi3DP has a strong LinkedIn presence, which I am a part of, and, on occasion, I have had referrals from other group members on candidates seeking new careers. The primary benefit for me has been the exceptional networking opportunities offered by Wi3DP, which are instrumental in my work as a recruiter. Most recently, I was a speaker during the TIPE conference on the Youth Track."

SJ Jones, speaking from a relatively early stage in her AM career, compared to many of the women interviewed here, added that she values the trust which Wi3DP builds between associated recruiters and companies, and potential job candidates. "I feel that in this era where diversity is a hot button topic, hiring a woman in any capacity is desirable for a lot of companies. However, it is significantly easier to trust or accept an invitation for a role when it comes at the recommendation of another member of Wi3DP. Members are fairly aware of each other's interests, so they can better match or recommend candidates for certain positions."

Maddie Frank also commented on the value of Wi3DP as a job candidate, stating, "Wi3DP, like any other organisation in AM, is basically a microcosm in itself. I have met people within Wi3DP that I'm like, 'Your company's really cool, can I work with you guys?' and got interviews through those companies, not necessarily because of Wi3DP, but because of the people I've met within the organisation. The networking that is happening within this organisation has definitely made me a more valuable candidate in having those introductions."

This value is only enhanced in the current landscape, where in-person networking opportunities are so limited. "When I'm coming out of school, especially in this new COVID world – and this applies to all students – to have the ability to network with industry people and not have to go to AMUG or RAPID, but just literally jump on a call with their Wi3DP chapter or attend a conference, like the TIPE conference, or go to a 3D Printing Happy Hour, it allows you to basically go out and meet people."

Fig. 22 Meera Ravi, Director of Digital at Viyoma Manufacturing (Courtesy Meera Ravi)

Tackling the image problem: Wi3DP Next Gen

Still in its early stages, Wi3DP's Next Gen youth initiative is the key weapon in its arsenal as it tackles AM's image problem and seeks to entice new talent into the industry. I spoke to Janet Kar and Meera Ravi, Director of Digital Viyoma Manufacturing and a Mentorship Community Manager for Wi3DP, about Next Gen's development, and what it was about their experience in the industry that made them so keen to create a support programme for youth in AM.

"When I joined the 3D printing industry about four years ago, I was pretty quiet – I didn't know anybody," Kar recalled. "Until I met one male mentor who told me, 'this industry is all about who you know and the relationships you've built. There's a lot of vapourware, people don't know what's true and what's not, and they want to work with people they trust.'" From then on, Kar worked hard to embed herself in the community, initially by volunteering for AMUG. "I saw that if you join a community, and you're open to supporting that community's growth, there are a lot of amazing opportunities that arise from that – not only friendship, but people who will tell you what's real, what's not real, how to solve a problem, how to grow your career, etc. People in 3D printing are really there to help you grow."

"In university, I participated in a lot of extracurricular student community groups and saw the power of how they can help students develop confidence, learn to network and learn how to build their plan for whatever future they want," she explained. "Exposure is so important; if you're not exposed to something, you will never do it. Knowing that the 3D printing industry is in dire need of more talent, I felt pulled to explore how we could bridge all of these pieces together, help accelerate the adoption of 3D printing and convince great people to enter and remain in our industry. I felt

"A lot of women [...] around the age of 14–15 don't feel like they get the support for STEM, and then just drop it. Even in the professional world, I recently spoke to someone who was doing 3D printing, she was the only girl, and she was about to leave because it didn't feel like an environment she wanted to be in..."

like Women in 3D Printing was very much set up to help that. I want to be working with amazing people, and I want that for everyone else, as well."

Explaining what drew her to Next Gen's Mentorship Program, Ravi explained, "I'm transitioning in my career from the social impact sector to engineering, leading my family-owned business, a manufacturing service provider. So I was reading a lot of articles and came across Janet, who was very generous in connecting with me and inviting me to come and be part of the community. I was drawn to the Mentorship Program because I had previously run one for a large social enterprise in New York City, focused on immigrant integration. For me, I felt at home working with the community and supporting early-career professionals or anyone looking to transition to 3D printing."

"Looking at what Women in 3D Printing does best, we realised it has an amazing professional network of vendors, engineers, etc – everyone is here," explained Kar. "So we came up with three main key areas for Wi3DP Next Gen to focus on: How can we increase the adoption of 3D printing? How can we increase awareness of career opportunities in 3D printing? And how can we provide a community that can help students support their growth?"

"What we found in our research and through conversation with different professionals was that it's often a very lonely experience, working in engineering and 3D printing. A lot of women, from a recent Deloitte study, around the age of 14–15, don't feel like they get the support for STEM, and then just drop it. Even in the professional world, I recently spoke to someone who was doing 3D printing, she was the only girl [in her company], and she was about to leave because it didn't feel like an environment she wanted to be in. After she met some people from the New York chapter [of Wi3DP], it changed her life – she found people she could bounce ideas off of, who were going through the same things and who were able to relate and support each other. That kept her in the industry."

But can these negative experiences be prevented in the first place? Perhaps, by providing the same level of support women find in their local Wi3DP chapters to girls at a much earlier stage in their AM journey. "How can we replicate the same thing for girls going through this process in STEM, as well as providing them with an awareness of what 3D printing can be?" asked Kar. "A lot of schools have 3D printers, but universities don't really teach it, unless you're exposed through an additive programme or as part of a welding programme."

Through a number of programmes – including, in the near term, a series of AM curricula taught by women in under-served communities; teaching tools to highlight career opportunities in AM, such as the distribution of career cards highlighting professionals in the industry and Ask Me Anything (AMA) interviews with women in AM designed from a high school perspective; the support of Wi3DP school clubs; a mentorship programme featuring both male and female mentors; company tour opportunities and virtual and local Wi3DP events – Next Gen hopes to increase the visibility of female role models in the industry, thus inspiring young people from middle or high school, as well as those already at a university level, to view AM as a viable career path.

"Originally, we wanted to focus on the group that's most in need, which is underestimated girls in areas that don't have access to 3D printing," Kar stated. "But with COVID, it's pretty hard to get a teacher to want to help students and stay in school longer with afterschool programmes! It's not very feasible, so we decided to switch gears."

Now, the short-term goal for Wi3DP Next Gen is to grow its network and community. "We're really good on the professional side, but our reach for students isn't as clearly cut and defined," Kar explained. "When

"With the support of Wi3DP school clubs, a mentorship programme featuring both male and female mentors, company tour opportunities and virtual and local Wi3DP events, the programme hopes to increase the visibility of female role models in the industry."

we're talking about students, what is the age range? We'd love to cover it all, but our current programmes are designed for high school and university students first, because we need help to create that data."

Next Gen's first digital event, 'Meet the Stars of 3D Printing', welcomed about 270 delegates (Fig. 23). At the time of writing, there are around 750 students in the Next Gen network, a number which continues to grow with each new event and activity the group organises. "We wouldn't have been able to have this reach if not for the amazing brands who are also trying to close the gender gap and create a supportive network for their employees," Kar noted. The organisation will continue to hold 'Meet the Stars' events, each showcasing a different end-user industry for AM.

Fig. 23 Speakers at Wi3DP Next Gen's first Meet the Stars of 3D Printing event (Courtesy Women in 3D Printing / Youtube)

As well as student programmes, Kar explained that the Next Gen programme includes a number of workshops to help educators understand the process of Additive Manufacturing and the career opportunities offered therein. "What we have learned is that teachers are exhausted," Kar stated. "They love their students, they want to give the best support for them, but they also want to be recognised for their work, and a lot of times they aren't remembered. We want to provide a stage for teachers to showcase their work, get recognised by industry, get recognised by other teachers and bounce ideas off each other so they can provide the best version of their educational programme to their students."

To support teachers with this goal, the Next Gen team is currently working on an Additive Manufacturing curriculum vetting programme, through which teachers can showcase their programmes. Judges will vet the submitted programmes and decide on a winner, after which Next Gen will repackage and scale that curriculum to make available to the wider teaching network.

At the level of young enthusiasts and university students seeking careers in AM, the first pilot of Next Gen's Mentorship Program is underway, running for one quarter and featuring sixty-six pairs of mentors and students; a digital kick-off event was held in late March (Fig. 24). "We're looking forward to learning from the pilot programme and seeing what we can do in terms of enhancements for subsequent cycles," stated Ravi. "At the very minimum, the Mentorship Program requires the mentor to meet with a mentee for three sessions. We also provide support through the community of volunteers, offering resources to facilitate continued engagement and support with mentee-specific goals, so that if at the end of the quarter they decide to pursue an internship, an expert is available to help them with that."

Next Gen also has another programme in the making, one which Ravi hopes will make it possible to connect students with internships. As Kar explained, "We're looking at ways to add value. Students don't know what job opportunities there are; mentorship is one way to support their career path." Another way, she added, is to work with corporate sponsors to highlight the true potential of AM for students coming from schools where the majority of their exposure to AM is based on very small-scale, polymer-based 3D printers of the kind used by makers and hobbyists.

Why is there no 'Men in 3D Printing'?

In light of the criticism which Wi3DP sometimes faces from certain members of the AM industry, I asked Toure and the other Women in 3D Printing who spoke to me how they would respond to that most common of criticisms which ambassadors of Wi3DP see levelled at them on social media and/or in the workplace. Why is there no Men in 3D Printing?

"We are not a women's club," said Toure. "I've said it quite a number of times, and it's true. Yes, we're a platform to promote women in the industry, but everyone is welcome, and we're actually starting to promote a few male allies that we want to recognise. In terms of our events, everyone is welcome – they're not woman focused, they're industry focused, it just so happens that all of the speakers are female."

"When you think of it, how many events have only men as speakers? Less and less, but we still have a number of panels with men only on them," she pointed out. "This wasn't shocking to the industry up until we started to have woman-only panels, at which point the idea of a single-gender panel suddenly became shocking."

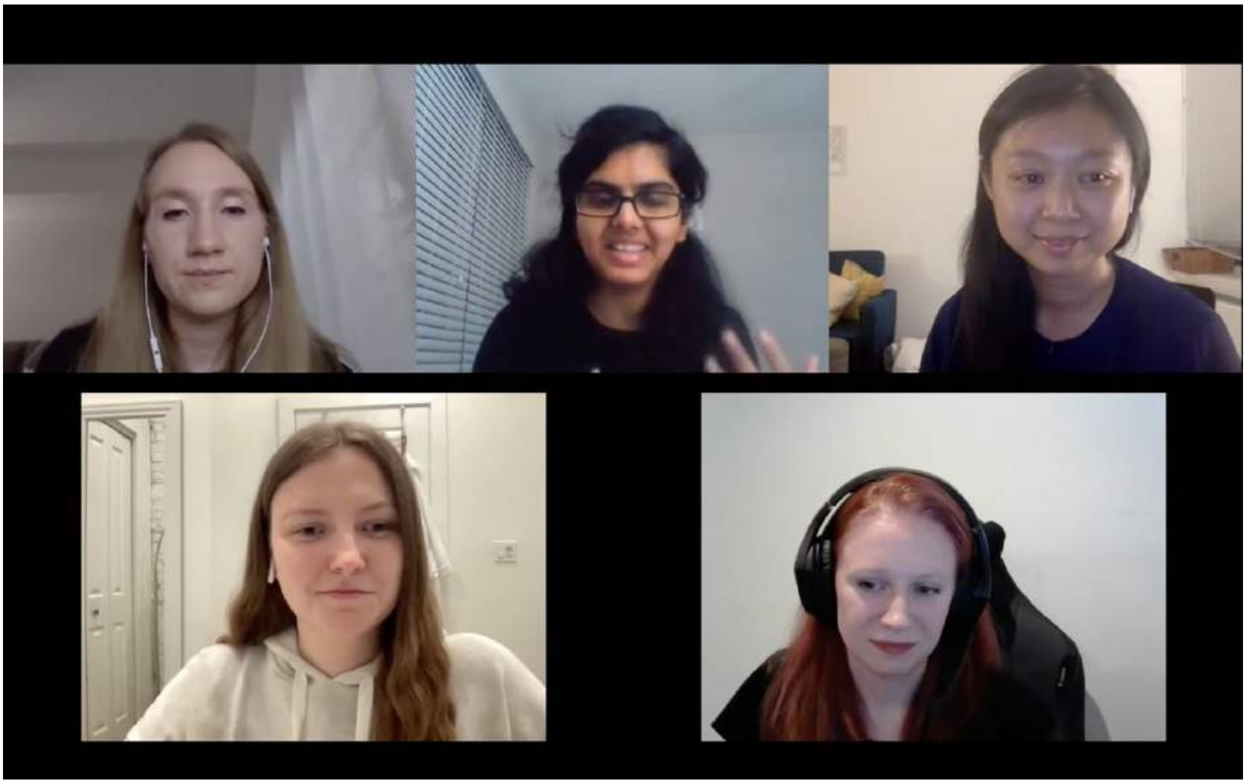

Fig. 24 Speakers at Wi3DP Next Gen's Mentorship Program Kick-off Event (Courtesy Women in 3D Printing)

On whether the aims of the organisation are indicative of 'reverse sexism', she explained, "We want 50/50 representation in the industry – we don't want more than that. It's not a big ask. Ideally, we wouldn't need Women in 3D Printing, because every panel would be, as much as possible, gender balanced."

"I assume that we all understand and agree that in the world we live in, men are automatically awarded space in all public and professional domains," answered Marie Langer. "However, the same access is not as readily available for women, people of colour and a myriad of other groups. As such, a group like Wi3DP is merely trying to create a space where women can thrive and become more visible to enable women's advancement in a professional setting. I feel these are positive efforts that are trying to help us create more diversity and inclusion in our small and young industry."

"...in the world we live in, men are automatically awarded space in all public and professional domains," answered Marie Langer. "However, the same access is not as readily available for women, people of colour and a myriad of other groups."

Maddie Frank, who grew up in the American Midwest, is familiar with the kind of thought process which leads people to criticise Wi3DP. "I grew up in a white manufacturing town, so I get where people are coming from. Even my dad will say 'Why don't they have a Men In 3D Printing? And to some extent I'd think, 'yeah, it does seem rather exclusionary,' but if you think about it, a lone woman going into a room with five men is just as intimidating as one man going into a group with five women. So, we're all here on the same page, if you just think about it from the other person's perspective; everyone gets intimidated when they're not in a group of people that looks like them or talks like them. You need to lower the boundaries somewhere, and Wi3DP does that."

In SJ Jones' view, the fact that some detractors still believe a women's organisation should be justified to them is indicative of the larger societal problems faced by women, and the industry. "I think that the fact we need to justify the existence of an organisation dedicated to supporting women – who make up half the Earth's population – speaks volumes about the AM industry. From my perspective, the purpose of Wi3DP is to provide a gender-inclusive space for people to come and be themselves in a supportive, nurturing environment where we all treat each other with respect. In Wi3DP we are freed from the gender norms expected of us in our day-to-day work lives – we don't have to be submissive, we don't have to pander to the male ego, we don't have to watch what we're saying or how we say it in fear of coming off as too 'bossy' or 'aggressive.' We can just be ourselves, and that is a privilege we don't get anywhere else."

On the differing expectations faced by women in AM in comparison to their male peers, she shared that, "It was recently brought to my attention that I am one of the few women in industry working directly with the metal printing machines. Upon further research and reflection, I think I'm the only one that does not hold a PhD. As I scrolled through the TIPE conference agenda, I counted the number of PhDs that make up Wi3DP and began to wonder how many women had to put Dr in their title to be taken seriously enough in the world of men to achieve the heights of their current positions or roles in AM. It reinstates this feeling that we must be twice as good or twice as smart to have our own seat at the table. Sharing that burden in our small band of sisterhood at Wi3DP can sometimes make it feel more bearable. Being able to be vulnerable, to ask each other for advice – not just about 3D printing, but about how to navigate this male-dominated landscape – I think is one of the greatest and most impactful qualities of this organisation."

"It would be great if we could one day get to the point where we decide we don't need a Women in 3D Printing, but, unfortunately, we're not there yet," explained Alex Kingsbury. "With women only consisting of 13% of the industry, we are still very much an underrepresented minority group.

"Fellas, if you're feeling a little left out, please don't, as you're most welcome to come to a Women in 3D Printing event. These are 'female friendly' spaces, and they may be a bit different to the usual networking event scene, but they're certainly spaces where you will feel welcome nonetheless."

While we remain a minority group, I think it's important that we still have a network that provides support and advocacy. I also think it's important to respect and acknowledge our non-binary and trans folk in 3D printing. Women in 3D Printing is often a space where they can feel comfortable as well, due to the inclusive nature of the organisation and the events we run. So, why isn't there a Men in 3D Printing? Because there's simply no need. Men are the majority group in our industry."

However, Kingsbury echoed Toure's statement that these events are in no way exclusive of men in the industry. "Fellas, if you're feeling a little left out, please don't, as you're most welcome to come to a Women in 3D Printing event. I think it's worth mentioning though, that these are 'female friendly' spaces, and they may be a bit different to the usual networking event scene, but they're certainly spaces where you will feel welcome nonetheless."

Stacey DelVecchio echoed the notion that, as a minority group in the field, it is important that women have a network to provide support, advocacy, and simple social networking. "It's not unusual for women to be the only one in their work group. For the men in the industry, it's difficult to understand that it can be lonely if you're the only woman in the room. That's not to say that the men aren't welcoming or that they don't respect us as women; they usually are welcoming and they usually do respect us. But there's also something comforting about connecting with someone who looks like you. And, hence, the need for a group like Wi3DP. So why isn't there a Men in 3D Printing organisation? There doesn't have to be, as all the men need to do is look around any company or group they are in and they will see people that look like them. It's almost like they have a ready-built Men in 3D Printing group available."

"I will admit that I was not initially sold on women's organisations as a whole in the workplace because I did not want to be recognised as the first woman anything, or the first Black woman anything," reflected Lisa Block. "I wanted to be recognised as the best in class, best in my industry, just the best, because I was the best, not because I was a woman. However, that opinion quickly changed when I realised that men are hired and compensated at numbers more than double the rate of women for the same position. I can remember being taught that I had to be smarter, harder and faster than my male counterparts to even be allowed in the room, let alone to be compensated at the same rate."

"My years working hand in hand with Human Resources showed me that it was a real problem, and no one was talking about it," she continued. "This experience changed my mind. And thank goodness for the men who were willing to teach me that lesson, because every lesson I have learned in business, positive or negative, I've learned from men. For 90% of my career, I have worked in environments where I was the only female, or one of a few. I am truly blessed to be in an environment now where I am supported not only in words, but some of my male counterparts actually attended the TIPE conference with me as well."

"Wi3DP is addressing institutionalised, unjust treatment of women in the workforce based on outdated societal norms," agreed Melissa Orme. "It is the organisation's intent to provide women with opportunities to network with other women and men in all aspects of the 3D printing value chain and to be a resource to industry to increase diversity in the workplace. The organisation welcomes male membership as well, as men play a critical role in creating a more diverse workforce through the recruitment activities sponsored by Wi3DP."

Conclusion

So, what are the benefits of an organisation like Women in 3D Printing? How do we justify the existence of an organisation which, by its nature, highlights one social characteristic over another?

It is clear from the experiences and statistics reported in this article that women remain very much a minority group in the AM industry, and that this can have a significant impact not only on the career prospects and wellbeing of individual women in AM, but on our industry's ability to attract the talent it so badly needs if it is to tackle the challenges of industrialisation and truly scale AM to meet the needs of large-scale manufacturing. Using Wi3DP as a marketing tool to reach young women and girls at early stages of their education, the industry stands a far better chance of filling this talent gap than it does in a landscape where the group most highly represented in higher education is the least represented in engineering [1].

Study after study has shown the benefits that diversity, not just in gender, but in all forms, brings to businesses. Gender diversity, at its core, asks only for 50% of the Earth's population to be represented equally as 50% of the workforce. This goal remains a long way off, but by encouraging their employees to get involved in Wi3DP and showing the organisation their support, AM companies can demonstrate their investment in the wellbeing and development of their staff, as well as their open-mindedness, and encourage applications from yet more diverse talent. As noted by Nora Toure and echoed by others throughout this article: gender is just the beginning.

Acknowledgements

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The need for speed, and how the right powder can reduce AM part production costs by 50%

If metal Additive Manufacturing is to compete with casting and other mass-production technologies, costs need to be reduced by a factor of ten. Optimising metal powder characteristics can get the industry halfway there, while anticipated improvements in equipment and processes will do the rest. Here, Equispheres' Doug Brouse and Dr Martin Conlon discuss how the use of advanced aluminium powders can improve the build rate for Laser Beam Powder Bed Fusion (PBF-LB) by two to four times, as well as offering significant advantages for Binder Jetting (BJT) production.

Metal Additive Manufacturing, although relatively new among manufacturing technologies, has been around for decades. The first commercial metal AM machines arrived on the market in the 1990s. When GE entered the market in 2016 with the acquisition of Concept Laser, and later Arcam, there was an expectation that the technology would experience rapid adoption and usher in a period of robust competition, price reductions and a supplier ecosystem of third-party services and products.

It has been roughly five years since then and there are now a considerable number of players in the market offering AM machines, feedstock, part manufacturing services, post-processing equipment, and software solutions, for an array of production technologies. Although this active ecosystem of suppliers has developed as expected, metal AM technology is yet to be widely accepted as production-ready. The advantages metal AM offers manufacturers – design freedom, weight savings, assembly simplification, and economic batch size reduction – have been demonstrated in some cases, but not fully realised.

Except for a handful of examples where geometries are complex, asset values high, and volumes low, the technology is not commonly used for production. Instead, it is used to conduct R&D activities and to produce prototypes and tooling.

Currently, compared with the $170 billion-per-year casting industry, metal AM generates less than $2 billion. If we assume the technology adoption cycle for metal AM is a leisurely twenty years, the industry should be generating closer to $14 billion in revenue.

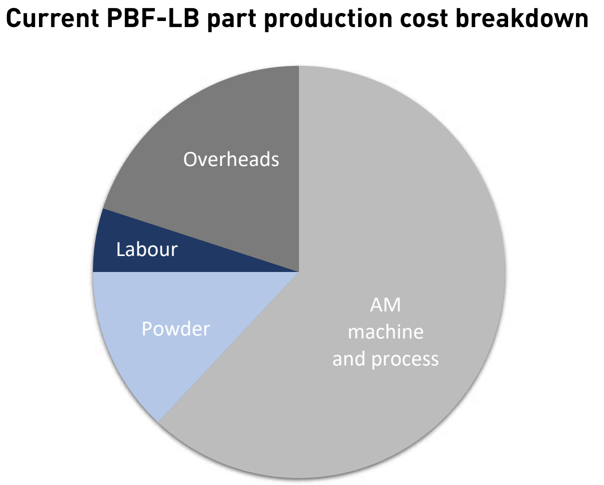

Fig. 1 Relative contribution of business inputs to part cost for PBF-LB

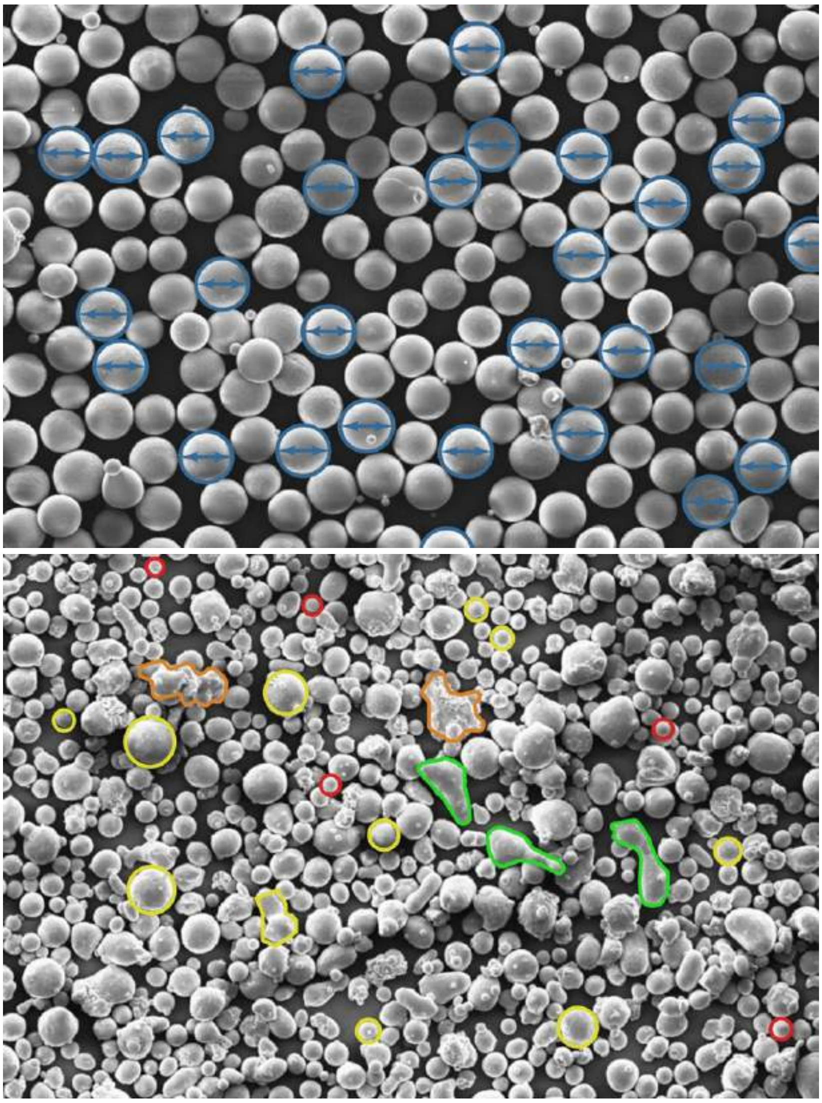

Fig. 2 SEM photograph of Equispheres monodisperse powder (top) compared with a competitor's conventionally atomised powder

The relationship between speed and cost

Why the slow uptake? In a word: Cost. The cost to additively manufacture a part is dependent upon the application (e.g., part design/geometry, desired mechanical performance, surface finish, material, post-processing). The relative contribution of each business input to overall cost for an aluminium part is provided in Fig. 1. These data were derived from information presented by BMW at Formnext 2019.

As depicted, the largest cost by far is the AM machine and associated processing costs. As a general rule, the manufacturer needs to recover the cost of the AM machine (which is in the order of $1-2 million) through the quantity of parts produced. These machines are understandably expensive, as they are complex, precise devices. The problem is that most current Laser Beam Powder Bed Fusion (PBF-LB) machines are very slow. Agonisingly slow. For example, when processing aluminium alloys, one can expect to achieve build rates (on a single-laser basis) in the range of 25–50 cm^3/h.

The lower production rates are more common in demanding aerospace applications, where mechanical performance is paramount, and the higher rates are seen in the automotive industry, where cost is the more dominant factor. Even at the higher build rates of 50 cm^3/h, it takes a PBF-LB machine nearly an hour to produce a 100 g component, at a cost of about $40–50. If that same part were made using casting technology, it would cost approximately $1–5, with an average price of about $1.50.

In fact, many industry experts have stated that, if metal AM costs could be reduced by a factor of ten, the technology would compete economically for a significant portion of the casting market, and a wide range of applications would become viable for mass production. For aluminium, this would mean targeting a cost of less than $5 for a 100 g component. Attaining this lower cost target would spark a market disruption cycle and trigger rapid adoption of the technology as manufacturers rushed to leverage the advantages of AM.

New technologies promise higher speeds

There are some exciting higher-speed developments on the horizon. New metal Binder Jetting (BJT) machines from companies such as Desktop Metal, HP and ExOne use a binder deposition process followed by sintering to fuse powder particles, instead of a laser beam, and are advertising speed increases orders of magnitude greater than those offered by standard PBF-LB. More radical technologies, such as the 'area printing' process in development by Seurat Technologies, also hold a lot of promise.

Importantly, standard PBF-LB machines have been improving their production speeds as well. Additive Industries and SLM Solutions have recently announced new machines that are packed with, respectively, ten and twelve powerful 1 kW lasers – a far cry from the 100–200 W single- and dual-laser machines that were the standard just a few years ago.

Powder quality not only determines mechanical properties, but also speed

While working towards the economics necessary for industry disruption, AM is demonstrating impressive advances in other, less obvious ways. One of these is powder quality. It is well known that the quality of the powder used in PBF-LB systems is important to the mechanical properties and consistency of the final part.

What is not well understood is that the powder can also have a significant impact on production costs, and has the potential to increase production speeds by a factor of four whilst reducing part costs by 50%. In this way, using an optimised powder in existing PBF-LB machines can move the industry halfway to the target for industry disruption of a tenfold cost reduction. To achieve these speeds and cost reductions, powder must exhibit certain characteristics. These are as follows:

Spherical and monodisperse
Near-perfectly-spherical particles with a uniform size (i.e., tight particle size distribution) pack 30% more densely and flow twice as quickly. This ensures dense, evenly-distributed powder layers that can efficiently absorb laser energy. Importantly, the narrow particle size distribution avoids the issue of overheating the smaller particles and the loss of critical but volatile elements such as magnesium.

Fine-free, agglomerate-free
Small particles (i.e., under 10 μm) are pernicious and interfere with the flowability and spread density of the powder.

Smooth surface area
Powder particles with a smooth surface adsorb half the moisture of a traditional powder (and desorb twice as efficiently). Adsorbed moisture can result in hydrogen porosity in the final build and can become a failure initiation point.

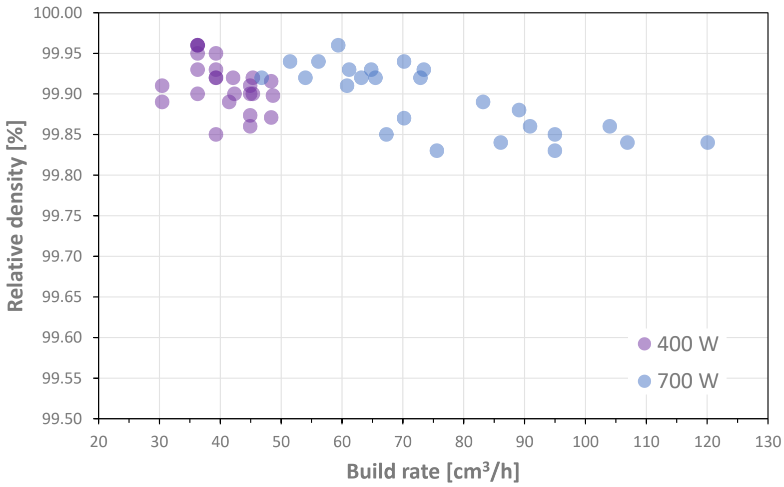

Fig. 3 Monodisperse powders maintain high density across a wide range of build rates and provide a large processing window

Thin oxide layer
Oxides in the powder can lead to defects in the final part, which impact mechanical performance.

Many of the identified features can be readily seen in the SEMs of monodisperse powder from Equispheres versus conventionally atomised powders (Fig. 2). It is our experience that these attributes can only be achieved by a carefully-controlled atomisation process that has been designed specifically to produce powder particles for AM applications.

Of particular importance for production, monodisperse uniform powder absorbs laser energy uniformly, melts uniformly and resolidifies uniformly. This translates to a very large processing window and allows for two important and multiplicative speed improvements:

1. Faster scanning speeds in the horizontal X-Y direction
2. Thicker powder spread layers, enabling a faster vertical build in the Z direction

Tests by service bureaus and industrial partners have repeatedly demonstrated that Equispheres' powder requires approximately 20% less energy input to achieve optimum density and mechanical properties. This provides the ability to increase laser scan speed and hatch distance without requiring an increase in laser power. Additionally, the wider processing range allows for further increases in speed (in some cases, up to 60%) with minimal impact on density or mechanical properties. When combined with the effect of increased layer thickness, this provides a significant advantage.

Successfully increasing layer thickness is dependent on the stability of the meltpool in each layer. The chaotic nature of the meltpool that results from standard AM powder means that achievable density rapidly decreases with increasing layer thickness, even as laser power increases. The meltpool stability achieved with a more uniform powder allows for layer thickness to increase well beyond the current limits, with minimal effects on density.

Fig. 3 shows the densities achieved at various single-laser build rates for current 400 W and 700 W systems. Data are from a parameter space investigation and the scatter is therefore expected. As shown, the monodisperse powders display a large processing window and maintain high density across a wide range of build rates and power levels.

Of course, density is only a proxy for mechanical performance; Equispheres is presently building

	UTS (MPa)	YS (MPa)	Elongation (%)
Minimum	436	274	6.8
Mean	437	276	7.0
Standard Deviation	1.2	1.3	0.1

Table 1 Mechanical results for 80 µm layer AlSi10Mg build

tensile coupons to verify performance at these higher build speeds. Tensile data for specimens built with 80 µm layers, shown in Table 1 and obtained just prior to the publication of this article, demonstrate positive results. While more data will be forthcoming, it is important to note the very tight variance around the mean, indicating excellent build consistency.

Depending on the class of machine available and its associated laser power and systems, there are distinct optimisation strategies the industry can use to achieve the fastest build speeds with the best results. Work conducted by Equispheres has demonstrated that a twofold speed increase over typical build parameters – without impact on mechanical performance – is readily achievable, and a fourfold increase is possible. The effects on speed are most noticeable with higher-powered machines capable of taking advantage of the meltpool stability provided by monodisperse powder to combine faster scan speed with higher layer thicknesses.

Optimising for current machines

Equispheres has been working to tailor-build parameters for its aluminium powders based on the intended use case (e.g., aerospace, automotive) and machine capability. Equispheres' baseline spread layer thickness is currently 60 µm, which is becoming common in the industry, and, depending on available laser power, the end-user can opt to build using a range of speeds. Using the readily available 400 W laser machines at the 60 µm layer thickness, a 45 cm^3/h, > 99.9% dense part is easily attained. Moving up to 500 W laser power allows for > 50% faster scanning speed with no impact on tensile properties, and build rates as high as 80 cm^3/h. For those end-users who desire higher build speeds but are limited to 400 W laser power, an 80 µm spread layer might be the better option; > 99.9% density is achievable with an 80 µm spread layer on that class of machine, with a 50 cm^3/h build rate.

Users with more powerful lasers can opt for even higher build rates. A 700 W single-laser system can produce > 99.85% dense parts built at 100–120 cm^3/h. In all cases, if a manufacturer has slightly lower density requirements, these speeds can be increased significantly. For example, with a density threshold of 99.5%, a 700 W laser machine can achieve single-laser build speeds in excess of 130 cm^3/h (Fig. 4).

Interestingly, with these higher scanning speeds, the recoating time becomes significant, and other less obvious technologies designed to improve production efficiency – such as the 'to the edge' recoater system used in Trumpf's PBF-LB machines, which aims to squeeze out every second of wasted build time – become important.

Optimising for high-power, high-speed machines

PBF-LB

Following the introduction of PBF-LB machines with more powerful lasers and advanced optics (which allow defocusing), spread layers of 120 µm suddenly become practical. Early tests by Equispheres using a 120 µm spread layer, but limiting laser power to 700 W, show that densities > 99.7% are achievable and the nature of the porosity suggests that a higher power, defocused beam will likely be key to optimising the meltpool.

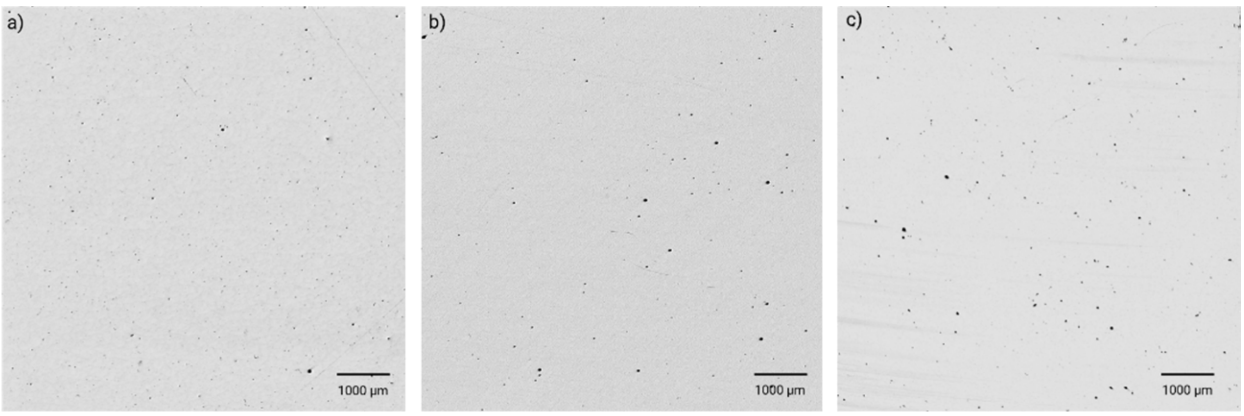

Fig. 4 Optical micrographs with relative densities above 99.85% at (a) 40 cm^3/h, (b) 80 cm^3/h and (c) 120 cm^3/h build speeds

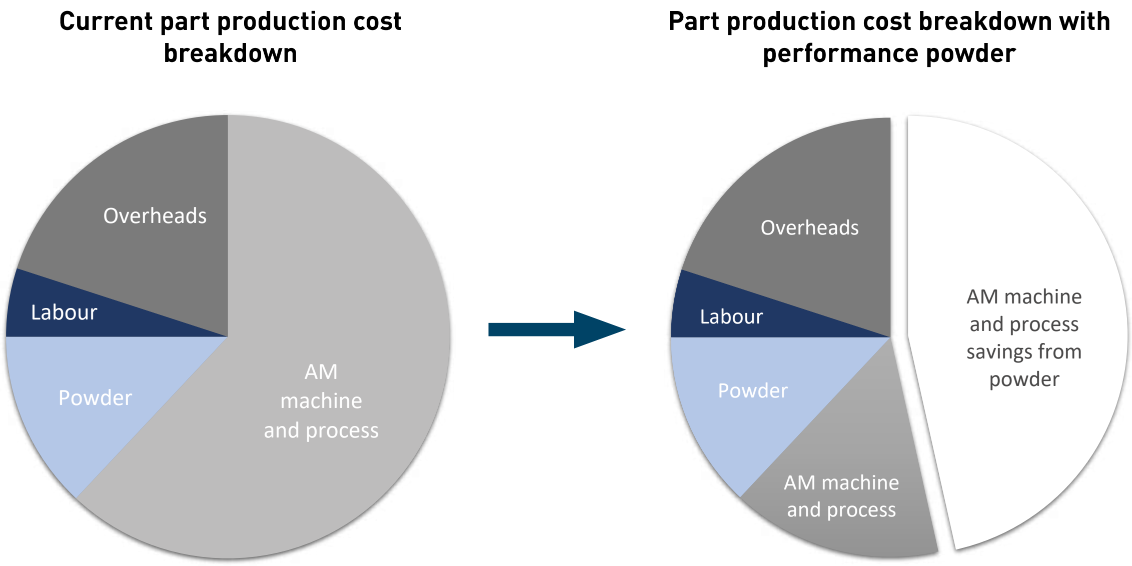

Fig. 5 Potential of monodisperse powder to reduce cost by ~50%

These speed results are exciting. Productivity improvements and lower costs can be readily achieved without new capital investment or special processing. Instead, simply using powder with the right attributes can enable higher build rates at various power levels. Even if one assumes no other improvements related to the cost of the machine, powder, overhead or labour, the improved economics that can be achieved from a superior feedstock range from 25–30% with a clear potential for 50% part production cost reduction in PBF-LB machines (Fig. 5).

BJT

Powder characteristics also play a role in the new high-speed BJT machines, which produce green parts that are then sintered to final density. The process is quick and inexpensive and works well with steels and other industrial metals. Sadly, the process struggles with aluminium, which is difficult to sinter due to its thick oxide layer and low melting temperature. This is unfortunate, as aluminium alloys are the second most commonly used industrial metal and are in demand from the transportation sector. Specifically, automotive manufacturers are rapidly changing the metal composition of their products in favour of aluminium due to its high strength-to-weight ratio that enables lightweighting, thereby reducing greenhouse gas emissions.

Fortunately, the same powder properties that enable fast PBF-LB speeds (spherical, smooth, fine-free, etc) also facilitate aluminium sintering. As shown in Fig. 6, dense microstructures can be achieved without compaction or the use of sintering aids. Bringing aluminium alloys to the BJT market is an exciting prospect and Equispheres is working with multiple industrial partners to achieve this objective.

In that regard, Equispheres continues to refine the characteristics of its powder for different applications. The atomisation technology used by the company can be tuned and powder characteristics such as, but not limited to, particle size distribution can be modified to best support objectives such as sintering, precision builds and high production rates.

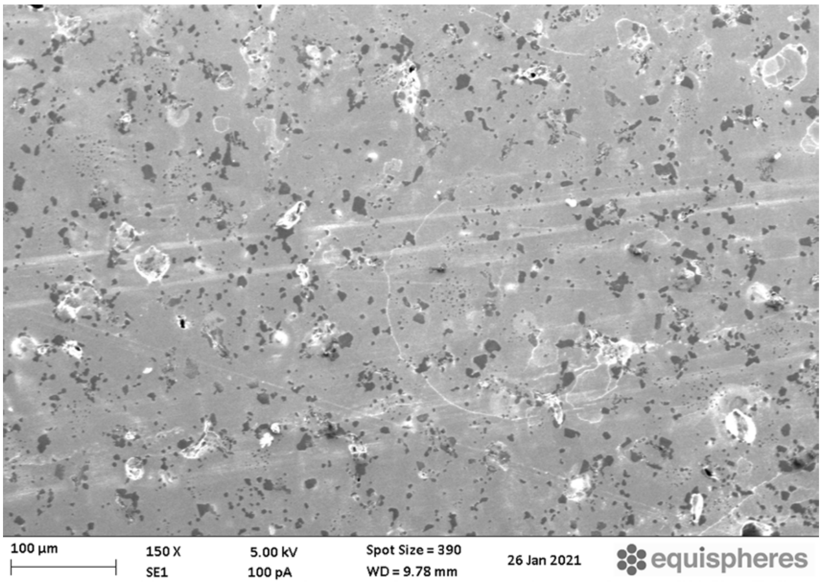

Fig. 6 Sintered dense microstructure without compaction or sintering aids

Field trials in progress

Field testing of the potential speed improvements achievable using Equispheres' powders are currently underway with key industrial users including aerospace, automotive and AM machine OEMs. PBF-LB and BJT machine OEMs have a keen interest in improved productivity and are exploring the use of the powder to increase speed. Severin Luzius, Head of Application and Consulting Additive Manufacturing at Trumpf, commented, "We are continually seeking ways to improve the productivity of our systems to reduce the cost of production for our customers. Obtaining a speed increase from Equispheres powder is definitely worth exploring."

ExOne is a well-established BJT machine manufacturer with a large installed base worldwide. The company is extending its material portfolio to aluminium and has been assessing the use of Equispheres' powder. "There is enormous demand for aluminium alloys in mass-production applications," stated Patrick Dougherty, Director of Commercial R&D. "The unique characteristics of the Equispheres powder are one potential route to meet this need."

Divergent 3D is a California-based startup aiming to disrupt the automotive sector with a technology platform to reduce the complication and cost in automobile production. A key component of its approach is the use of AM to produce car chassis, suspension and subframe components. Simon Pun, Materials Engineering Leader and Lead Metallurgist at Divergent 3D, stated, "As a technology startup company in the automotive sector, we are seeking disruptive technology that provides superior products at a superior price. We are excited to be testing Equispheres' material against our goals in build speed, mechanical properties and cost."

In addition to the cost-focused automotive sector, the aerospace market has also taken an interest in the material. Frank Palm, Senior Researcher at Airbus Central Research & Technology, explained that, "The unique characteristics of the powder are intriguing, and we and other industrial partners are currently conducting tests to determine the impact these attributes may have on potential future products as well production scenarios."

Conclusion

It is important to note that other cost improvements are on the way in Additive Manufacturing. In addition to continued AM machine hardware efficiencies, machine and powder prices are expected to drop and new technologies to minimise pre- and post-processing will be developed. In the meantime, simply utilising improved powder has the potential to bring the market for aluminium parts halfway to the targeted goal of a tenfold reduction in price.

The industry is gathering momentum toward the tipping point that will bring about technological disruption. Brace for it.

Authors

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Doug and Martin collaborate closely in the development of metal powder specifically designed to meet the unique needs of Additive Manufacturing.

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Metal Additive Manufacturing: Why standards lay the foundation for continued industry growth

As the metal Additive Manufacturing industry evolves towards widespread use for series production, the need for globally-recognised standards is also increasing. In this article, Prof Dr-Ing Christian Seidel, Chairman of ISO Technical Committee (TC) 261 'Additive Manufacturing' and Member-at-Large on the Executive Committee of the ASTM F42 'Additive Manufacturing' Committee, outlines why standards are so important, presents an overview of the current AM standards ecosystem, and highlights current key areas of standardisation activity.

In recent years, more and more organisations have started to develop standards for Additive Manufacturing. This is because the size of the industry has now reached a level where effective business is only possible on the basis of a reliable and complete set of accepted industry standards.

I write this article as Chairman of ISO Technical Committee (TC) 261 'Additive Manufacturing' and Member-at-Large on the Executive Committee of the ASTM F42 'Additive Manufacturing' Committee. These two committees have been cooperating since 2011 to provide the Additive Manufacturing industry with the needed standards. In this article I intend to outline recent progress and some fundamental aspects of standards. An overview on the organisation of ISO/ASTM joint standard development is provided, and the current strategic direction of standardisation is introduced.

What readers will discover is that, on the one hand, a powerful structure for international standardisation has been built up in recent years and is now available and, on the other hand, a large number of relevant standards is already available.

The need for standards in Additive Manufacturing

The Additive Manufacturing industry as a whole is rather niche and still in its infancy. However, the market has recorded high growth rates in recent years and has, therefore, received a lot of attention. A comprehensive set of industry standards is a requisite if this is to remain the case. Most recently, Additive Manufacturing technologies have gained significance as production technologies. Originally, the only field of application for AM was the time-efficient production of prototypes – also known as Rapid Prototyping. During the last five to ten years, a significant increase in applications for direct part production can be observed, especially in the aerospace and medical industries, as well as in general engineering.

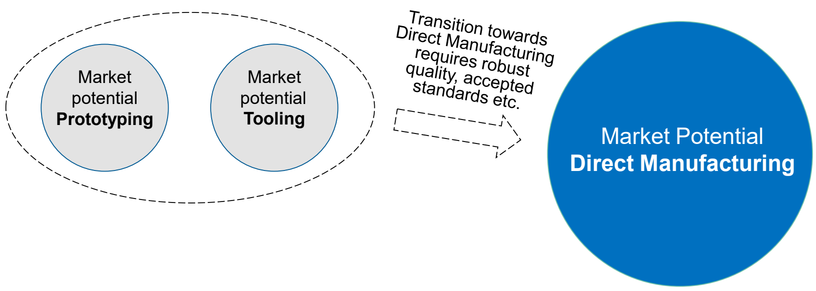

Fig. 1 Market potential of the prototyping, tooling and Direct Manufacturing application of Additive Manufacturing (qualitative, size indicates market potential)

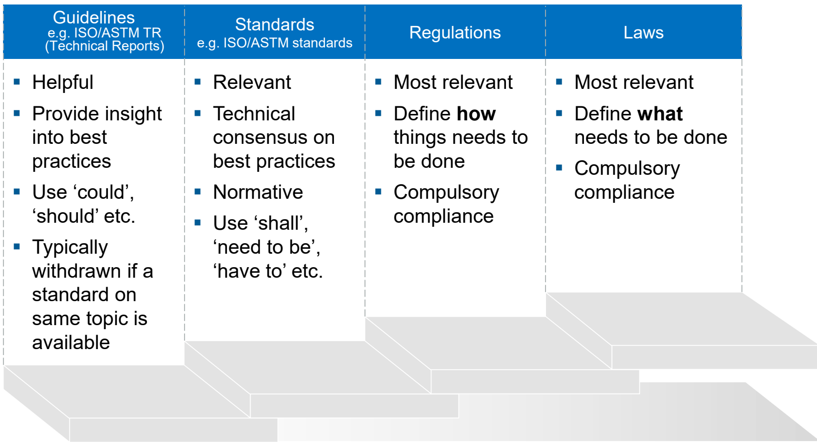

Fig. 2 Simplified ranking between laws, regulations, standards and guidelines

This extension in application from prototyping to manufacturing is crucial to continue the growth rates seen in recent years, because prototyping often does not require the production of more than ten parts. However, to achieve a double-digit compound annual growth rate over the coming years and to further mature Additive Manufacturing technologies, it is necessary to identify and exploit business cases within small- and medium-scale series. As a result, machine and material sales will increase and Additive Manufacturing technologies will further establish themselves as production technologies.

Fig. 1 is intended to show, qualitatively, that the market potential for direct manufacturing is many times greater than that of prototyping and tooling. In addition, the growth potential in prototyping applications has largely been exploited at this point. Standards can be seen as a key enabler for the transition towards direct manufacturing; economic utilisation of AM processes in a production environment on an increasing scale simply isn't possible without a comprehensive set of industry-specific standards.

The role of standards

The foremost aim of international standardisation is to facilitate the exchange of goods and services by eliminating technical barriers to trade. Standards serve as a common language that promotes the flow of goods between buyer and seller and protects their general welfare. Typical benefits of standardisation in the field of AM comprise:

- Providing a common language (e.g., terms & definitions)
- Assisting users with the assessment of different AM processes, resulting in the use of appropriate technology for specific product demands
- Specifying requirements for processes, materials, design, and test methods
- Standardising data formats, structures and metrics for AM models
- Providing guidance on environment, health and safety concerns
- Providing qualification schemes and defining requirements for personnel qualification
- Standardising the process chains of AM technologies, securing functionality, compatibility and easing the design of efficient global and local supply chains
- Communicating guidance and possible courses of actions
- Documenting best practices.

Thereby, standards can help accelerate the adoption of new technologies and ease international collaboration. In the field of Additive Manufacturing, standards are a key enabler for the upscaling of the industry. However, standards should not be confused with laws and regulations; compliance is not compulsory (Fig. 2).

Ecosystem of international standardisation for AM

We are currently seeing a lot of standardisation activity, with various Standards Development Organisations (SDOs), certification bodies and associations being active in the field of AM. Fig. 3 provides a partial overview of this, but, nevertheless, only contains an extract of the worldwide activities. In general, a distinction can be made between standardisation activities that are intended to bring national added value: for example, in Germany, the German Welding Society, versus those intended for international recognition, such as ISO/TC 261 and ASTM F42 on Additive Manufacturing.

Furthermore, it makes sense to picture SDOs, certification bodies and associations within one umbrella, as there is a close link between these organisations. SDOs intend to develop technical regulations, which are then used by certification bodies to develop their certification procedures. Associations serve as the voice of the industry and provide both SDOs and certification bodies with information on the needs of their members.

In addition, standards only become of value when applied in industry. For that reason, Associations also serve as information and marketing channels for SDOs as part of a win-win situation.

In Fig. 3, the text blocks are marked with logos or flags that indicate the origin of the above groupings. The upper row shows the situation for Germany, where, primarily, the DIN and VDI are promoting standardisation in the area of AM. The middle row contains information on AM-relevant committees within the ISO organisation and the EU. The bottom row gives an insight into the standardisation landscape in the USA.

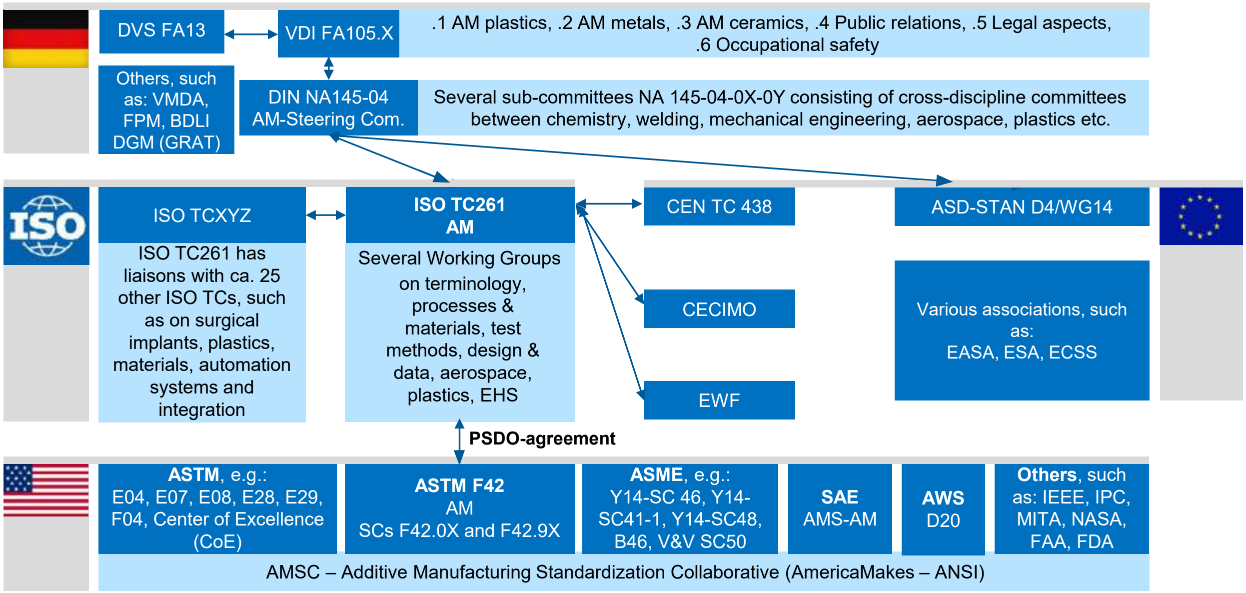

Fig. 3 Selected worldwide standardisation activities covering selected associations, certification bodies and SDOs. Arrows indicate formal cooperation. TC =Technical Committee; FA & NA = German for Committee; AM = Additive Manufacturing; EHS = Environment, Health and Safety; PSDO = Partner Standards Developing Organization; SDO = Standards Development Organizations (Source USA: AMSC Standardization Roadmap for Additive Manufacturing, Version 2.0, June 2018, based on a graphic developed by Joerg Lenz, former chairman of ISO TC261)

Introducing ISO/TC261

ISO, the International Organisation for Standardization, is a legal association, the members of which are the National Standards Bodies (NSBs) of some 140 countries - organisations that represent a country's social and economic interests at the international level. ISO is supported by a central secretariat based in Geneva, Switzerland. In total, 23,413 international standards have been published by ISO as of October 2020, covering almost all aspects of technology and manufacturing. In 2020, 792 Technical Committees (TC) and subcommittees took care of standards development.

ISO TC261 is the technical committee within ISO on Additive Manufacturing. The scope of ISO TC261 is stated as, "Standardisation in the field of Additive Manufacturing (AM) concerning their processes, terms and definitions, process chains (Hard- and Software), test procedures, quality parameters, supply agreements and all kind of fundamentals."

As of Q1 2021, ISO TC261 had twenty-five participating and eight observing members. Moreover, nineteen ISO standards were published, with an additional 31 were under development, most of which were joint ISO/ASTM standards. The most current information on published documents and ongoing work can be found at [1].

The structure of ISO/TC261 is characterised by Working Groups (WGs). As of Q1 2021, five Working Groups are available (Table 1). Currently, there is no WG5 – this gap is a result of a renumbering of so called Joint Working Groups (JWGs),

TC261 Working Groups	Area
WG1	Terminology
WG2	Processes, systems and materials
WG3	Test methods and quality specifications
WG4	Data and Design
WG6	Environment, health and safety
TC261 Joint Working Groups	**Area**
JWG10	Joint ISO/TC 261 – ISO/TC 44/SC 14 WG: Additive Manufacturing in aerospace applications
JWG11	Joint ISO/TC 261 – ISO/TC 61/SC 9 WG: Additive Manufacturing for plastics
TC150/JWG1	Joint ISO/TC 150 – ISO/TC 261 WG: Additive Manufacturing in surgical implant applications

Table 1 ISO/TC261 'Additive Manufacturing' – Working Groups and Joint Working Groups

F42 Subcommittee	Area
F42.01	Test Methods
F42.04	Design
F42.05	Materials and Processes
F42.05.01	Metals
F42.05.02	Polymers
F42.05.05	Ceramics
F42.06	Environment, Health, and Safety
F42.07	Applications
F42.07.01	Aviation
F42.07.02	Spaceflight
F42.07.03	Medical/Biological
F42.07.04	Transportation/Heavy Machinery
F42.07.05	Maritime
F42.07.06	Electronics
F42.07.07	Construction
F42.07.08	Oil/Gas
F42.07.09	Consumer
F42.08	Data
F42.90	Executive
F42.90.01	Strategic Planning
F42.90.02	Awards
F42.90.05	Research and Innovation
F42.91	Terminology
F42.95	US TAG to ISO TC 261

Table 2 F42 Additive Manufacturing subcommittees

which operate as a collaboration between two committees to mutually benefit from domain-specific expertise. Cooperation with other ISO/TCs has always been in the DNA of ISO/TC261 in order to meet application-specific AM needs. For this reason, the three JWGs shown in Table 1 have been established so far. In addition, around twenty formal liaisons were established with other ISO/TCs and relevant organisations in order to ensure exchange of information and a foundation for collaboration.

Introducing ASTM F42

ASTM International is a Standards Development Organisation (SDO) and has been developing standards for more than ninety industry sectors since 1898. Currently, there are more than 12,800 ASTM standards operating globally [2], including 140 technical committees with more than 30,000 volunteer members representing more than 140 countries.

The ASTM F42 Technical Committee on Additive Manufacturing Technologies was formed in 2009. F42 is one of the technical committees within ASTM and it passed the thousand member mark in late 2020, with over twenty-eight countries contributing actively to its AM standards development work. The F42 committee meets in person twice a year, typically in conjunction with ISO/TC261, and there have been twenty-two meetings since 2009, ten outside of the US. To date, F42 meetings continue to attract large industry interest and participation from the AM community, including representatives from government agencies, industries, academia and trade associations. Besides the biannual meeting, members within each working group attend regular conference calls to progress standard development.

Generally, each main committee in ASTM is composed of subcommittees that address specific segments within the subject area covered by the technical committee. F42 follows the same structure and is composed of the subcommittees listed in Table 2. The general set-up is, intentionally, similar to the structure of ISO/TC261.

ISO/ASTM collaboration

In 2011, ISO and ASTM signed a cooperative agreement to govern the ongoing collaborative efforts between the two organisations to adopt and jointly develop international standards that serve the global marketplace in the field of Additive Manufacturing. The purpose of this Partner Standards Developing Organisation (PSDO) cooperative agreement is to eliminate duplication of effort while maximising resource allocation within the industry.

ISO/TC 261 and ASTM F42 are striving for 'dual logo' standards, 'ISO/ASTM'-standards, that reflect a strong international consensus, allowing these standards to be used by companies worldwide. For the development of these joint standards, a 'Three Level Approach' has been developed, as shown in Fig. 4.

Ideally, generic and generally relevant 'general top-level AM standards' are developed in all subject

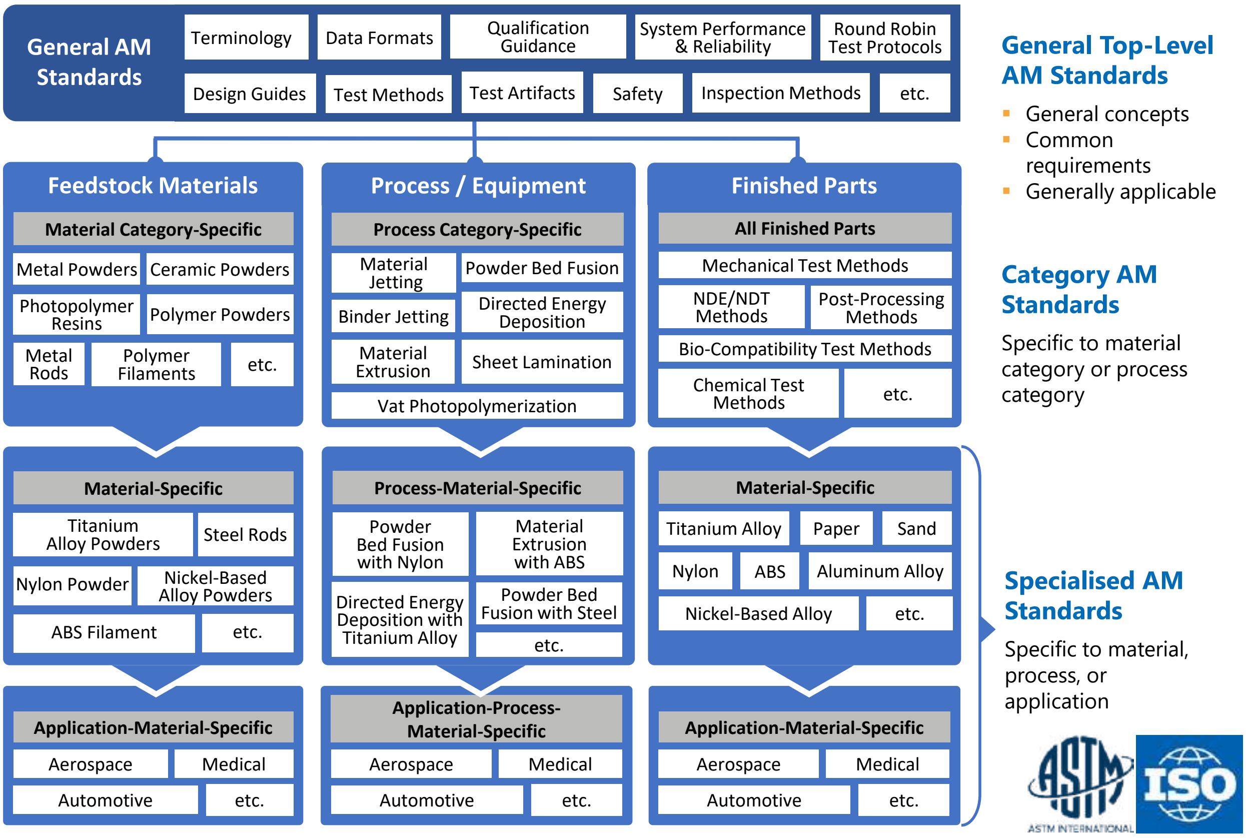

Fig. 4 The three-level approach of joint standard development between ISO/TC261 and ASTM F42

areas at the beginning. Building on this, the development of 'category AM standards' should then begin, which apply to specific material or process categories, for example. 'Specialised AM standards' can then be developed for specific needs, building on the first two levels. It is important to highlight the 'etc.' - boxes in Fig. 4: since ISO/TC 261 and ASTM F42 aim to serve all industries' current needs, the topics mentioned in the chart are meant as examples. The fact that technologies are developing rapidly, as the latest research results on smart parts shown in Fig. 5 demonstrates, means that standardisation must also be organised in an adaptable manner and driven by market demand.

The objectives of this collaboration can be summarised as follows:

- Deliver ISO/ASTM-standards needed for industry
- Consider worldwide standard needs
- Deliver comprehensive sets of industry-specific standards
- Cooperate and collaborate with relevant players in the AM industry
- Serve as a 'melting pot' for the international AM community.

As of Q1 2021, there are now sixteen published joint ISO/ASTM AM standards [3] and 50+ joint standards [4] under development. For 2021, projects will increasingly address standardisation requirements of the automotive, construction and space industries, as well as other sectors such as oil/gas, etc. To meet standards demand from the

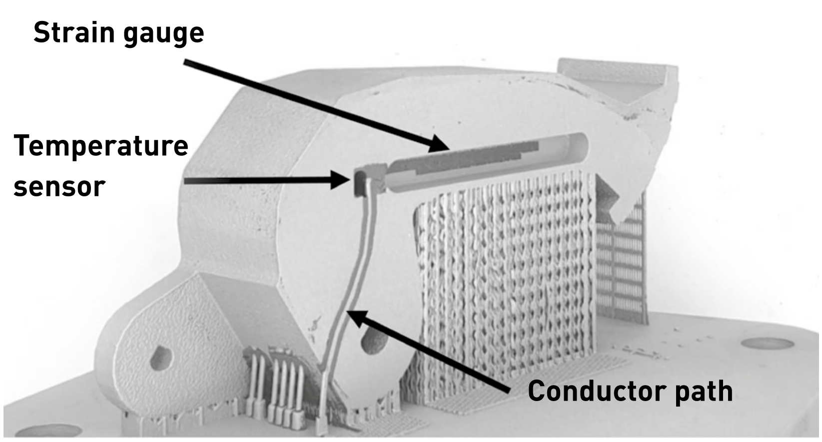

Fig. 5 Demonstrator for a sensor-integrated smart part, built on a modified PBF-LB machine, courtesy Fraunhofer IGCV, Augsburg, Germany

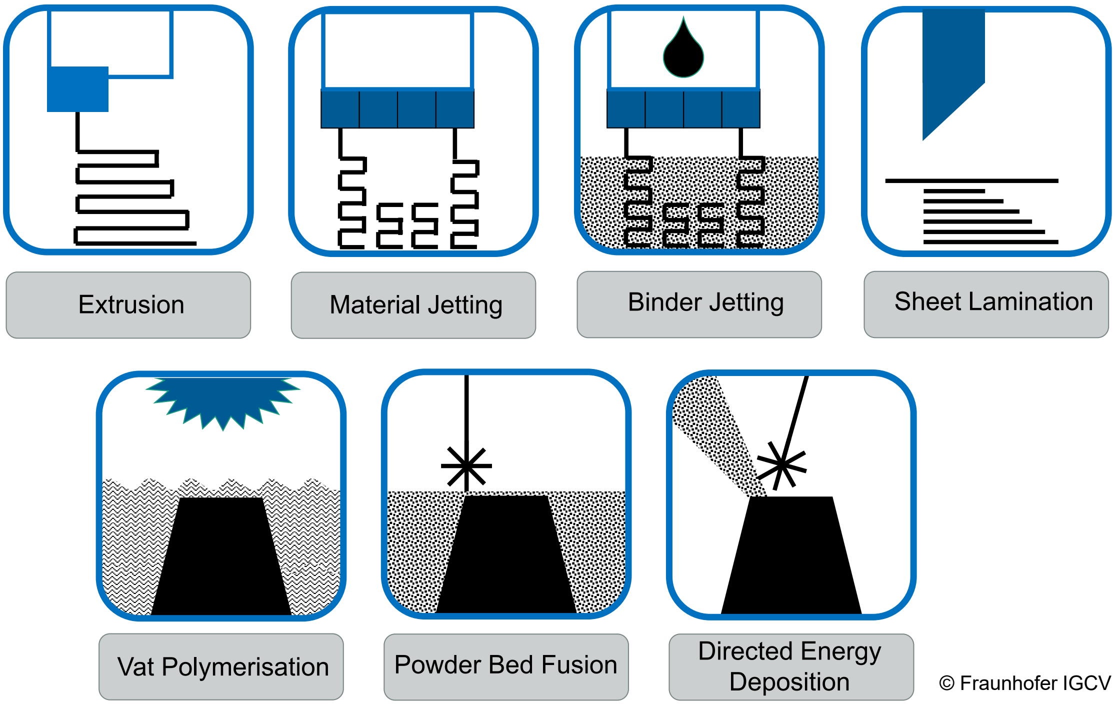

Fig. 6 Additive Manufacturing process categories defined by ISO/ASTM 52900:2015 (Courtesy Fraunhofer IGCV)

automotive industry, Joint ISO/TC 261 – ASTM F42 Group 'Qualification for AM processes in automotive applications' was established in late 2020.

Introducing terminology standard ISO/ASTM 52900

When a new technology emerges, the first topic to which technical regulations are devoted is always terminology. This is established practice, since without a common terminology, or language, no in-depth technical exchange is possible. For this reason, terminology was also addressed by the first standardisation project in the field of Additive Manufacturing. In 2015, the result was published as ISO/ASTM 52900 'Additive Manufacturing – General Principles – Terminology'. Within ISO/ASTM 52900:2015, for example, seven process categories were introduced to classify AM technologies (Fig. 6). Furthermore, new terms emerging from the further work in Additive Manufacturing will be included in upcoming amendments, such as the Draft International Standard update as of 2020.

"When a new technology emerges, the first topic to which technical regulations are devoted is always terminology. This is established practice, since without a common terminology, or language, no in-depth technical exchange is possible."

Spotlight on selected international Additive Manufacturing standards

As mentioned above, currently nineteen standards have been published by ISO/TC261. Fig. 7 allocates selected documents in a generic AM process chain and teasers in which areas the international standards could be applied. The following is a brief introduction to the standards published in 2020.

Material Extrusion (MEX)
With ISO/ASTM 52903-1:2020 and ISO/ASTM 52903-2:2020, the first international standards on Material Extrusion processes are now available. Part 1 covers feedstock material and Part 2, corresponding process equipment. This is a significant milestone to enable extrusion-based technologies to further gain market relevance.

Pre-process

- **Use design standards**, cf. e.g. ISO/ASTM 52910:2018 (general) ISO/ASTM 52911-1:2019 (metal) ISO/ASTM 52911-2:2019 (polymer) ISO/ASTM TR 52912:2020 (multi-material)
- **Use AMF-File Format 1.2** instead of STL – perfect fit to AM requirements, cf. ISO/ASTM 52915:2020

In-Process

- **Check machine capability by using test artefacts;** cf. ISO/ASTM 52902:2019
- **Powder**, cf. ISO/ASTM 52904:2019 and monitor work of Joint ISO/TC 261-ASTM F 42 Group 71: Powder quality assurance

Post-Process

- **Non-destructive testing:** cf. ISO/ASTM AWI TR 52905 Non-destructive testing (NDT) of additive manufactured products
- **Post-processing methods:** cf. ISO/ASTM AWI 52908 Quality assurance and post processing of powder bed fusion

- **System performance and reliability**
  ISO/ASTM 52941:2020 Acceptance tests for laser-based powder-bed fusion machines for metallic materials for aerospace application
- **No own machines? "Buy Scenario"**
  Check ISO/ASTM 52901:2017 for Requirements for purchased AM parts
- **Qualification Principles**
  Qualification of machine operators: cf. ISO/ASTM 52942:2020 (aerospace) and ISO/ASTM 52926 series part 1 to 5

Fig. 7 Selected standards put into perspective with regards to generic AM process chain

System performance and reliability

ISO/ASTM 52941:2020 covers an acceptance test for Laser Beam Powder Bed Fusion (PBF-LB) machines for metallic materials for aerospace application. Therefore, it eases and supports certification procedures in the aerospace industries. Though being specifically developed for the aerospace industry's needs, it can also be used in other industries, if suitable.

Data format

ISO/ASTM 52915:2020 is an international standard covering a specification for the Additive Manufacturing File Format (AMF), version 1.2. AMF is a standardised open data format specifically designed for the needs of Additive Manufacturing processes. It is technically more suitable than the quasi-standard format STL, by far, but has not yet gained industrial significance. With the 2020-released AMF version 1.2, described in ISO/ASTM 52915:2020, this is likely to change.

Qualification principles for Additive Manufacturing

As Additive Manufacturing technologies are increasingly used in production, there is a demand for qualified staff. For that reason, six international standards are currently under development within ISO/TC 261 to provide qualification principles for several profiles. ISO/ASTM 52942:2020 is the first published international standard of a series of qualification principle standards to be followed in 2021. ISO/ASTM 52942 covers requirements for machine operators of PBF-LB machines and related equipment used in aerospace applications.

Design

ISO/ASTM TR52912:2020 is an international Technical Report that provides an overview on functionally graded Additive Manufacturing. As an ISO/ASTM Technical Report (TR) it is an informative and non-normative document. An example multi-material part is shown in Fig. 8.

Fig. 8 Multi-material part, consisting of tool steel (1.2709) and a copper alloy (Courtesy of Fraunhofer IGCV)

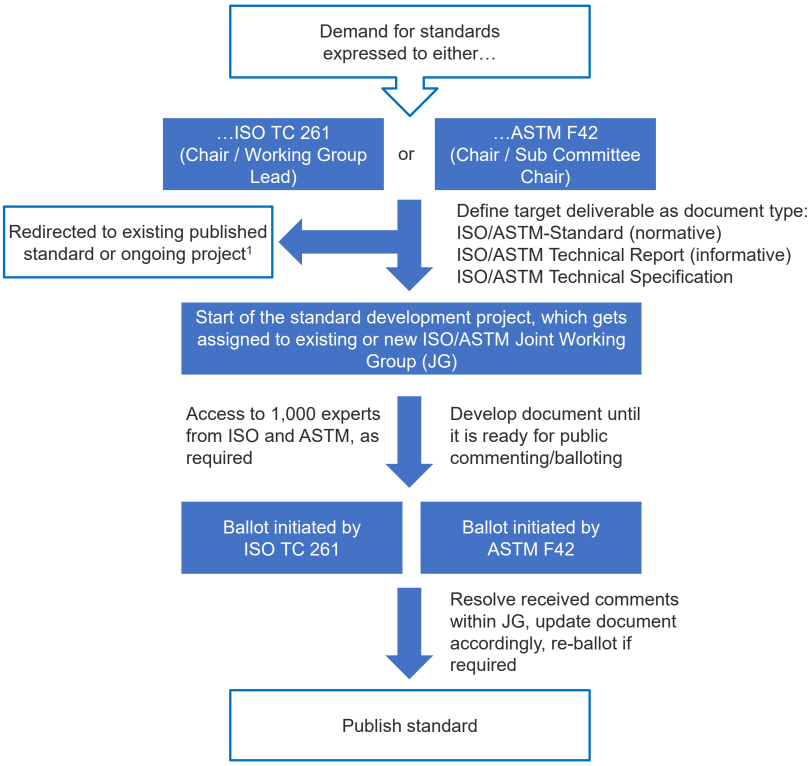

Fig. 9 How to get involved? [1]

How to get involved?

The standardisation network is constantly growing and welcomes new interested experts. There is no defined group of experts that develops standards for everybody – it must be demand-driven and "for users, by users". Fig. 9 shows a flowchart of how interested parties can get support if they are looking for a standard or wish to develop a standard.

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References

[1] https://committee.iso.org/home/tc261

[2] www.astm.org

[3] https://www.iso.org/committee/629086.html

[4] https://committee.iso.org/home/tc261

The advantages of Additive Manufacturing for the processing of platinum group metals

There is growing interest in the use of metal Additive Manufacturing for the production of jewellery and luxury watch components. This interest is driven not only by the potential design innovation offered by Additive Manufacturing, but also by the recognition of the environmental and economic advantages to be gained from it. In this in-depth report, Jochen Heinrich, Thomas Laag and Thierry Copponnex review the processing of platinum group metals by Additive Manufacturing.

Alloys of platinum group metals (PGM) show outstanding characteristics for jewellery and watch making: they are precious, strong and white. Technical users appreciate their biocompatibility and unrivalled resistance to corrosive or thermal wear. At the same time, these alloys represent the most challenging materials with respect to processing, refining and high costs in capital.

The powder metallurgical processing of PGMs is a practice essentially different from conventional manufacturing. This paper gives an insight into the processing of platinum and palladium alloys by Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing technology.

Many indicators show that using AM provides an opportunity to make production more efficient, environmentally friendly and customer-oriented. It is clear that the combination of AM with CNC machining offers resource-efficient manufacturing for high-quality jewellery and watches, as well as for technical or medical applications.

PGM alloys used in this study

A selection of representative alloys have been used for the experimental work in this study. In the following, three major alloys are briefly described:

Pt800Ir200

This is a well-established platinum alloy with 20 wt.% of iridium, and is widely used for medical and technical applications. It offers excellent chemical resistance, as well as thermal and mechanical stability.

Pt950Au

This is a universal Pt jewellery alloy, hallmarkable by 950‰, with high strength and extraordinary casting performance. It is a four-component alloy with 95 wt.% platinum content and gold, indium and ruthenium used as alloying elements to adjust the desired properties, such as a high

Fig. 1 Cuff link additively manufactured from Pt950Au, with an integrated clasp, produced together in a single process

Alloy (weight‰)	Pt950Au	Pt950CuGa	Pt950Ru	Pd500Rh500	Pt800Ir200
Hardness (HV)	165-270	160-235	125-210	185-350	190-260
UTS (MPa)	500-1000	430	410-800	680	630
Yellowness Index (YI)	10	13	9	8	-

Table 1 Properties of selected PGM semi-finished products

hardness, a perfect white colour, a low melting range, a fine microstructure, and high biocompatibility and ductility.

Pd500Rh500

This is one of the most outstanding alloys for high-end jewellery, with a hardness of up to 350 HV and a tensile strength of up to 680 MPa. The alloy, with 50 wt.% rhodium, is perfectly white like rhodium-plated products (yellowness index of 8). Pd500Rh500 is difficult to process traditionally, due to its high hardness and its liquidus temperature of 1800°C, requiring powerful casting equipment and hot forming or forging. On the other hand, powders of the alloy behave like any other Pt powder. These characteristics make Pd500Rh500 ideally suitable for PM technologies like AM.

Significant quantifiable properties of the alloys are listed and compared with literature data for other common alloys in Table 1.

Conventional processing of PGM alloys

Conventionally, the processing of PGM alloys includes the production of semi-finished products, the manufacture of products by punching and CNC machining, including a recycling loop of scrap, if possible, and end-of-life refining. End-of-life refining is much more complex than that required for gold [10]. While the underlying hydrometallurgical processes are selective for gold, the refinement of PGMs takes place in complex separation processes, with dissolving and precipitation treatments taking place afterwards for purification. The effort involved is much higher, and the whole recycling process requires special equipment and knowledge, intricate analytical methods and more energy. In addition permission from local authorities may be needed, as well as environmental emissions monitoring.

Additionally, the time required to obtain pure PGM, as the outcome of the refining process, is significantly longer, which is also an important cost factor. Thus, it is highly desirable to reuse scrap and to reduce end-of-life scrap to a minimum.

The production of semi-finished products is a multi-step process starting with the alloying and casting of ingots or bars. Typically, vacuum induction melting furnaces are used to reach the high melting temperatures of PGMs. These melting units are fundamentally different from the continuous casting machines used for processing metals with lower melting temperatures, which can process large amounts of metal at low cost. Because cost-effective graphite crucibles are not suitable for use with PGM alloys (due to the reaction of platinum and palladium alloys with carbon), costly zirconia ceramic crucibles must be used [1]. The cost and effort involved in producing semi-finished products from platinum or palladium alloys is high, mainly due to the limitation of the batch process, the resulting amount of scrap from removing sections with shrinkage cavities and from surface machining to produce defined surface finishes. Consequently, the material input factor and the amount of recycling is high in conventional processing of PGM alloys.

As a result, the manufacturing of PGM alloy parts follows one of two paths. One is investment casting to produce parts close to net shape. This is, again, a multi-step process, where the quality of the part is determined by the quality of each step. Investment casting is a challenging task, in particular for the manufacture of platinum parts. Many studies have been carried out in the past to control the quality and to understand the occurrence

Fig. 2 Scrap from stamping (left) vs a near-net-shape AM watch case (right)

of casting defects. Extensive work in recent years, by Klotz *et al.* [2], Frye *et al.* [3] and Maerz *et al.* [4], reported the effects, problems and opportunities for quality improvement of platinum castings by Hot Isostatic Pressing (HIP), the prevention of crucible reaction, special gate and sprue design or correct choice of alloy and investment sand. Another problem is the embrittlement of the material due to contamination by the ceramic crucible during melting. Refining of residues is essential in ensuring part quality. The bottom line is that the casting of platinum is more difficult than casting gold or silver.

The second manufacturing path is based on the processing of semi-finished products by CNC machining. When following this route, material quality is primarily determined by the quality of the semi-finished product. PGM semi-finished products are produced on an industrial scale according to quality standards. The material input factor is also high for this path, since milling from solid or stamped parts involves a high level of material and tooling investment (Fig. 2). A certain proportion of PGM scrap is recycled in a closed-loop production cycle; this requires clean and dry scrap, without any extraneous materials or chemical contamination. Pure PGM scrap is fairly easy to recycle and turn into new products, using vacuum melting and recasting, at low risk. End-of-life refining of PGM scrap, however, in contrast to recycled scrap, requires a complex and time-consuming hydrometallurgical refining process. Chemical substances in the PGM recovery process need to be handled cautiously, resulting in high standards with respect to operational safety, waste gas and water treatment. The specialised facilities required are subject to very high federal legislative requirements, as well as regulations and a code of practice by the Responsible Jewellery Council (RJC).

In summary, the traditional processing and refining technology of PGMs is characterised by many production steps, the need for special machinery and tools, a high input factor of pure material, and a long and complex refining process. Consequently, the traditional processing of PGM alloys is expensive and material-intensive.

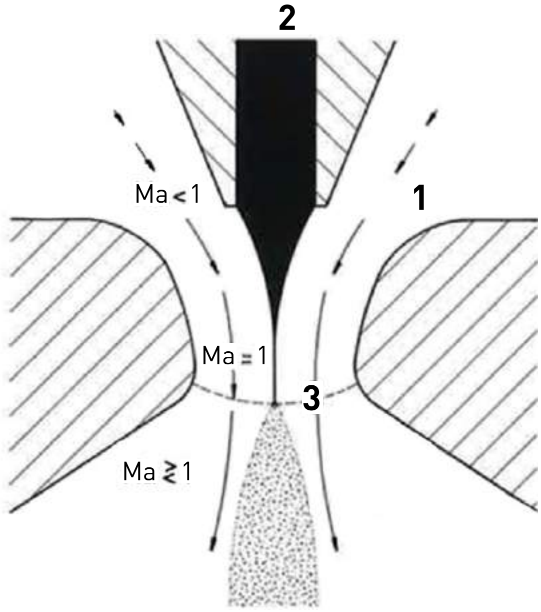

Fig. 3 Laval-type nozzle used in the Nanoval process [5]

Powder metallurgical processing of PGM alloys

Powder-based processing of PGMs opens a fundamentally different window of opportunity to create a lean production route at improved quality. The overall process is shorter, with a significantly reduced material input factor and quantity to be refined.

Powder production

Starting with the production of PGM powders, there are various techniques for producing metal powders according to their metallurgy, configuration and costs. As processing technologies like AM and Metal Injection Moulding (MIM) usually require powders of high sphericity, gas atomisation of melts for production of precious metal powders is the method of choice. The gas atomiser with the most spherical powders uses the Nanoval process [5]. Such systems are capable of atomising the whole range of precious metal alloys, including high-melting PGM alloys with Ir and Rh.

The process is based on a Laval-type nozzle placed concentrically below the heated feeder of a melt stream at the opening of a pressure chamber (Fig. 3). The nozzle's converging cross section accelerates the inert atomisation gas to the velocity of sound, while the melt stream is compressed to a thin filament. The filament finally atomises at the transition to the diverging cross-section of the nozzle. This setup creates very fine droplets with very little convection, to provoke the formation of powder particles without undesired satellites. While powder batches produced by free fall or coaxial (close-coupled) nozzles have mean particle diameters (d50 = d(Q3 = 50%)) of down to 30 µm to 70 µm, respectively [6, 7], using the Nanoval

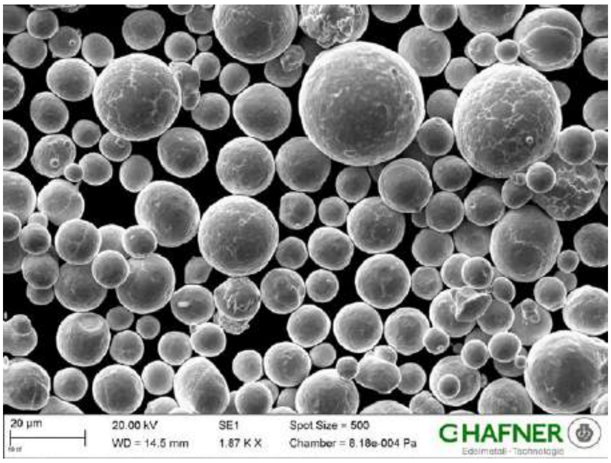

Fig. 4 Gas atomised Pt powder particles at high resolution

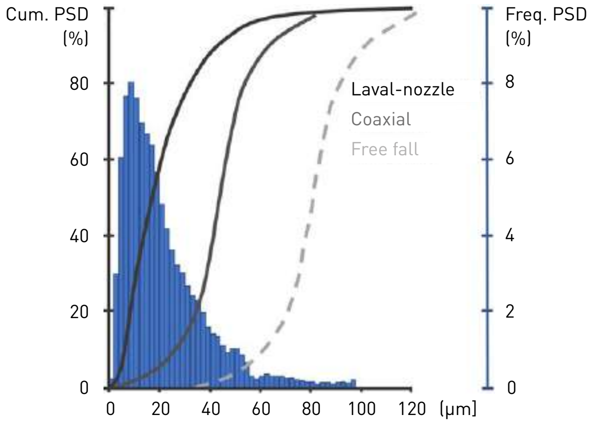

Fig. 5 Typical particle size distributions for different atomiser types

process reduces that value to as little as 15 µm (Figs. 4 and 5).

The consequent classification of the powders is inevitable for further utilisation. Each method and application requires a specific particle size distribution (PSD), such as a fine range for highest resolution, optimised sintering performance or a yield-optimised range. The small particle size of powders, produced by atomisation using the Nanoval process, already correlates well with the desired PSD of powders for use in AM and MIM, resulting in a high yield after classification.

Fig. 6 shows the typical PSD of a Pt950Au alloy qualified for PBF-LB. According to experience in material qualification for a PBF-LB process, a PSD with a range of 9–53 µm (lowest particle diameter d1% = 9 µm to cumulative upper size limit d99% = 53 µm) achieves the best combination, with regard to density, surface roughness and feature size of AM parts made of Pt950Au. The yield for this PSD is about 80% of an atomisation batch.

The sizing process can be done by sieving or air classification. The limiting factor for selecting either method is not only the cut size, but the density of the powder and the practical classification rate. Cuts containing small particle sizes are predestined for air classification, because fine sieves are limited to a mesh size of ≥ 25 µm and very low throughput, i.e., low classification rates. On the other hand, cuts containing larger particle sizes are limited by the basic principle of drag, centrifugal forces and rotation speeds versus the density of the particles. Smaller cuts can be done by air classification, while large PSD cuts are executed by sieving.

The typical classification rate is 5–10 kg/h for air classification and up to 15 kg/h for sieving. Tumbler screening machines have even higher rates, although the focus of batch sizes and flexibility of system changes need to be taken into consideration.

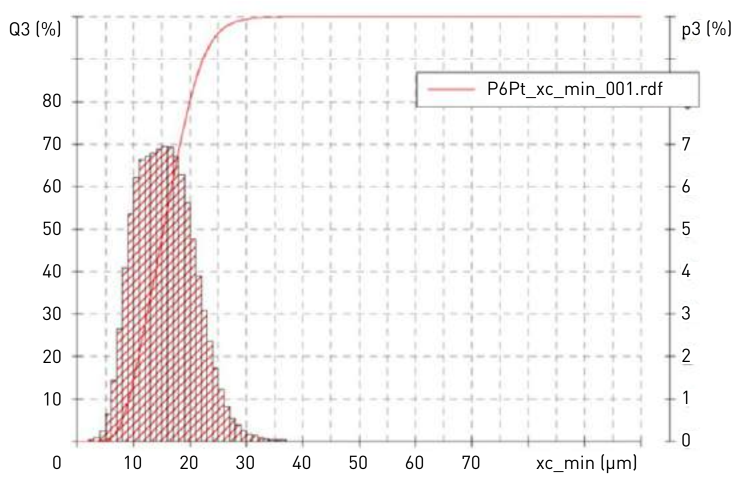

Fig. 6 Typical PSD of a Pt950Au powder for AM

Additive Manufacturing with PGM powders

The AM parts shown in this work were produced by PBF-LB. The process development and material qualification process included optimisation of the process parameters of hatch, contour, and support strategies, based on the specific metallurgy of the alloy, PSD of the powder and design of the part. Major parameters to be considered were slice thickness, laser power, scanning speed, scanning order, hatch distance, field offset, border distance and platform material – in total more than ten essentially individual parameters. Fundamental issues are:

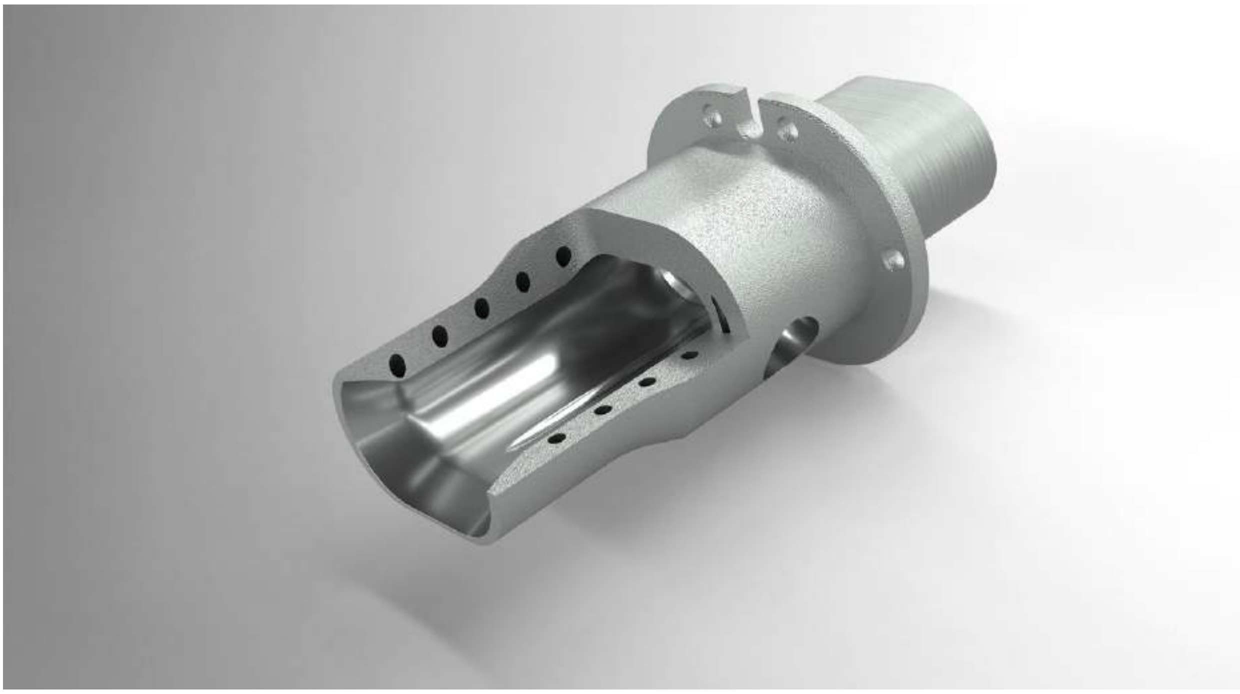

Fig. 7 Technical application example made of Pt800Ir200

Energy

Modern systems with several hundred watts of actual output provide enough energy for building a melt pool, even for materials with a high liquidus temperature like Pt. However, the quality of the melt pool is influenced by material-specific reflectivity, absorption and thermal conductivity. For example, the reflectivity of a 1070 nm (red) laser wave by Pt is about 75% and more than 90% by Au, Ag and Cu. PBF-LB machines with a green laser source (wavelength 535 nm) reduce the reflectivity to about 70% for Pt and Au [8].

Ambient conditions

Unavoidable smoke during the process needs to be dragged away reliably without disturbing the energy input and contaminating the powder bed. Additionally, the partial pressure of oxygen needs to be limited to 0.1% for PGM powders to reduce porosity, according to recent studies. With this limit, powder is reusable many times without an oxygen enrichment exceeding 100 ppm. C Pogliani *et al* recommend a limit of 0.15% for 18K gold alloys [9]. PBF-LB machines specifically designed for precious metal applications are usually small and are not engineered to have the same temperature control of the powder bed as can be found in larger systems. The resulting temperature fluctuations can reduce part quality tremendously in terms of density and accuracy.

Design

Although PBF-LB systems can provide high energy outputs, bulky or filigree designs have different limits in energy dissipation. While bulk sections can be built at high building rates, small features or thin-walled structures need a reduced energy input to avoid pores and deformation due to residual stresses. These issues can be addressed through design optimisation for AM, different parameter sets with scanning strategies dedicated to certain features, and software that calculates risk depending on parameters such as heat gradients due to slice-by-slice scanned volume changes vs part orientation.

Support structures need to be adapted to the part design, considering requirements such as support of overhanging surfaces, thermal conductivity and a steady connection to the substrate material. Various requirements can result in an impossible build job, e.g., a bulk section requiring strong, large-area supports at a position difficult to access for finishing, or easy-to-remove thin supports for a bulk part with insufficient heat dissipation and weak connections. In some cases, scanning pauses or a change of substrate material can help. Copper or bronze substrate plates are recommended for processing most precious metal powders. Design optimisation might also be necessary - even inevitable.

A unique advantage of AM is the freedom of design, allowing extraordinary geometric designs to be produced. Even functional features can be integrated, where usually assemblies would be needed. Examples are the technical parts shown in Fig. 7, featuring built-in cooling channels, or the cuff links with an integrated clasp shown in Fig. 1, produced in a single step. The assembly of a multipiece casting and finding is no longer necessary. Although, there are certainly limits

Fig. 8 Watch case and hollow bracelet links made of Pt950Au produced by PBF-LB and CNC machining

in terms of feasibility, size and accuracy, as well as limits imposed by the high quality standards of the target industries, the combination of AM with other technologies opens up new opportunities.

For instance, the combination of AM with CNC machining not only facilitates the serial production of parts to high accuracy, but also allows the use of Additive Manufacturing at high build rates without the need to spend a large amount of time on contours and support structures. At the same time, the hybrid manufacturing method of CNC machining of AM near-net shape products with a material allowance of about 0.3 mm significantly reduces the chipping volume, tool wear, time and refining efforts, and, ultimately, the total cost. Just imagine the difference in volumes when compared to punching grids or machining off solid semi-finished products. Manufacturing of hollow applications is an extreme example for material and weight saving: applying a hollow construction to the strap links of a luxury watch made of platinum saves 40% compared to solid bracelets. Final finishing achieves flawless, perfectly shiny surfaces and guarantees tolerances of down to a few micrometers (Fig. 8).

Metal Injection Moulding comes into play for the production of larger series. Costs for feedstock production, injection moulding machines and tools, and the heat treatment steps need to be covered. Of course, it is beneficial to have similar designs of the same material that can be produced in one production line, including the extra step of green body milling. The yield offered by MIM cannot be beaten by conventional processing techniques, as MIM produces complex parts to near-net shape, and even sprues can be recycled immediately, resulting in a minimum of end-of-life scrap needing to be refined. A proof of concept with different PGM alloys was performed in earlier studies [10].

Material properties and influences

Property values can vary significantly as a result of only slight changes in the material, such as powder shape and classification, as well as AM processing parameters, like scanning strategy and heat treatment. The development and monitoring of these key parameters is unavoidable for the successful application of the technology and to fulfil quality standards.

The requirements of the jewellery and watchmaking industries are probably the most challenging with regard to material defects and surface quality. Qualified processes meet requirements with a minimum material density of 99.9% and a very fine-grained and highly-ordered microstructure due to the digital process. The grain size is usually significantly lower in comparison with traditional cast materials (examples are shown in the micrographs in Fig. 9). Grains for as-built pieces of Pd500Rh500 are about 50 µm and can be as small as about 20 µm, as seen for Pt950Au (Table 2). However, grains can grow much larger in the vertical direction with sizes up to several millimetres, as seen in cross-sections of PBF-LB parts, which are built at disadvantageously high energy inputs (Fig. 10). The columnar grain shape is promoted by unfavourable high temperature gradients during the scanning process and material purity, reminiscent of epitaxial growth or the growth of single crystals by zone melting. The resulting non-uniform microstructure can cause anisotropic material behaviour.

The mechanical properties of additively manufactured specimens slightly exceed those of castings. An overview of typical properties is given in Table 2. The hardness of AM parts is about 10% higher in comparison to castings, due to the fine grain size of the 'digital' microstructure. This behaviour also applies to tensile strength. Although work hardening is not an option for AM parts, age hardening mechanisms are available. Heat treatments can influence the properties significantly, especially HIP. HIP increases part density up to 100%, age hardens and alters microstructures.

As an example, HIP studies of Pt950Au showed grain growth resulting in a highly uniform microstructure, with globular grains having a mean grain size of about 70 µm (Fig. 11). Ductility is increased considerably, and the workability of the material should further improve. Short treatments for densification do not necessarily cause a relevant reduction in hardness. On the other hand, long HIP runs can further coarsen the microstructure, and specimens show significantly lower mechanical properties compared with as-built samples. It needs to be noted that the yield strength (YS) of Pt950Au is reduced from about 75% of UTS to about 50% UTS and the hardness is reduced to about 80% during an unfavourably long HIP run.

Conclusion and summary

Qualified powders of major PGM alloys are available for various metallurgical manufacturing methods. This opens up the opportunity to use AM methods for leaner and less expensive manufacturing of PGMs in comparison with conventional processing.

PBF-LB processes can be used for the serial production of precious metal products, as well as the tool-free production of pilot series, small series and intricate designs. The combination of AM with CNC machining is a powerful hybrid manufacturing processing chain for the serial production of parts to high accuracy. MIM can also serve as a supplementary processing method for larger series. Prices do not scale greatly for AM, in comparison with MIM, where equipment and mould costs are considerable, meaning the process only becomes economical when used to produce much larger numbers of pieces.

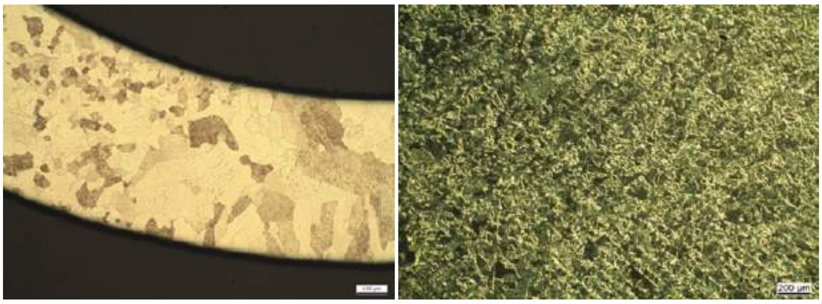

Fig. 9 Microstructures of etched samples made by casting vs PBF-LB

Method	PBF-LB		
Material	Pt950Au	Pd500Rh500	Pt800Ir200
Density (%)	99.97	99.95	99.97
Grain size (µm)	21	12	-
Hardness (HV)	186	240	207
UTS, z (MPa)	578	682	598
YS, z (MPa)	443	588	481

Table 2 Typical properties of PGM specimen additively manufactured

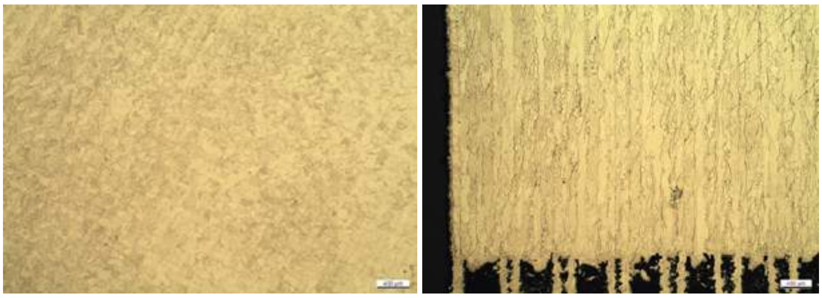

Fig. 10 Microstructure of PBF-LB samples at different high energy inputs

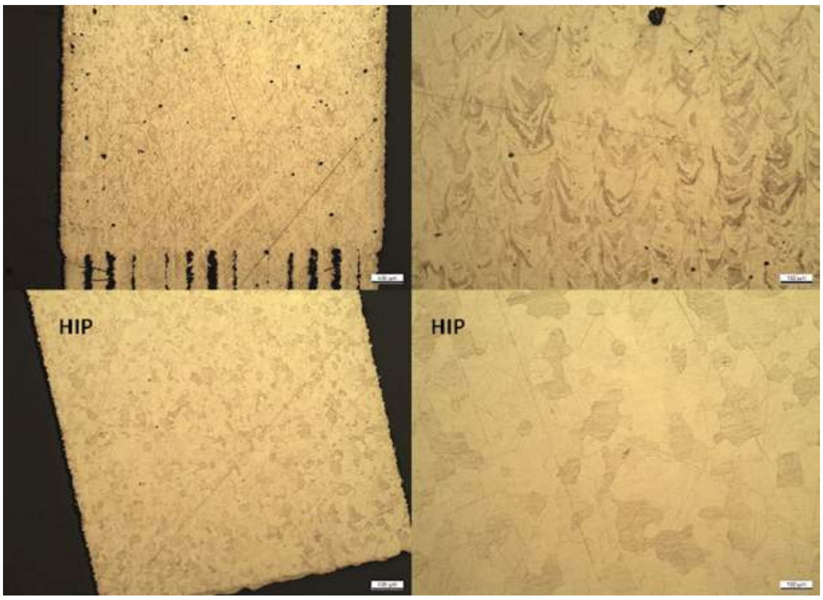

Fig. 11 Vertical cross sections of a Pt950Au PBF-LB sample at different magnifications without and with HIP-treatment

Comprehensive characterisations of additively manufactured parts confirm both a high density and competitive mechanical properties. The densities of PBF-LB parts produced in Pt950Au, Pd500Rh500 and Pt800Ir200 achieve values of up to 99.97%. The remaining porosity of 0.03% is comparable with cast products. Polished surfaces are flawless, suggesting that residual porosity is negligible. With additional HIP treatments, PBF-LB parts can even reach 100% density, eliminating any defects and risks for the extremely high requirements.

The PBF-LB process produces parts with a 'digital microstructure' and extraordinarily fine grains, having sizes down to 20 µm. These values are impossible for cast products. The homogeneous microstructure produced is ideal for polishing and machining, and properties can be tailored, to a certain extent. The mechanical properties of these parts typically slightly exceed the properties of castings. Additional age hardening to strengthen the material is also possible. It needs to be emphasised, however, that seemingly slight changes to processing parameters can have a significant influence on part quality. The highest qualities are only achievable when using a three way optimisation of powder, equipment and process.

Yield, being a crucial factor for economic success, is an advantage of AM over the traditional processing of PGM alloys. In a typical business case of watch parts, the yield was approximately 10–20% for traditional casting, rolling, punching and machining, approximately 50–60% for PBF-LB and up to 75% for MIM. The material input is about five times higher for the traditional vs the AM route, i.e., a factor of five in cost.

The material allowance for punched parts is about three times higher than for AM pre-products, resulting in twice the chipping volume in subtractive CNC-finishing. The end-of-life refining scrap volume of all processing steps totals a factor of five higher for conventional vs AM processing in combination with CNC finishing. Of course, part geometry and the required number of pieces has a strong influence on these calculations. In any case, the capital employed, and refining efforts, are directly related to the yield. For PGMs – being an expensive material group and costly to refine – the use of PBF-LB is highly recommended, as long as the size and geometry of the part is suitable.

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Obstacles to the adoption of metal AM by small- and medium-sized enterprises

It is no secret that metal Additive Manufacturing still faces significant challenges that stand in the way of broader adoption in industry. Aside from AM service providers, very few small- to medium-sized enterprises have brought metal AM in-house; many lack the capabilities, knowledge and resources to do so, even if the will is there. In this article, Olaf Diegel, Noah Mostow and Terry Wohlers discuss the complex, and often multi-faceted, obstacles that stand between AM and its wider global adoption, and how those obstacles can be addressed and resolved in order to clear the path to achieving the technology's full market potential.

According to the data collected and analysed for publication in *Wohlers Report 2021*, the Additive Manufacturing industry grew by 7.5% in 2020 despite the coronavirus (COVID-19) pandemic. When examining the growth across the broader industry, the bulk of metal AM expansion has been by large companies. Except for service providers, few small- and medium-sized enterprises have adopted metal AM. The Additive Manufacturing industry faces challenges that stand in the way of broader industry adoption of metal AM. Most of these challenges are complex and involve multiple factors; some obstacles have sub-challenges that interconnect with one-another.

Powder Bed Fusion (PBF) is currently the most popular method of metal AM. The process involves a laser or electron beam energy source that scans across layers of powder and selectively melts the material. The scanning is a linear process in which the laser must 'hatch' all material that needs to be melted. A part is made up of hundreds or thousands of layers, typically 20–100 μm (0.0008 – 0.004 in) in thickness. To estimate build time, one can multiply the number of layers in a part by the time it takes to process one layer.

Binder Jetting (BJT) is another metal AM process receiving considerable attention. It is used mostly for small parts due to shrinkage that occurs during a secondary sintering process. For small parts designed for this process, it has the potential for wide acceptance due to the promise of high processing speeds and lower costs.

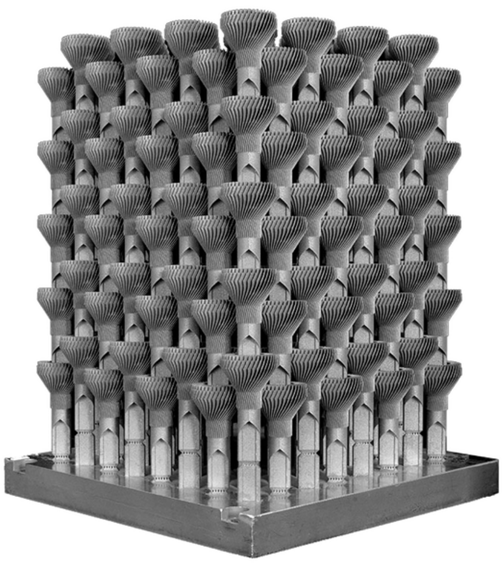


Fig. 1 384 LED headlight heatsinks produced in a single build on a PBF-LB machine (Courtesy Betatype)

Speed, cost and scalability

The start-to-finish metal AM process is slow compared to most conventional methods of manufacturing metal parts. Ten hours is considered a short build time for a batch of parts using AM. This excludes the time needed to prepare the machine, remove the parts after manufacturing and post-process them. Build times can often be 40–100 hours, sometimes stretching to hundreds of hours.

Post-processing is also often a slow and labour-intensive process. Research and development programmes are underway to automate parts of the process. The relatively slow build speed of PBF-LB is one of its biggest barriers and a primary contributor to its high cost, making it difficult to justify it for anything but relatively small parts and/or limited production runs.

"The relatively slow build speed of PBF-LB is one of its biggest barriers and a primary contributor to its high cost, making it difficult to justify it for anything but relatively small parts and/or limited production runs."

The scaling of production volumes is impacted greatly by machine speed. Suppose it is possible to produce 100 parts on a machine in twenty-four hours; if the project requires 1,000 parts per day, the job would need the capacity of ten machines. The average selling price of a metal AM system was $467,635 in 2020, according to *Wohlers Report 2021*, so the job would require in the range of $4.7 million in equipment. Another approach might be to design the parts so they can be stacked vertically to fit more into the build volume (Fig. 1). This is not an option for many designs because the parts are attached (i.e. welded) to one another, making post-processing difficult or impossible. If neither approach is an option, most companies will revert to conventional methods of manufacturing.

Manufacturers are working hard to increase the speed of systems. This is usually achieved by adding more powerful and/or a greater number of lasers. In the past few years, the newest machine models often offer four or more high-powered lasers. Last year, SLM Solutions introduced a twelve-laser system. Meanwhile, EOS is developing a polymer process called LaserProFusion in which a million diode lasers are used to melt the material.

The cost of systems, materials, ancillary equipment (e.g. CNC machining and heat treatment), and experienced personnel prevents many companies from investing in metal AM. Even so, a doubling of machine speed could substantially expand the size of the market, which is why speed is so important. Increasing build speed does not impact the costs associated with data preparation and post-processing. These steps can represent up to 40% of the total cost, according to our research for *Wohlers Report 2021*.

Design practices

Many companies approach metal AM as a direct replacement for conventional manufacturing, but in most cases, this is not an effective use of AM. It is vital that good approaches to design are applied when preparing to produce parts by metal AM. This not only improves build speed and cost, but it often improves the functionality and performance of a part by making it lighter and stronger, with features such as improved cooling.

The first step to adopting metal AM effectively is understanding its strengths, limitations, and when to use it. Due to the associated speed and cost, it is important to evaluate a part or assembly to determine whether it is a good candidate. If AM does not offer sufficient value to overcome the higher manufacturing costs, it is probably not a viable option. Design for Additive Manufacturing (DfAM) can significantly impact this decision-making process and can make the difference in building a business case on whether to use AM.

One of the primary goals of DfAM is to reduce the time-intensive melting of material. It is the inverse of designing for CNC machining, in which as little as possible is machined to minimise the required time. This results in parts with excessive amounts of material. With AM, more material means longer manufacturing times and higher cost per part. One way to reduce build time is to consolidate two or more parts into one, digitally, prior to manufacturing. This is one of the most important considerations of DfAM and a way to justify the use of AM.

Other ways to reduce material and scan time are topology optimisation and generative design. Both methods involve the use of mathematics to optimise the strength-to-weight ratio of a part, thus using the least amount of material required for the application. Another method of material reduction is to use lattice, mesh, or cellular structures inside the walls of a part. At its most basic, DfAM is about considering whether the material serves a useful engineering function.

Post-processing is a major obstacle of metal AM, which requires sacrificial support material. These supports, also referred to as anchors, serve as a heatsink to the build plate. They are used to help secure the part and prevent it from distorting due to stress caused by heat while it is built. Downward facing surfaces will have a rougher surface finish than

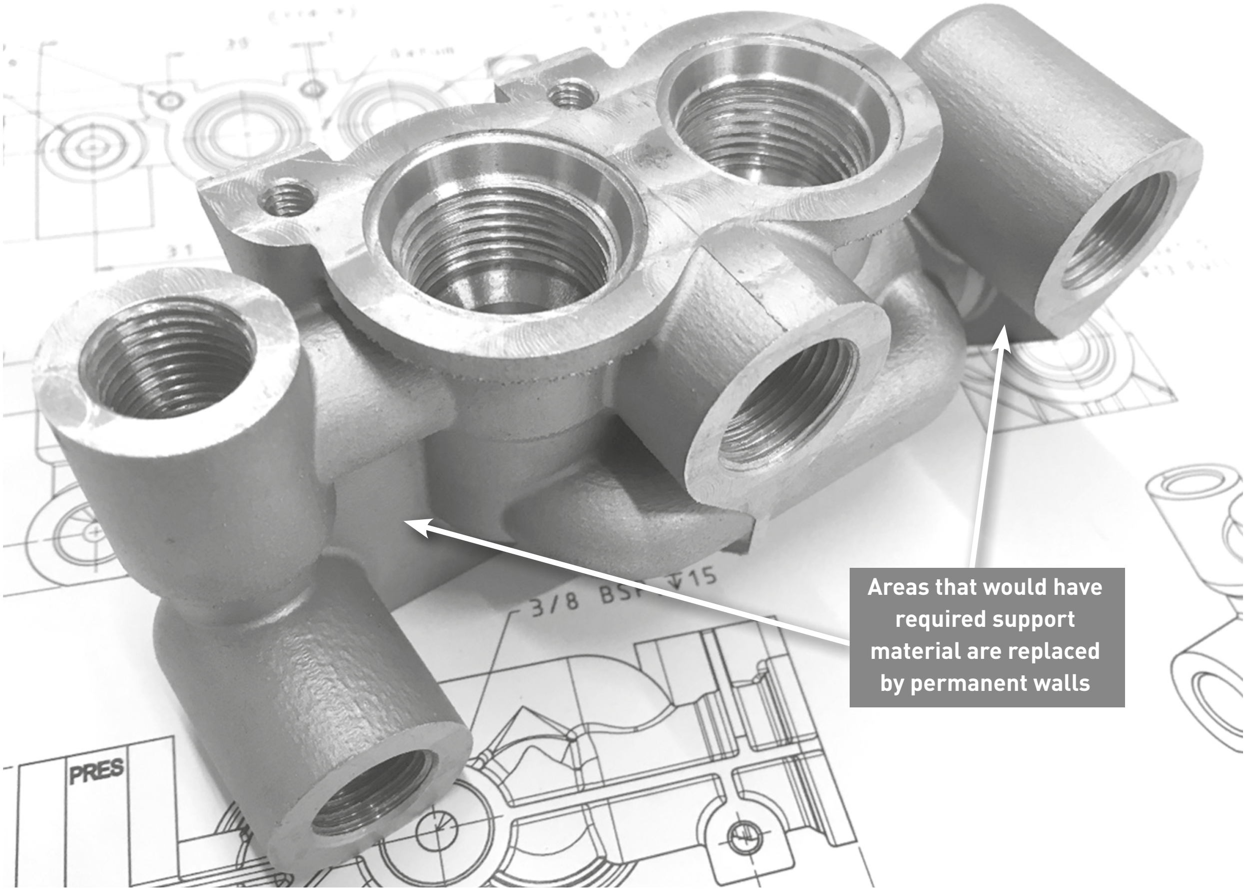

Fig. 2 A hydraulic manifold with 65% weight reduction and minimal use of support material

upwards facing or vertical faces. If not designed correctly, a part may require substantial post-processing to achieve the required engineering tolerances or cosmetic surface finish.

An approach that works for some parts is to design a part so the support structures become permanent features, which reduces the time and expense of removing what would otherwise be support material. With experience, it is not difficult to achieve, although determining whether it is an option must be done on a case-by-case basis. The hydraulic manifold shown in Fig. 2 provides an example of what is possible. It also reduced weight by 65%, compared to the machined version.

Over the past few years, DfAM has risen in importance, with hands-on courses on the subject being conducted around the world. These courses help to educate and train professionals on how to design for AM. As this field grows, it will become part of mainstream design and engineering education. We will continue to see a more skilled workforce emerge which, in turn, will help increase the acceptance of metal AM.

We have always done it this way

Product design decisions, including the design of materials and features, are not always chosen because they are the best option. Many times, these decisions are based on what has been done in the past. Engineers and managers tend to be risk averse: if something has worked well previously, they will continue using that process and material, even if the design and its performance can be improved with AM. Changes inherently cause hesitation.

AM supports the notion of designing products in entirely new ways, such as features that reduce weight or improve the transfer of

"As this field grows, it will become part of mainstream design and engineering education. We will continue to see a more skilled workforce emerge which, in turn, will help increase the acceptance of metal AM."

heat. If a part is designed for AM, it may use substantially less of a more specialised material, such as titanium, compared to a conventional design. This may improve the strength, reduce material and weight, and/or increase performance without increasing its cost.

Qualification, certification and health and safety

Qualification and certification are also obstacles to adoption. However, the actions involved are not entirely different from conventional manufacturing: if a part must include specific characteristics, they apply irrespective of how it is made. Unquestionably, the exact procedures of certifying metal AM parts differ from those made conventionally. Once these steps have been established, it is a process of rigorously following them. Many organisations in the AM industry have worked hard to create repeatable processes that help to ensure quality.

Questions associated with the health and safety of metal AM, particularly with the handling of powders, are valid. Fine powders, such as titanium and aluminium, are explosive. Preventing accidents is a matter of following well-established safety protocols. Most manufacturers have documented guidelines for working with their systems and for handling and storing metal powders, as well as for disposing of used materials.

Conclusions

Innovation often comes from looking at things differently. For effective applications of metal AM, one must consider new approaches to a design. This new way of thinking can also improve our approach to conventional design and manufacturing.

Companies worldwide face challenges related to the adoption of metal AM. The potential it offers to companies of all sizes can add substantial value to their product offerings. Manufacturers continue to improve the speed of their machines. This, coupled with DfAM and automation, will help increase the acceptance of metal AM as a viable mainstream method of production.

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Additive Manufacturing of aluminium parts by Directed Energy Deposition: Possibilities and challenges

SAMOA, a European Union funded EIT RawMaterials project on 'Sustainable Aluminium Additive Manufacturing for High Performance Applications', investigated the processing of aluminium powders by Directed Energy Deposition. In this report, Himani Naesstroem, Joerg Volpp, Stefan Polenz, and Frank Brueckner review the effects of processing parameters and feedstock material age, as well as presenting an industrial case study.

Aluminium and its alloys have been utilised in numerous industries for many decades, as its properties – a high strength to weight ratio, malleability, electrical conductivity, and corrosion resistance – make it invaluable in the aerospace, automotive, biomedical and electrical industries. To date, conventional manufacturing processes such as casting, sheet metal forming, and some subtractive processes like machining, are the most commonly-used production technologies for aluminium alloys. During the last few years, however, scientific studies regarding various AM technologies, as well as developments towards their industrial applications, have made the news.

When compared to materials like steel or titanium, the processing of aluminium using a laser beam has some challenges. Aluminium has a high reflectivity towards the typical fibre laser wavelength [1], high thermal conductivity [2] and a low melting point [3]. Among the laser-based AM processes, the two most-used processes are Laser Beam Powder Bed Fusion (PBF-LB) and Directed Energy Deposition (DED), the latter of which can use powder or wire as a feedstock. Typically, DED offers higher deposition rates, as well as lower costs per unit volume, when compared to PBF-LB.

During the DED process, feedstock material is fed into a laser-generated meltpool. For most three-dimensional applications, a ring-slit or multi-jet coaxial nozzle is used to feed powder (Fig. 1). Since aluminium material forms a natural oxide layer, the powder particles carry oxides into the processing zone, which means that, in the processing of aluminium, there is a risk of oxide inclusions in the deposited clads. In addition, the risk of degassing elements and the formation of porosity and cracks is high [4].

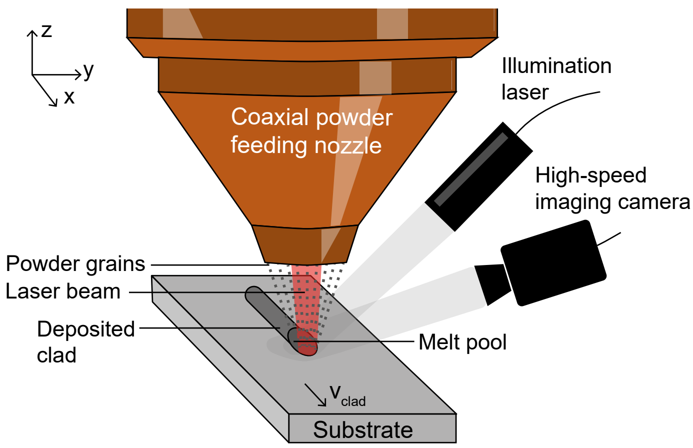

Fig. 1 Schematic illustration of the DED process along with process observation through high-speed imaging

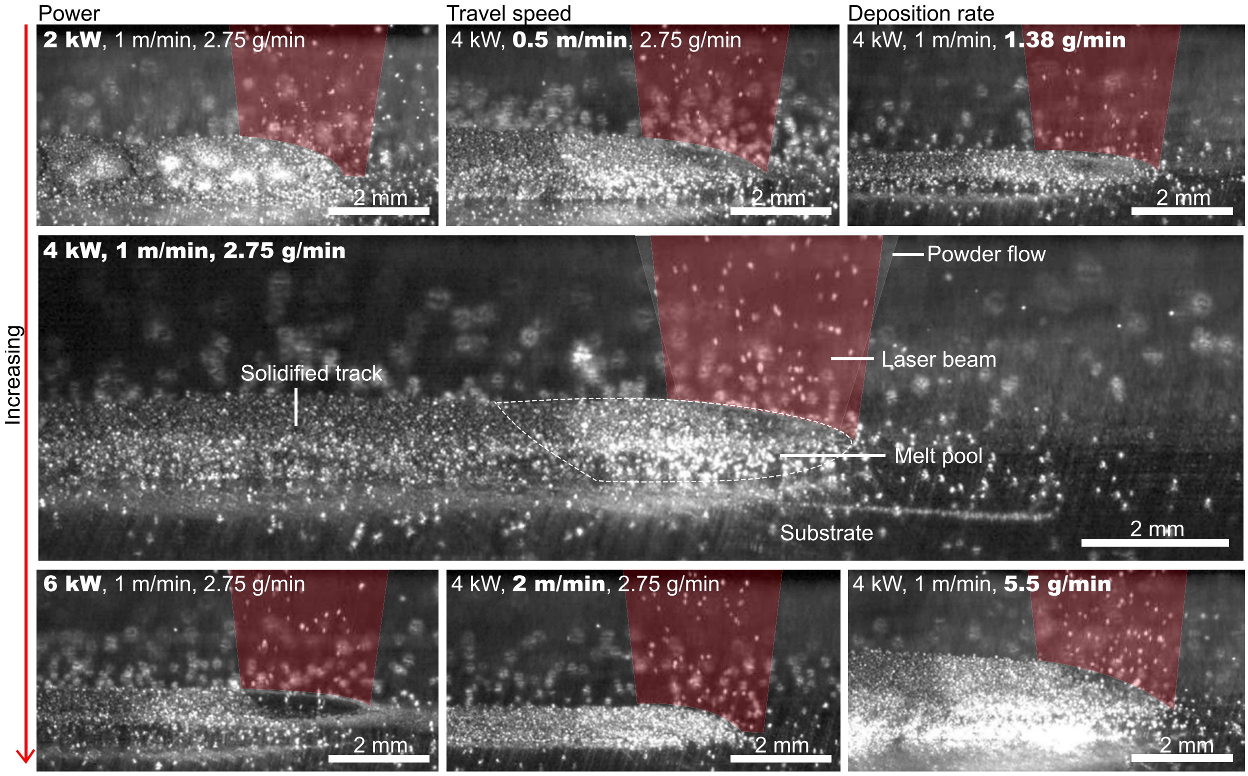

Fig. 2 Frames from high-speed imaging of the DED of AlSi10Mg for increasing laser powers, travel speeds and deposition rates

During the DED of AlSi10Mg powder using a fibre laser (with a Gaussian distribution and a 3 mm spot) on EN-AW 6082 substrates, the main possibilities and challenges of aluminium powder can be visualised: the process characteristics, effects of the dominant processing parameters and ageing of the powder.

Effects of processing parameters

The Directed Energy Deposition processing of aluminium is stable at a wide range of parameters for the first layer, which was visualised using high-speed imaging at a recording frequency of 10,000 fps, allowing the process to be replayed at a rate thousands of times slower than reality. The laser-generated meltpool and the incorporation of single-powder particles in the meltpool can be observed in the DED process; frames from high-speed imaging, showing the influences of a change in laser power, travel speed and deposition rate, can be seen in Fig. 2. In all shown scenarios, the deposited track demonstrated good attachment to the substrate. In the lowest power scenario shown (2 kW laser power), the clad track deposited showed a lumpy appearance and was not stable. All other parameter sets resulted in a stable process with minimum dynamic effects such as spattering. The process is more complex when building several layers, or larger volumes, using some aluminium alloys.

The main difference in the AM of aluminium compared to many other metals is that aluminium forms a natural oxide layer; in most cases, the meltpool is almost entirely covered with a thin, solid skin. This phenomenon is unique to aluminium, unobserved during processing of most other metals, such as steel or titanium, which form this skin along the edges of the meltpool [5]. The oxide skin was seen to affect the incorporation mechanism of powder particles into the meltpool during DED. Often, the powder

"The main difference in the AM of aluminium compared to many other metals is that aluminium forms a natural oxide layer; in most cases, the meltpool is almost entirely covered with a thin, solid skin"

particles rest on the surface of the skin and are slowly incorporated into the meltpool, resulting in longer incorporation times. If the meltpool under the oxide skin solidifies before the particles incorporate, they will be slightly attached to the outside of the skin [5, 6].

For aluminium processing, a direct incorporation seems unlikely due to the oxide skin on the meltpool. However, it can be seen from the high-speed videos that this skin can break on impact of the powder. In some cases, there are areas not covered by a solid oxide skin, where high energy densities (such as with high laser power, low travel speeds or low deposition rates) are applied. In these cases, the meltpool is exposed and the full incorporation of powder into the meltpool is more likely and faster. All powder particles that arrive outside the meltpool are not incorporated and do not contribute to the formation of the track, emphasising the importance of using an appropriate nozzle for the chosen laser beam characteristics to enable directed powder guidance into the meltpool.

Some general trends regarding the widths of the deposited tracks can be observed in Fig. 3. An increased energy input (high laser power or low travel speed) led to better wetting and more efficient particle incorporation, generating wider tracks. An increase in the deposition rate shows a slight increase in track width followed by a slight decrease. There is an increase in the volume deposited, to an extent, after which the volume decreases, likely due to the attenuation of the laser beam by the fed powder particles.

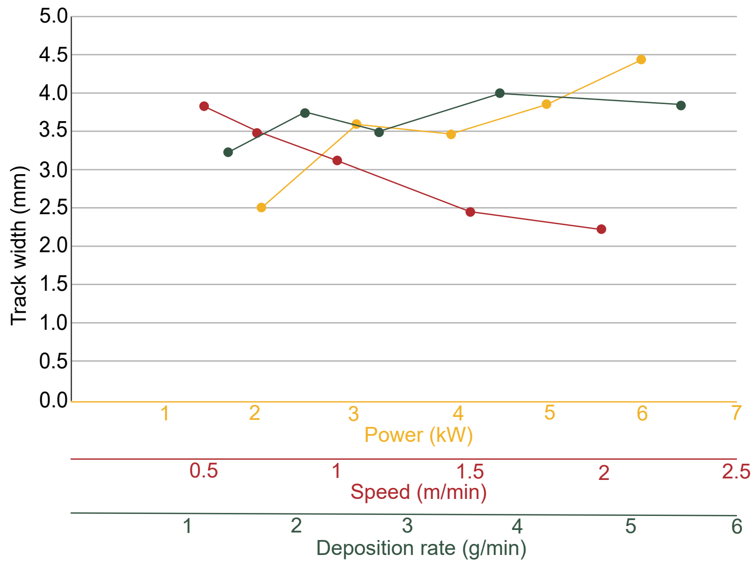

Fig. 3 Widths of the deposited tracks for increasing laser power, travel speed and deposition rate

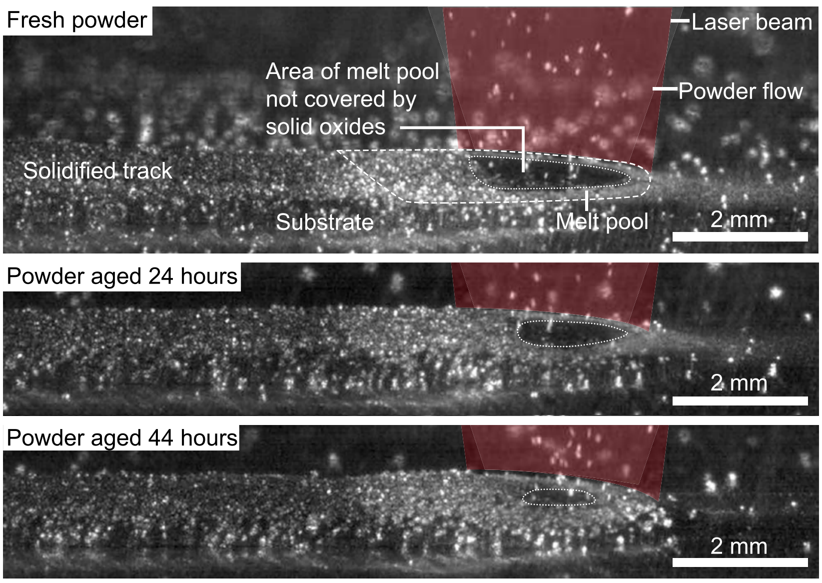

Fig. 4 Frames from high-speed imaging showing the process for fresh and aged powder for the same processing parameters (laser power 6 kW, travel speed 1 m/min and deposition rate 2.75 g/min)

Effects of feedstock material age

The DED process has a high powder utilisation. Often, over 85% – in optimised cases, up to 90% – of the fed powder is used in the clad tracks deposited [7]. However, due to the time taken to stabilise the powder flow after starting it, movements of the workstation or the robotic arm may lead to a non-negligible amount of powder spillage. One strategy to reduce powder waste is to sieve the spilled powder and reuse it in the process.

In order to simulate the reuse of powder stored for a long time, or previously used for processing in a controlled manner, fresh powder from a sealed container was artificially aged at 80°C without an inert atmosphere, using an oven for 24 hours and 44 hours. It is clearly visible in Fig. 4 that the ageing of the powder had a significant effect on the resulting processing and track appearance.

The exposed area of the meltpool (not covered by the skin) is smaller in the case of the aged powder batches, with a further decrease

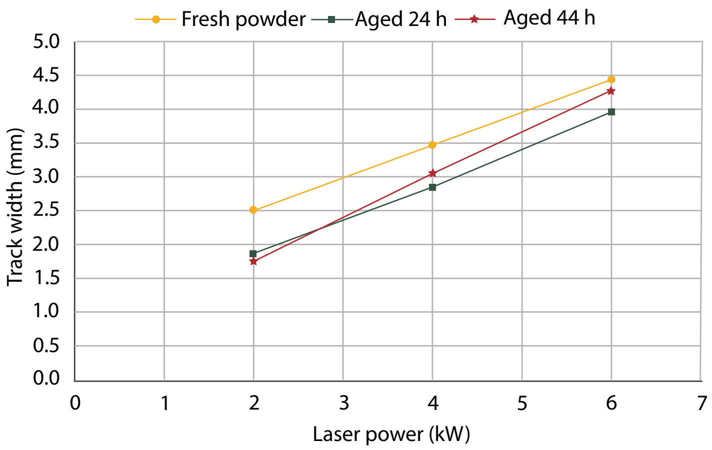

Fig. 5 Influence of powder age on track width for three steps of laser power

between the batches aged for 24 and 44 hours. This reduces the fraction of the powder grains that are directly incorporated into the meltpool. Additionally, the clad tracks deposited with the powder aged for 44 hours are geometrically non-uniform, as compared to those deposited using fresh powder. Ageing seems to increase the oxygen content of the powder particles. The oxides are transferred into the meltpool, leading to an increased formation of the oxide skin on the meltpool.

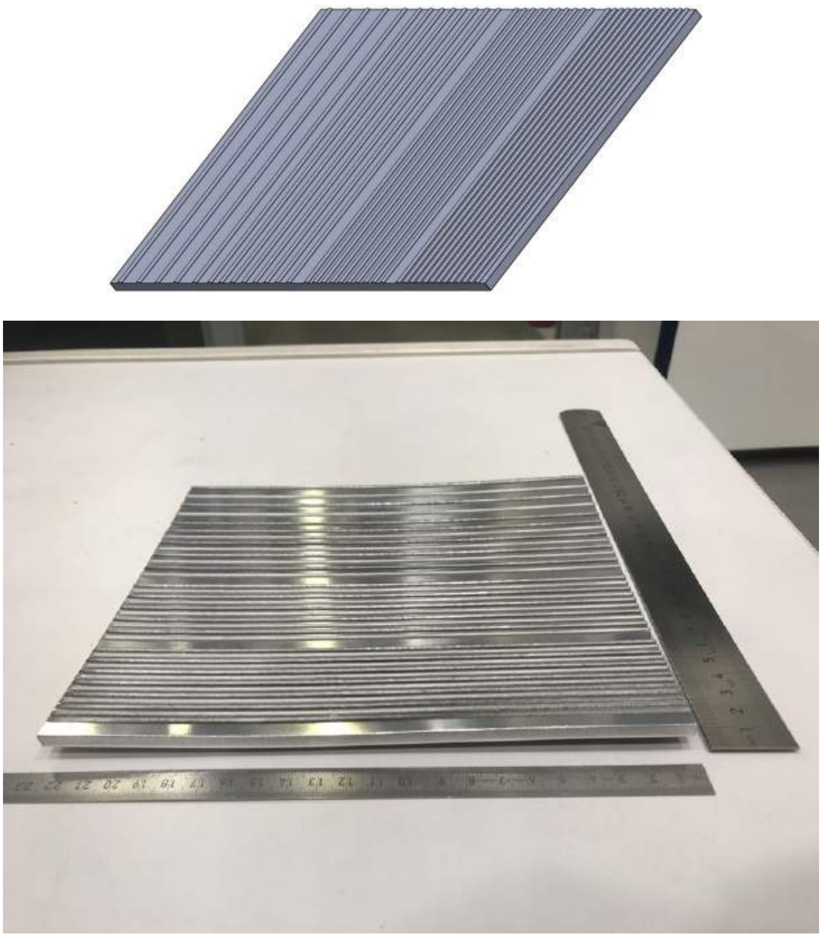

Fig. 6 Stiffening structures potentially used in automotive and railway systems

The effect of the increased oxidation can also be seen in the decreased widths of the deposited clad tracks for the batches of aged powder compared to the fresh powder (Fig. 5). For all steps of DED, the track widths are higher for the fresh powder. Using aged powder brings additional oxides into the process, directly affecting the characteristics and track morphology.

Example of an industrial application

In the passenger transport and logistics sector, reductions in the volume of materials used offers enormous potential. In addition to saving material while maintaining functionality, the weight of transport may increase whilst energy is saved. One possibility to achieve this is through stiffening structures on thin-walled sheet metal components. In the SAMOA project [8], these structures are built and tested using DED of AlSi1Mg on a substrate material made of EN AW 6082. A first dummy part can be seen in Fig. 6.

Die-cast parts are frequently used in automotive applications and can be rapidly and cost-effectively manufactured on large-scale serial production lines with fixed part designs. Compared to this, AM requires more processing time, but enables very high geometric freedom from part to part. Hence, the combination of technologies can offer high productivity in tandem with increased geometrical flexibility.

In the first processing step, casting is performed and acts as a basis for the subsequent laser metal deposition, in which, for example, clamping elements or reinforcing structures are applied to the component. The cast components, once designed, can, thus, be adapted to different product versions at low cost. This reduces the lead times for series changes or possible modifications. Small series can also be produced on the basis of low-cost series parts with reduced tooling costs. This leads to an extended market access of the AM by saving production time with high geometric flexibility. The component shown in Fig. 7 consists of a die-cast AlSi12Cu1(Fe)-substrate component with additively built reinforcement structures and connecting elements made of AlSi1MgMn [9].

Summary

Thus far, the importance of aluminium and its alloys in manufacturing has been seen, chiefly, in conventional manufacturing methods. Despite the challenges inherent to the processing of aluminium with laser beams, laser beam DED has demonstrated its potential as a possible processing choice for the metals. Directed Energy Deposition of aluminium can be a stable process, albeit one currently in need of further research to overcome the formation of oxide skins over the meltpool. Bearing this in mind, the DED of aluminium may lend itself to joint use with conventional manufacturing for industrial applications.

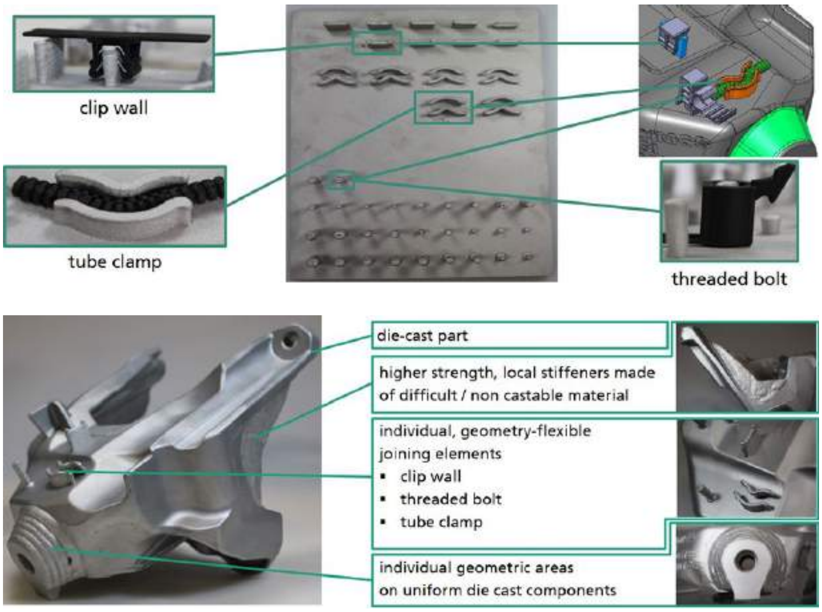

Fig. 7 Die-cast substrate component with additively manufactured reinforcement structures and connecting elements

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Euro PM2020 technical review: Advances in process control for metal Binder Jetting (BJT)

Within the programme of the well-received Euro PM2020 Virtual Congress, held October 5–7, 2020, and organised by the European Powder Metallurgy Association (EPMA), a technical session was held on process control in metal Binder Jetting. In this article, Dr David Whittaker provides a summary of two of the papers presented, which look at applying the Master Sintering Curve for 316L parts, and process parameter optimisation for 17-4 PH parts.

The Master Sintering Curve and its application on 316L steel produced by Binder Jetting

This paper was presented by Markus Schneider, Philipp Gabriel, Simon Hoeges and Christopher Schaak (GKN Sinter Metals Engineering GmbH, Germany) and addressed the benefits of using the Master Sintering Curve (MSC) approach in optimising the sintering of 316L stainless steel in Binder Jetting [1]. The main hurdles in BJT are the achievement of the required final sintered density ρ_s and a proper control over the sintering process. The Master Sintering Curve approach is a helpful tool to understand the sintering kinetics and to predict the resulting final sintered density ρ_s from simple dilatometry experiments. In the reported study, different industrial sintering profiles T(t) were numerically integrated to obtain the MSC.

The MSC approach assumes a sigmoidal evolution of the densification parameter Ψ as a function of the logarithmic sintering work Θ(t, T), which incorporates the whole sintering profile T(t). In most cases, the sintering profile T(t) is too complex for an analytical integration, because the corresponding antiderivative cannot be found. Only for isothermal conditions, T(t)=const, can the integral be solved. However, the integral can be solved numerically by the summation of the sintering work increments if the sintering profile T(t) is partitioned into time increments of width Δt.

Several applications of the MSC approach are focused on the estimation of the apparent activation energy Q_{MSC} (an average of all contributing transport mechanisms) by minimising the perpendicular distance (error) to the average residual squares R by varying of the apparent activation energy Q_{MSC}. A simple estimation for the activation energy for self-diffusion/sintering Q_s is based on the Engel-Brewer theory, in which the activation energy is related to the crystal type and the absolute melting temperature Tm.

In the study, gas (argon) atomised austenitic 316L stainless steel powder was used for all tests. Typical values of the skewed powder particle size distribution Q_3(d) were in the range of d_{10}=4.85 µm, d_{50}=12.74 µm and d_{90}=24.24 µm.

"The Master Sintering Curve approach is a helpful tool to understand the sintering kinetics and to predict the resulting final sintered density ρ_s from simple dilatometry experiments."

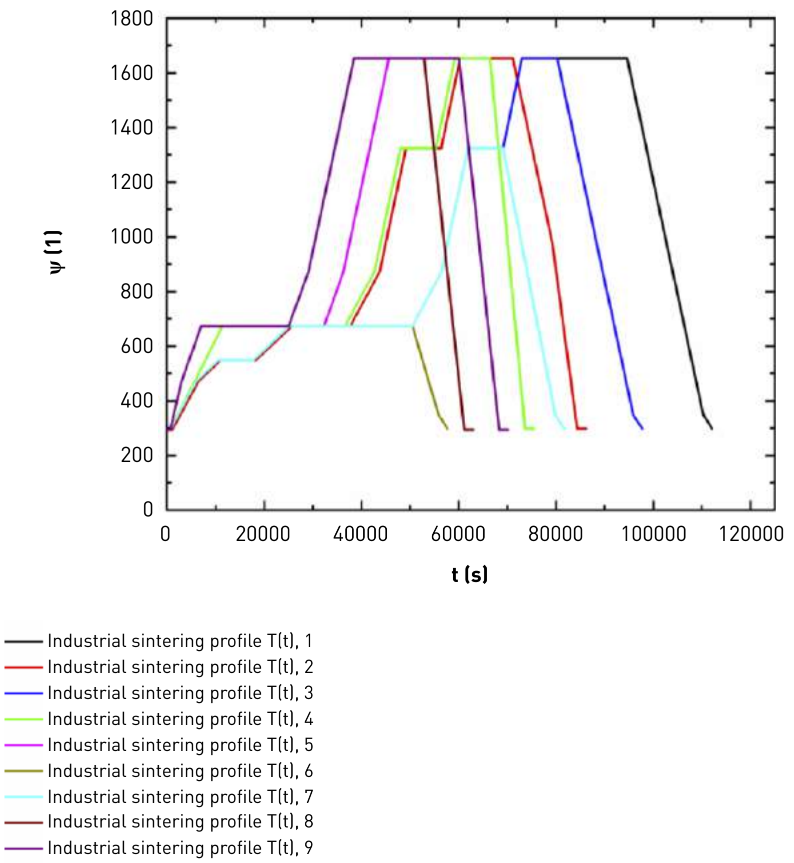


Fig. 1 Industrial sintering profiles T(t) which were numerically integrated with a time increment of Δt=10 s to obtain the corresponding sintering work Θ(t,T) values, a heat transfer coefficient of $\alpha \rightarrow \infty$ W/m²K was assumed to link the furnace sintering profile T(t) to the component sintering profile $T(t)_{comp}$ [1]

For the proof of concept of the MSC approach, nine different industrial sintering profiles with thirteen different runs/replications were followed. The recorded industrial sintering profiles T(t) are shown in Fig. 1. The local measurement of the component temperature/sintering profile $T(t)_{comp}$ was not possible in the batch sintering furnace. Therefore, the first boundary condition for the heat transfer (heat transfer coefficient $\alpha \rightarrow \infty$ W/m²K) was assumed. This was not fully correct, since the heat transfer, primarily through convection and radiation from the furnace walls to the components, was neglected. As a result, the industrial sintering profile T(t) of the furnace was assumed to be identical with the component sintering profile $T(t)_{comp}$ (no thermal inertia of the components). Therefore, the real sintering profile of the components $T(t)_{comp}$ would have been shorter and without sharp dwell time plateaux, resulting in smaller sintering work Θ(t, T) values.

The full density of 316L was assumed to be ρ_0=7.93 g/cm³, to derive the densification parameters Ψ in Table 1. With its face centred cubic austenitic crystal type and its melting temperature of T_m=1673K (1400°C), the activation energy for self-diffusion/sintering Q_s could be estimated with the Engel-Brewer theory as 264 kJ/mol. This estimate was quite close to the measured and published value of Q_s=280 kJ/mol.

The initial green density ρ_g values in Table 1 were measured using the volume V and mass m of the binder jetted component, whereas the final sintered density ρ_s values were measured using Archimedes principle. The average value of ρ_g=4.47 g/cm³ was taken for the further calculations and the derivation of the densification parameters Ψ in Table 1.

Several MSCs, derived for fine MIM powders, can be found in the literature, and these results could be taken as a reference to compare the MSC based on the computed values from Table 1. The sigmoidal evolution of the densification parameter Ψ as function of the logarithmic sintering work Θ(t, T) can be described with different functions, with a very common fitting function being an exponential type. Dilatometry results from the literature on MIM 316L (push-rod dilatometer with a 100% H_2 atmosphere) are plotted in Fig. 2, together with the authors' own results. It can be seen that the derived data points reduce to a common curve.

Some industrial sintering profiles T(t) were repeated (No. 1, No. 2, No. 7 and No. 8). The reproducibility was not very high, due to slightly different variations of the chemical composition between the powder lots (even within the tolerances). However, the derived data points are clustered in a narrow range. More data points are needed at very low and very high densification parameters Ψ to approximate the MSC progression more accurately. Therefore, there is uncertainty regarding the fitting function shown in Fig. 2, and the authors recommended the use of in-house, systematic laboratory dilatometer sintering runs to investigate the sintering kinetics in more detail.

Since the sintering response depends strongly on powder particle size distribution Q_3(d) and chemical composition, in-house dilatometer sintering runs were needed. These runs were performed with a horizontal, single push-rod dilatometer in a 100% H_2 atmosphere. Three different heating rates, $\Delta T/\Delta t$, were applied (3 K/min, 6 K/min and 10 K/min). A dwell time of t=3600 s (1 h) to remove the binder at T=673 K (400°C) was introduced (debinding plateau). Beyond that plateau, the temperature T(t) had been increased to the final

Sintering profile	ρ_g (g/cm³)	ρ_s (g/cm³)	ψ (1)	θ(t, T) (s/K)	log θ (log (s/K))	ln θ (ln (s/K))
1 (#1 run)	4.42	7.49	0.872	6.51579E-08	-7.186	-16.546
1 (#2 run)	4.40	6.45	0.573	6.51579E-08	-7.186	-16.546
2 (#1 run)	4.56	7.17	0.780	3.53937E-08	-7.451	-17.157
2 (#2 run)	4.46	6.40	0.556	3.53937E-08	-7.451	-17.157
3	4.35	6.96	0.718	2.54723E-08	-7.594	-17.486
4	4.40	6.21	0.504	2.39614E-08	-7.620	-17.547
5	4.47	6.94	0.715	2.39304E-08	-7.621	-17.548
6	4.47	4.36	-0.032	1.27693E-19	-18.894	-43.505
7 (#1 run)	4.47	5.09	0.180	2.41029E-10	-9.618	-22.146
7 (#2 run)	4.49	5.16	0.201	2.41029E-10	-9.618	-22.146
8 (#1 run)	4.52	7.19	0.787	4.37732E-08	-7.359	-16.944
8 (#2 run)	4.53	6.87	0.695	4.37732E-08	-7.359	-16.944
9	4.65	7.59	0.902	6.3616E-08	-7.196	-16.570

Table 1 Initial green densities ρ_g, final sintered densities ρ_s, densification parameters Ψ and corresponding sintering work $\Theta(t, T)$ values generated with the given sintering profiles T(t) from Fig. 1 on BJ 316L samples [1]

sintering dwell time of t=3600 s (1 h) at T=1653K (1380°C) with the same three heating rates. The cooling rate $\Delta T/\Delta t$ was not defined (free cooling). For the correction of the thermal expansion, a constant coefficient of thermal expansion of $\alpha=18*10^{-6}$ K^{-1} was assumed for the binder jetted 316L. Small cylindrical specimens were additively manufactured with a layer thickness of x=70 µm to a green height of h≈7 mm and a green diameter of d≈5 mm. Due to their small size, the dilatometer sintering profile T(t) is identical with the component sintering profile, $T(t)_{comp}$. For the identification of potential build anisotropies, two different building directions were studied (Z-direction vs XY-direction).

A green density of ρ_g=4.218 g/cm³ was achieved for both building directions after Additive Manufacturing. The green density ρ_g was measured using Archimedes principle. The full density of 316L was assumed to be ρ_0=7.93 g/cm³. However, the real full density ρ_0 depends on the chemical composition and on the resulting microstructural phases (heat treatment history). From the dilatometer sintering runs, it was seen that densification (linear shrinkage ε) occurs above T≈1273 K (≈1000°C). Densification was typical of the intermediate sintering stage II. Therefore, the dominating transport mechanism seems to be lattice (bulk or volume) diffusion. For the definition of the densification parameter Ψ, the measured linear shrinkage was converted into the corresponding final sintered density ρ_s, assuming isotropic shrinkage.

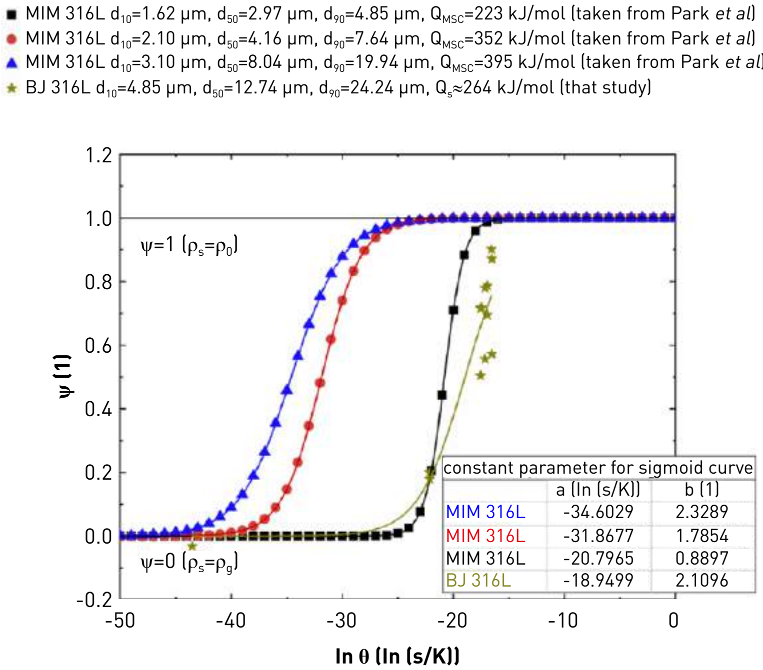


Fig. 2 MSCs of MIM 316L with different powder particle size distributions $Q_3(d)$ (and the result of the study of BJ 316L with n=13 data points (the full density of BJ 316L was assumed to be ρ_0=7.93 g/cm³ to harmonise the current MSC with pycnometer density measurements reported in the literature) [1]

$\Delta T/\Delta t$ (K/min)	ε (%), built in Z-direction and ρ_s (g/cm³), measured with the Archimedean principle	ε (%), built in XY-direction and ρ_s (g/cm³), measured with the Archimedean principle
10	-23, 7.48	-13, 6.04
6	-24, 7.44	-13, 5.99
3	-26, 7.79	-13, 6.07

Table 2 Achieved magnitudes of the linear shrinkage ε and the corresponding final sintered densities ρ_s (measured using Archimedes principle) as a function of the building direction [1]

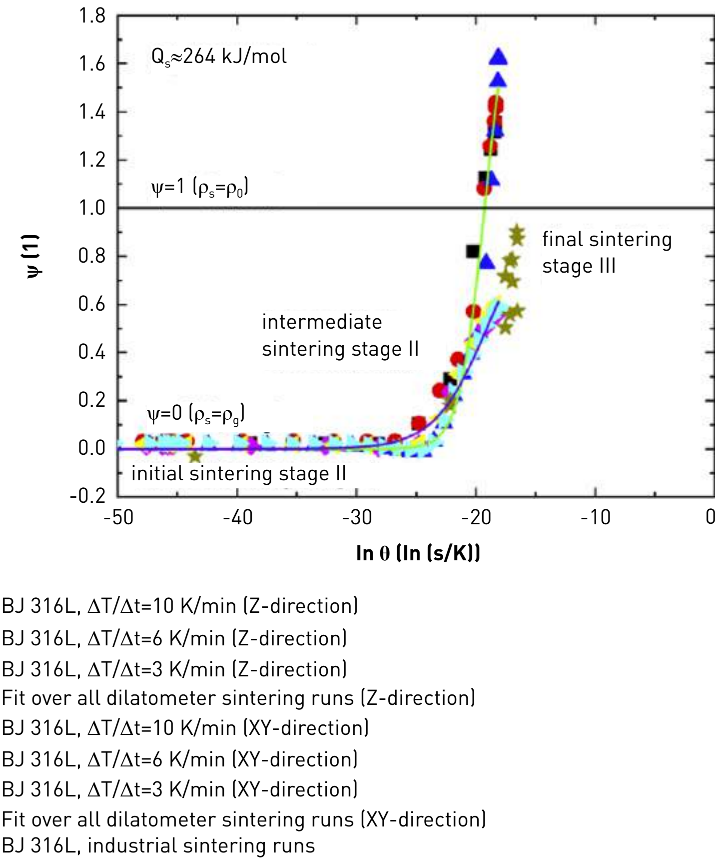


Fig. 3 MSCs of BJ 316L from the different dilatometer sintering runs with n_t=96 data points (the full density of BJ 316L was assumed to be ρ_0=7.93 g/cm³ to harmonise the current MSC with pycnometer density measurements reported in the literature) [1]

The highest achieved magnitudes of the linear shrinkage ε and the corresponding final sintered densities ρ_s are given in Table 2 as a function of the dilatometer sintering profile T(t) or heating rate $\Delta T/\Delta t$ and as a function of the building direction. A large anisotropic shrinkage is evident from the data points in Table 2, although the reason for this anisotropy is not yet understood. A factor of two can be recognised between the two building directions and this anisotropy results in a difference between the calculated and the measured final sintered density ρ_s. As a result, the densification parameter Ψ exceeds its maximum value of one in Fig. 3 (Z-direction). This underlines the incorrect assumption of isotropic shrinkage; the shrinkage in the lateral direction must be smaller. Fig. 3 shows the MSCs based on the authors' six in-house dilatometer sintering runs (using three different heating rates with two different building directions).

All derived sintering work Θ(t, T) values for one building direction fall onto a common curve, independent of the applied heating rates. Due to the incorrect final sintered density ρ_s, the true response will be located between the two MSCs (Z-direction and XY-direction). This confirms the correctness of the MSC approach. The very good agreement between Fig. 2 (industrial sintering runs in a batch furnace) and Fig. 3 (experimental dilatometer sintering runs) is remarkable. This means that most of the densification occurs between ln Θ=-20 ln (s/K) and ln Θ=-15 ln (s/K). Moreover, the second plateau (asymptote, final sintering stage III) of the sigmoidal shaped MSCs is not reached. It seems that a superimposed debinding/sintering effect hinders further densification. Further research is needed to investigate if trapped gas, grain or pore coarsening or a debinding effect could explain this phenomenon.

A step towards a robust Binder Jetting technology: Process parameter optimisation for 17-4 PH steel to increase powder bed homogeneity

The final paper in the session came from Asier Lores, N Azumendi and Iñigo Agote (TECNALIA, Spain) and Unai Andres (MIM-TECH ALFA, Spain) and reported on a process optimisation exercise for binder jetted 17-4 PH stainless steel to increase powder bed homogeneity [2].

The inhomogeneity in the properties of parts manufactured by Binder Jetting is one of the main concerns for the industrial adoption of the technology. The latest trends are towards the use of finer powders in order to improve green part sinterability. As a by-product, however, the additive manufacturability of the powders becomes compromised, as flowability and powder packability deteriorate.

Chemical Analysis (wt %)											
Fe	Ni	Cu	Si	Nb	Mn	Mo	P	N	O	C	S
Balanced	4.5	3.9	0.4	0.32	0.8	0.1	<0.01	0.07	0,09	0.03	0.003
Particle Size Distribution (μm)											
D10	D50	D90									
5.6	14.9	27.5									

Table 3 Chemical composition and PSD of the 17-4PH stainless steel powder supplied by Atomising Systems Limited [2]

Apparent density (ρ_b)		Tap density (ρ_t)(g/cm³)		Hausner ratio $H=\rho_t/\rho_b$	Carr's index (%)	Flow characteristics
(g/cm³)	%	(g/cm³)	%			
3.96	50.77	5.00	64.10	1.26	20.8	Passable

Table 4 Powder density, Hausner ratio and Carr's index for the 17-4PH powder [2]

Currently, powder deposition and spreading technologies are evolving rapidly, with new double-roller spreaders, ultra-sonic powder vibration systems and enhanced powder monitoring techniques. These new developments are focussed largely on the improvement of powder packing and the homogeneity of the AM process.

In the reported study, a single roller powder spreading system has been used, along with a pneumatic vibration-based powder deposition hopper system. With this type of system, it has been observed that parts manufactured in the same build job present some deviations in density and dimensional accuracy. Therefore, the authors tried to shed some light on the control of BJT process inhomogeneities by studying the effect of some major parameters on the dispersion of green part properties.

In this study, gas atomised 17-4PH powder, supplied by Atomising Systems Limited, was used. The powder composition and characteristics given by the manufacturer are shown in Table 3. A relatively small powder particle size (D90: 27.5 μm) was selected, due to the higher achievable packing densities, allowing higher densification after the sintering process.

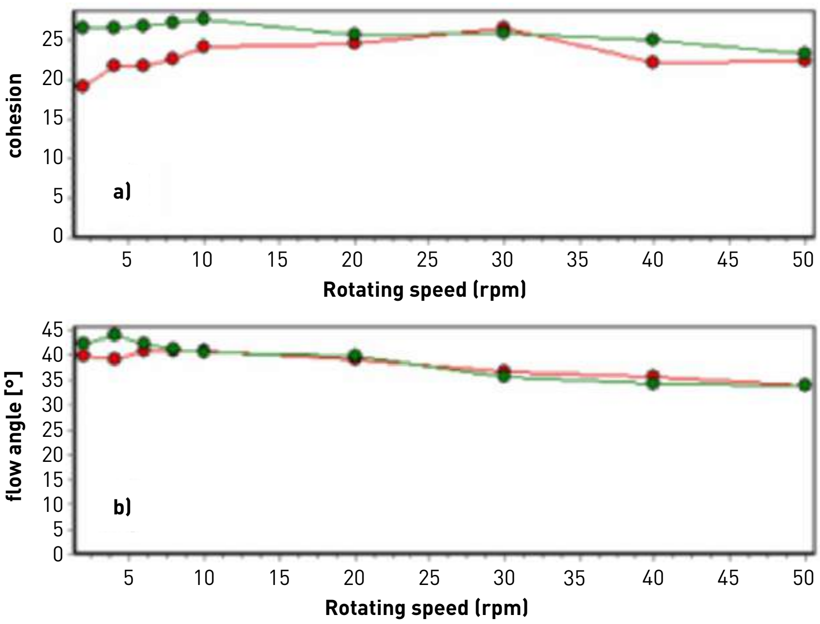


Fig. 4 Powder analysis with GranuDrum: (a) cohesion coefficient, (b) flow angle vs rotating speed [2]

The authors' powder characterisation tests showed that most of the powder particles had a diameter between 10 μm and 20 μm and a near-spherical morphology with some satellite particles bonded to the surface. Spherical particles enhance powder packability. Powder cross-sectional examination revealed the presence of pores within a few particles, probably due to gas entrapment during atomisation. The particle size distribution showed a typical, one sized log-normal distribution, with a D50 of 17 μm.

Table 4 and Fig. 4 show the results related to powder packability and flowability properties. According to the computed Hausner ratio value, the powder has a 'passable' flow capability, similar to other powders used for Binder Jetting purposes.

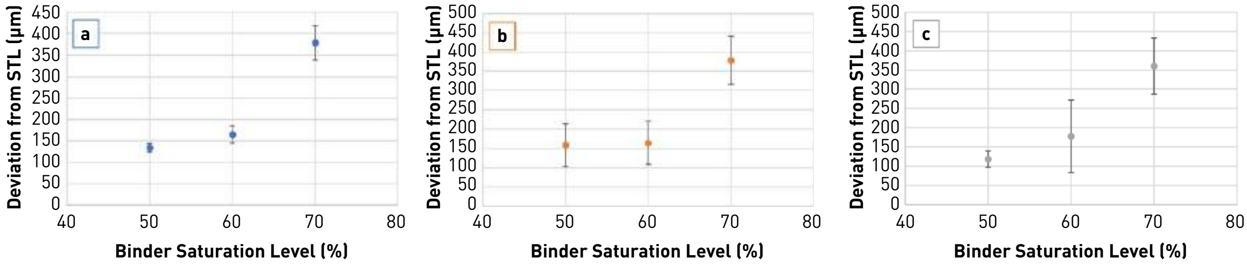
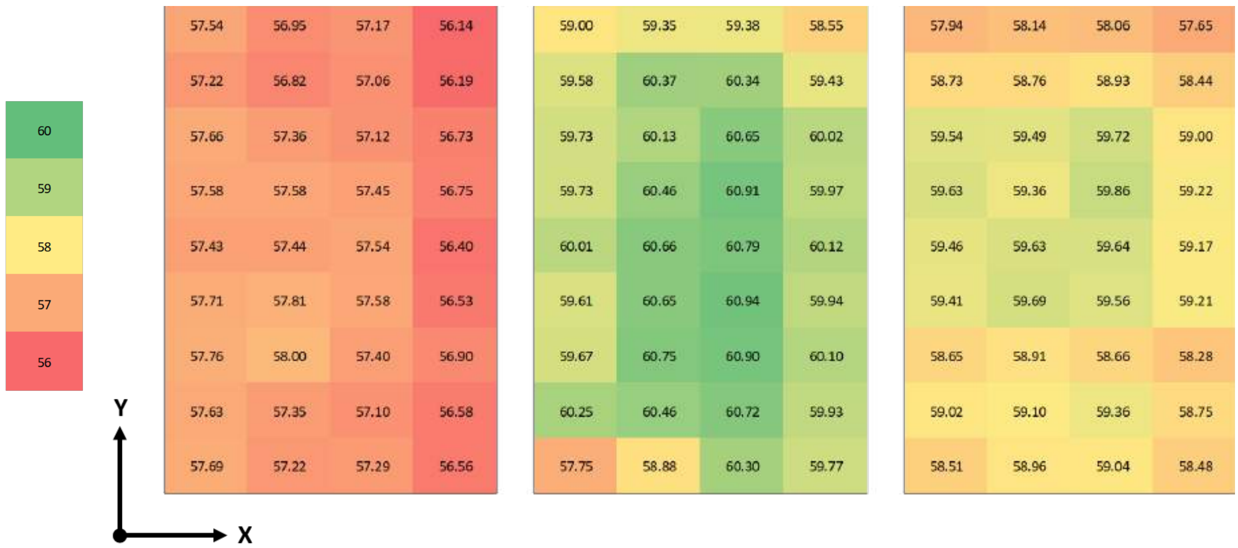


Fig. 5 Dimensional deviations from STL file of binder jet additively manufactured green parts with different BSLs in the three directions a) X, b) Y and c) Z [2]



BSL (%)	70	60	50
Average green density (%)	57.2	59.9	59.0
Std(%)	0.48	0.71	0.56

Fig. 6 Green density distribution along the powder bed in Binder Jetting as a function of binder saturation level [2]

The cohesive index and repose angle also rank the powder as 'passable'. Moreover, the cohesive and repose angle response to a variation of rotation speed will keep the powder's flow properties stable for different dynamic conditions, thus meaning that the powder behaviour may be suitable for a wider processing parameter window.

An ExOne Innovent BJT machine was used for green part build. Thirty-six small cubic samples were uniformly distributed on the printing layout in order to study the dimensional and density differences along the powder bed. The dimensions of the green parts were measured with a digital calliper and the green mass with a high precision balance. The experimental study was attempted in two different stages. In the first stage, the Binder Saturation Level (BSL) effect on the green part dimensional deviation and green density was studied. In the second stage, the effect of the deposited powder amount and part location along the Z-axis was evaluated. This second stage was performed using a L^4 fractional factorial Design of Experiments (DoE) arrangement, in order to detect possible parameter effects and interactions.

Fig. 5 shows the dimensional deviations from STL nominal values as a function of the BSL. Each point represents the average of the thirty-six printed and tested samples, while the error bars correspond to the standard deviation. These results clearly show a reduction in the deviations from the STL file with the reduction of the BSL. Moreover, the reduction of the BSL also reduces the deviation of the samples from the same printing process. Despite the fact that the reduction of BSL can improve the part dimensional homogeneity, it should be noted that an excessive reduction will lead to significantly decreased green part strength and surface quality.

As could also be observed, the effect of the deviation dispersion reduction is less significant in the

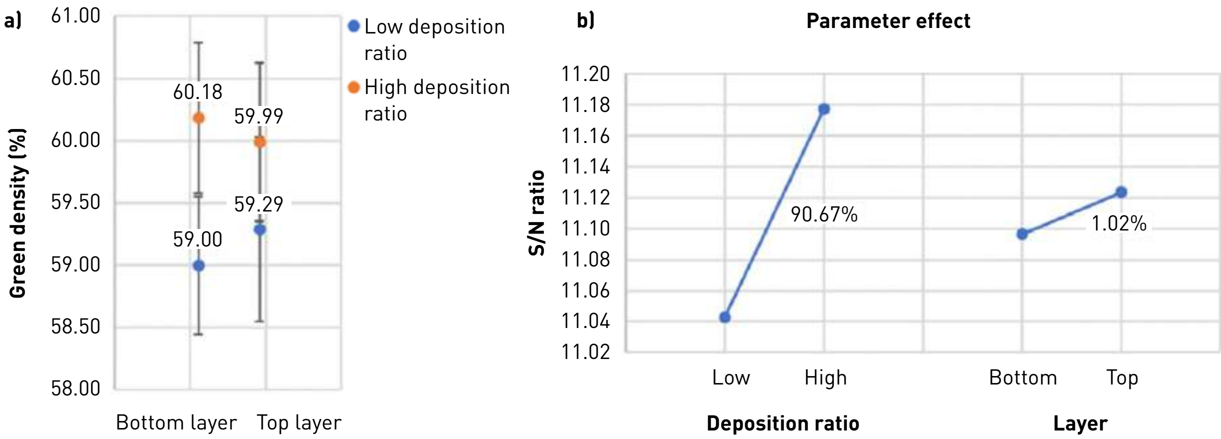


Fig. 7 a) Green density values of the stage 2 experimental trial showing the differences between part location and the amount of material used for powder layer generation; b) parameter effects in green density improvement [2]

Y-direction, which is parallel to the print head motion and drop deposition direction. The asymmetric drop deposition, along with the different kind of powder bed alterations driven by the dynamic interaction behaviour between the droplet and the powder bed, explains the slight increase of the part dimensional dispersion in the Y-direction.

Fig. 6 shows the green density distribution of the powder bed and the mean values as a function of the BSL. As can be observed, the highest average green density achieved corresponded to the 60% saturation printing, although this printing parameter also showed the highest density deviations. The green density dispersion along the powder bed does not seem to follow a common pattern between the different printings. On the one hand, the error propagation in the geometric green density measurement could hinder the appreciation of slight patterns or differences in the powder bed. On the other hand, there are multiple process parameter interaction effects that can dramatically affect the green part density and the green part dimensions and, thus, these effects may change the green density distribution along the powder bed. The roller spreads the powder from the right to the left side of the powder bed in the X-direction. The size of the powder wave generated in front of the roller thus increases, influencing the powder packing behaviour and, therefore, the green part properties.

The influence of the amount of deposited material for powder layer creation and the effect of part location along the Z-axis on green part densities are shown in Fig. 7, together with the parameter effect influence obtained from ANOVA analysis. As can be observed, there is a correlation between the green density and the amount of deposited powder. According to these results, where the higher S/N ratios indicate a green density increment, the higher the amount of powder used for layer generation, the higher the obtained green density. The amount of deposited material also has a 90% effect on the green density variation, meaning it is an influencing factor. The average green density for parts binder jet additively manufactured with low powder feeding settings was 59.14% with an std of 0.66%, while, for the high powder feeding ratio, 60.06% with an std of 0.63%. No significant difference in green part density was observed as a function of part location in the Z-direction. Additionally, the measured dimensional deviations from STL values has remained essentially unchanged between the different printings. Therefore, there has not been observed any detrimental effect in the dimensional accuracy from the rise in powder feeding ratio.

Parts built with a high material deposition ratio and 50% BSL were selected for sintering, as they showed the best green properties, with reference to green density and dimensional deviations. A relative density of 98.62% was obtained, similar to MIM values, with a standard deviation of 0.58%.

"As can be observed, the highest average green density achieved corresponded to the 60% saturation printing, although this printing parameter also showed the highest density deviations."

The obtained microstructure was composed mainly of two phases: martensite and δ- ferrite. Finally, the measured hardness was 32 ± 1 HRC, which is a typical value for as sintered 17-4 PH stainless steel.

In future work, the authors plan to study the interaction between more process parameters and their influence on powder bed inhomogeneity patterns, in order to build a precise dimensional deviation prediction model.

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[2] A step towards a robust Binder Jetting technology: Process parameter optimisation for 17-4PH steel to increase powder bed homogeneity, A Lores, N Azumendi, I Agote and U Andres. As presented at the Euro PM2020 Virtual Congress, October 5–7, 2020, and published in the proceedings by the European Powder Metallurgy Association (EPMA)

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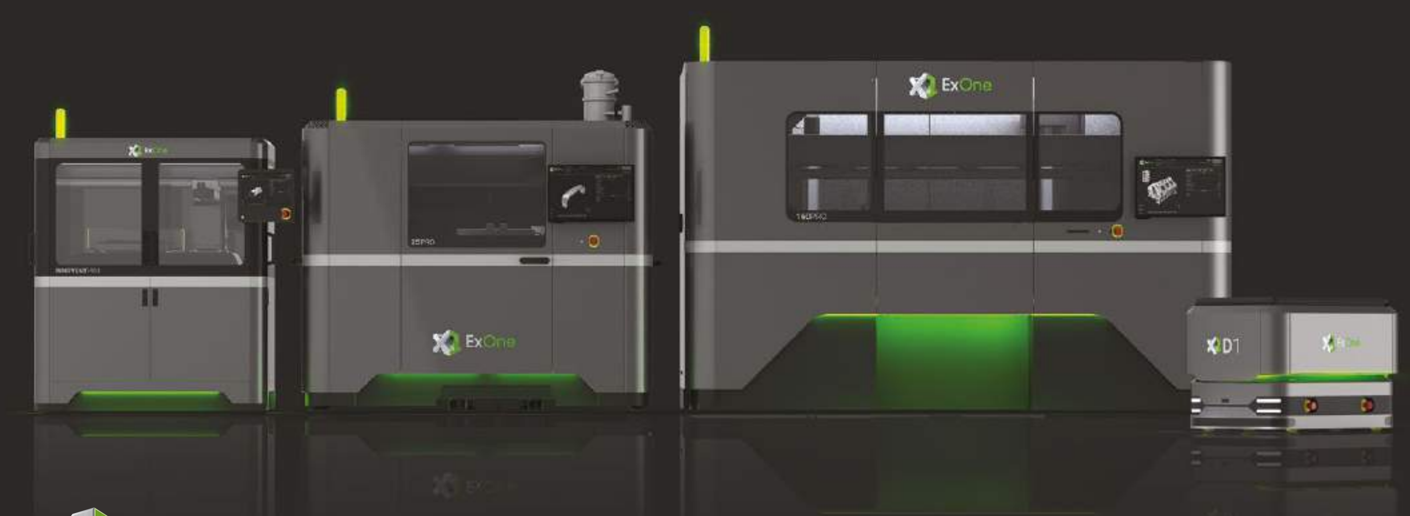

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