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THE MAGAZINE FOR THE METAL ADDITIVE MANUFACTURING INDUSTRY

METAL AM

in this issue

COMPANY PROFILE: OERLIKON

ADDITIVE MANUFACTURING & HIP

METAL POWDER PRODUCTION

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METAL ADDITIVE MANUFACTURING

A barometer for the AM industry

This issue of *Metal AM* magazine comes to you only a matter of weeks after the close of formnext 2017. For those of you that may still be unaware of this trade exhibition and conference, the third event in the formnext series took place in Frankfurt, Germany, from November 14-17 and attracted over 21,000 visitors.

In a very short period of time, formnext has become the largest and most important international exhibition for Additive Manufacturing. With a concentration on industrial applications rather than the consumer side of the technology, the event has a significant focus on metal AM and the complete process chain was represented in the exhibition hall, from powder producers through to part makers.

As such, formnext is very much becoming a barometer for the status of AM. Coming close to the end of the calendar year, the event gives participants the opportunity to review the achievements of the past year, as well as to launch the innovative technologies, materials and applications that will drive growth in the year ahead.

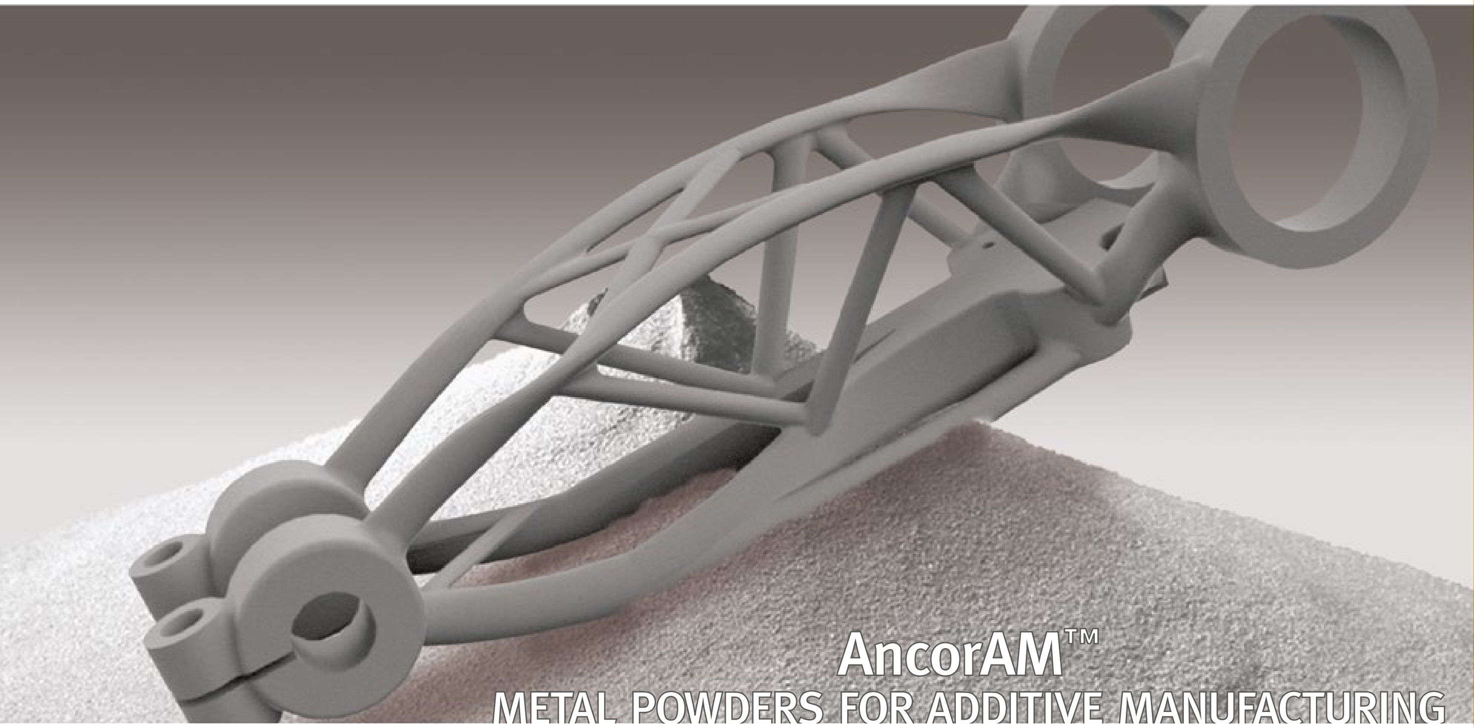
Though in the past there have been many words of caution in relation to the 'hype' around AM, the impression that many left Frankfurt with is that the wider industrial community is embracing metal AM faster than most of us could have imagined just a few years ago. With industrial-scale AM machines now selling 'in bulk' for the real commercial production of metal components, perhaps it is time to look beyond cautionary warnings and embrace this new reality as the technology continues to thrive.

On behalf of the team at *Metal AM*, season's greetings and best wishes for a prosperous and successful 2018.

Nick Williams
Managing Director
Metal Additive Manufacturing

Cover image
An additively manufactured AlSi10Mg distributor housing produced by Oerlikon's AM facility in Barleben, Germany (Courtesy Oerlikon)

HOEGANAES



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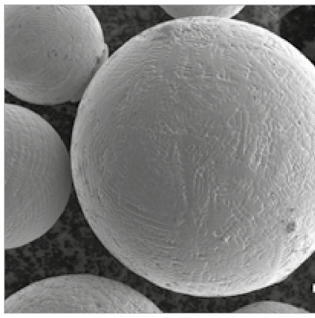
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industry news

Metal AM parts in series production for BMW's new i8 Roadster

BMW Group's newly launched i8 Roadster features a lightweight metal additively manufactured cover carrier. The part is used to carry a cover which unfolds when opening the roof of BMW's advanced open-top hybrid sports car.

Manufactured from AlSi10Mg0.5 in a Powder Bed AM process, the part offers increased stiffness and reduced weight. Each i8 Roadster will include two of the AM cover carrier components, a left and right hand version. Production is expected to run to several thousand parts.

According to BMW Group, the use of metal AM allowed the topologically optimised parts to be produced in a geometric form which would not have been possible using conventional casting techniques. This ensures the optimum balance between the component's rigidity and weight.

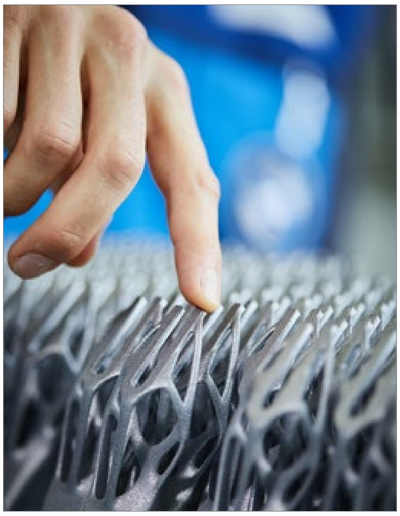
BMW's new i8 Roadster incorporates metal additivity manufactured parts

The ability to reduce the weight and part count of automotive components is a key advantage of AM, with vehicle light-weighting being one vital way in which vehicle manufactures can increase fuel efficiency.

The i8 Roadster premiered during the Los Angeles Auto Show in December 2017 and will see its market launch in May 2018.

www.bmwgroup.com

The part is used to carry a cover which unfolds when opening the roof



Production is expected to run into several thousand

GE gas turbine breaks efficiency record through metal AM optimisation

GE Power, Schenectady, New York, USA, reports that its largest gas turbine has broken efficiency records thanks to an optimised redesign using metal AM. The GE Power-produced 9HA.02 gas turbine is now said to offer 64% efficiency in combined cycle power plants – reportedly higher than any other competing technology today.

According to GE Power, the turbine's increased efficiency was achieved largely due to GE's advances in metal Additive Manufacturing, as well as developments in combustion. The new turbine replaces the company's former HA model, which broke efficiency records in 2016 with its ability to power a combined-cycle power plant at 62.2%.

Using AM's capacity to achieve more complex geometries, GE Power was able to optimise the design of the 9HA.02's combustion system for better premixing of fuel and air. As a result, the 9HA.02 can be quoted at 64% net efficiency in specified conditions with total output of 826 megawatts in 1x1 combined cycle configuration. According to the company's estimates, an additional percentage point of efficiency in gas turbines can translate to millions in fuel savings for customers globally.

"The HA is our most advanced gas turbine technology, and we've never stopped pushing the boundaries of what it can do," stated Joe Mastrangelo, President and CEO, GE's Gas Power Systems.

www.gepower.com


GE Additive
Sparking a new era in design and manufacturing
Through innovation, collaboration and consultation, GE Additive has built a network of people and businesses that are advancing additive manufacturing. Not just for us, but for everyone. We've taken our additive experience and made it even stronger, bringing together machine and material providers as well as design experts to help you incorporate additive technology into your operations. Together, we're helping guide manufacturing in a bold new direction.
Let us help you find new ways to grow your business at ge.com/additive.
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a GE Additive company
Arcam EBM
a GE Additive company
AP&C
a GE Additive company
DTI
a GE Additive company

FIT and NIK form joint venture to open up Russian AM market

FIT Additive Manufacturing Group, Lupburg, Germany, has partnered with Russian research and engineering company NIK Ltd to form a new joint venture company aimed at opening up the Russian market for Additive Manufacturing.

The new company, FITNIK, will be based in Zhukovsky, Russia, with production at the site expected to be fully operational within two years. Zhukovsky, 30 km south of Moscow, is an important Russian aircraft centre for scientific R&D. This carefully chosen location is said to be an environment for creative innovation and allows access to excellent engineering expertise and talent.

"Through FITNIK, we gain incredible synergy," stated Carl Fruth, Founder and CEO of the FIT Group. "Not only are we able to penetrate the Russian market very quickly via access to many target markets, this joint venture also gives us the opportunity to offer our international customers qualified additive engineering at very competitive prices. We are happy to team up with NIK."

Alexander Korneev, NIK CEO, added, "By creating this joint venture, we are ensuring a robust manufacturing process, incorporating the entire chain of product creation with the help of additive technologies — from designing, according to the customer's specifications, to production implementation, certification, and post-production support. FITNIK combines the expertise of two leading companies regarding additive design and manufacturing, thereby allowing for the realisation of truly comprehensive services."

http://fit.technology

www.avianik.com

GE Additive acquires GeonX for enhanced software simulation capabilities

GE Additive has announced its acquisition of GeonX, a privately-owned developer of simulation software. Headquartered in Belgium, GeonX provides simulation software for Additive Manufacturing, welding, machining and heat treatment processes in various industries such as aerospace, automotive and energy.

GeonX's simulation software tool, Virfac®, assesses products prior to production; predicting defects, distortions and stresses and the impact manufacturing has on a product's durability. This helps to reduce the number of prototypes built during the development phase, while improving the quality and lifetime of the manufactured products, and is said to have the potential to minimise time to market and development costs.

Mohammad Ehteshami, VP and General Manager, GE Additive, stated, "As a business, GE Additive is committed to accelerating the Additive Manufacturing industry. Innovative simulation software solutions like Virfac do just that by adding real value to our customers who want to speed up product design and development, while maintaining the best possible quality. We're delighted to welcome GeonX to the GE Additive family."

Laurent D'Alvise and Michel Delanaye, Co-founders and CEOs, GeonX, added, "GE Additive is the innovator in the AM sector and we're thrilled to join the team. Software is of course integral to digital transformation, so we are equally excited to be part of GE's Digital Industrial journey."

www.ge.com/additive

www.geonx.com

Höganäs acquires new atomisation technology for spherical powders

Höganäs AB, Sweden, has acquired the start-up Metasphere Technology, Luleå, Sweden. Metasphere, founded in 2009, has developed a new technology for atomising metals, carbides and ceramics at very high temperatures in a reactor using plasma and centrifugal forces.

"Metasphere's technology is unique and innovative," stated Fredrik Emilson, Höganäs CEO. "We will be able to offer new and specialised metal powders for surface coating and Additive Manufacturing, among other areas. Thanks to the high temperatures, we can achieve very pure and spherical metal powders.The metal powders produced today are especially well suited for surfaces that need wear, corrosion and impact resistance, for instance within mining, oil and gas and other heavy industries."

The acquisition reportedly took place in early November 2017. Höganäs' customers are currently being supplied with products from the pilot reactor, with work ongoing to finalise the production reactor during the first quarter of 2018.

"When we have scaled up to industrial production we will go to market with a broad spectrum of products," explained Emilson. "Mainly within additive manufacturing, where there is a large demand for innovative materials."

www.hoganas.com

Urban Rönnbäck, founder of Metasphere Technology in Luleå, and Fredrik Emilson, Höganäs CEO

SLM Solutions secures €37 million order for twenty new SLM 800 systems

SLM Solutions Group AG announced that it received a major order worth at least €37 million during the first day at formnext 2017, Frankfurt, Germany. The deal will see the sale of twenty new SLM 800 type Additive Manufacturing machines to a customer from the energy sector headquartered in Asia. SLM Solutions added that the final deal may include additional SLM 500 systems, further increasing the order volume.

The new SLM 800 machine concept enables integration into automated and fully automated production processes. The system includes new, permanent filter technology, melt pool monitoring and laser power monitoring (now also for multi-laser operations), improved machine control software and an optional powder feeder unit using vacuum technology.

"Technological integration into production processes has succeeded with the SLM 800. The SLM 800 is very convincing for our industrial customers. We are very pleased that we have been able to get such impressive confirmation of our development steps on the first day of the fair. The machines from this order will be continuously delivered until the end of 2019," stated Uwe Bögershausen, board member of SLM Solutions Group AG.

Henner Schöneborn, board member of SLM Solutions Group AG, added, "We have reached another milestone towards automation of manufacturing processes with the SLM 800. Technologically, we want to become the market leader thanks to total manufacturing integration with both existing factory and production processes as well as Industry 4.0 connectivity over the next few years. In addition to the size of the construction chamber, outstanding component quality and our market-leading multi-laser technology are the convincing and proven parameters for our customers."

www.slm-solutions.com

The deal will see 20 new SLM 800 type AM machines shipped to a customer in Asia

Record visitor numbers at formnext 2017

The formnext powered by tct exhibition took place in Frankfurt, Germany, November 14-17 and drew a total of over 21,492 attendees, representing an increase of over 60% on the previous year. Organised by Mesago Messe Frankfurt GmbH, the four-day event attracted a total of 470 exhibitors from thirty-three countries and showcased new and existing products from all areas of the AM process chain. "The numbers show just how successful formnext 2017 was: In our third year, the sheer amount of world premieres we hosted, and the huge gains we saw in exhibitors and visitors, bolstered formnext's reputation not only as the industry's leading exhibition but as a key source of inspiration for the complete sector," stated Sascha F Wenzler, Vice President for formnext at Mesago.

Next year's formnext is scheduled to take place November 13-16, 2018.

www.formnext.de

Magnus René, CEO and Johan Brandt, CFO to leave Arcam

Arcam AB has announced that its President and CEO, Magnus René, and its CFO and deputy CEO, Johan Brandt, have both chosen to terminate their respective employment agreements with the company. René has been CEO of Arcam since 2001 and Brandt has been CFO since 2012. René has a notice period of six months and will remain in his position until a new CEO is appointed, or at the latest until June 3, 2018. Brandt has a notice period of three months and will remain in his position until a new CFO is appointed or at the latest until April 30, 2018.

"Magnus René has with energy and decisiveness built Arcam to a leading company in the Additive Manufacturing sector. He has together with his team, customers and partners worldwide developed the company from a start-up to a global industry. Magnus has also been instrumental in bringing Arcam into its new future with GE as an owner," stated Göran Malm, Chairman of Arcam. "Johan Brandt has as CFO and deputy CEO built the structure of the company and thereby facilitated our growth and globalisation. Johan has with his leadership and his team developed first class management of Arcam's and our subsidiaries financial functions."

Commenting on the announcement, René added, "I have had a fantastic journey, being part of the team building Arcam during those 16 years. Today, Arcam is well positioned, with a great team, world-class products, strong leadership in our companies and a strong cash position after the recently concluded share issue. With GE as majority owner this is a good time for me to move on and for a new CEO to take over and develop the company in the new environment."

www.arcam.com

Renishaw's four-laser Additive Manufacturing machine unveiled

Renishaw unveiled its four-laser metal Additive Manufacturing machine at this year's formnext 2017, Frankfurt, Germany. Titled the RenAM 500Q, the four-laser system has the potential to significantly improve productivity in the company's most commonly used machine platform size.

The use of four lasers in an AM system can increase production speed by up to four times. Renishaw stated that it expects the RenAM 500Q to broaden the market appeal of metal Additive Manufacturing into applications that are presently uneconomic, and potentially into new industries that have yet to embrace AM for production.

"Multiple laser technology in a small footprint system will broaden the appeal of Additive Manufacturing in new markets and applications," explained Robin Weston, Marketing Manager at Renishaw's Additive Manufacturing Products Division.

According to the company, the primary benefit offered by the system is a substantial reduction in cost per part, whilst maintaining the quality and precision offered by standard single laser systems.

"The technology is moving towards applications where it's not just the technical benefits of AM that are attractive but also the production economics of using it in a serialised manufacturing process for high-quality components."

During formnext, Renishaw also presented its new High Temperature Build Volume technology, which it states will enable manufacturers to build components from materials that are not currently feasible. High Temperature Build Volume technology reportedly enables the production of bulkier parts with less risk of thermal stress effects. This has the potential to further expand the capabilities of AM and provide a platform for research and development.

www.renishaw.com/additive

The RenAM 500Q is a four-laser system that offers users a substantial reduction in cost per part

Materialise acquires ACTech, a manufacturer of complex metal parts, in $52.9 million deal

Materialise has acquired ACTech, a German-based company which specialises in the production of limited runs of highly complex cast metal parts for the automotive and aerospace industries. According to the companies, the transaction aims to bring together Materialise's Additive Manufacturing solutions and the casting experience of ACTech, to provide a comprehensive metal manufacturing offering.

The acquisition of ACTech's knowledge and in-house infrastructure is expected to enable Materialise to accelerate the development of its existing metal competence centre and strengthen its position in the market for the production and delivery of unique and complex metal AM parts.

"ACTech knows metal and how to shape it to production standard, and we know Metal 3D Printing," stated Wilfried Vancraen, founder and CEO of Materialise. "Bringing those two competencies together is vital to the delivery of high added-value metal 3D-printed parts for specialised applications."

The acquisition will also enable Materialise to develop and improve its software suite for metal AM through close collaboration with ACTech's team and its metal manufacturing environment. In turn, ACTech customers will gain immediate access to metal AM parts for pre-production design iterations.

"Through the acquisition, we are further enhancing the manufacturing and software backbone position that will support the entire industry. For over twenty-seven years, we have always been there as a leading, comprehensive provider of solutions in industrial polymers printing," continued Vancraen.

"That position has enabled us to both develop and serve a growing demand for certified manufacturing with dedicated software and solutions. By joining forces with ACTech, we will accelerate that same strategy for metal manufacturing."

Materialise states that it acquired ACTech based on a total enterprise value of $52.9 million for a total cash payment of $42.7 million to the sellers. In 2016, ACTech realised German GAAP revenue of $40.3 million with $9.6 million in EBITDA and $2.7 million in net profit. Materialise financed $32.9 million of the acquisition price through long-term bank financing.

www.materialise.com
www.actech.de

GE Additive unveils Project A.T.L.A.S. metre-class metal AM system

GE Additive unveiled the first BETA machine developed as part of its Project A.T.L.A.S. program at the recent formnext 2017 exhibition in Frankfurt, Germany. The metre-class, laser powder-bed fusion machine has been designed to provide manufacturers of large parts and components with a scalable solution that can be configured and customised to their own specific industry applications.

Project A.T.L.A.S. (Additive Technology Large Area System) is GE Additive's company-wide program to develop the next generation of large additive machines. This first BETA machine was developed in just nine months and complements the company's existing portfolio of products. Ideally suited to industries that require large complex metal parts, such as the aviation, automotive, space and oil and gas industries, the new BETA machine builds on technology previously developed by GE, combined with Concept Laser's expertise in laser additive machines. The first few BETA machines are currently being evaluated by a small group of customers and more will be available for delivery in 2018.

The Project A.T.L.A.S. system is said to be suited to industries that require large complex metal parts

"Irrespective of industry, every customer has its own specific needs and its own unique levels of complexity. We regularly hear that next-generation machines need to be customisable and configurable. The new meter-class machine we're debuting at formnext is our response to that feedback – a solution that is scalable and customisable and meets the needs of our industry, as it matures," stated Mohammad Ehteshami, Vice President and General Manager of GE Additive.

The BETA machine has a build volume of 1.1 x 1.1 x 0.3 m (x,y,z) with scalable architecture that can increase the 'z' axis to 1 m and beyond. It is powered by a 1 kW laser with process and machine health monitoring enabled by Predix software, GE's cloud-based operating system.

"Our Project A.T.L.A.S. is one way we are helping our customers be more efficient and nimble as the sector matures," added Frank Herzog, founder and CEO, Concept Laser. "This demonstrates what's possible when we combine the strength of Concept Laser with GE."

www.geadditive.com

GE Additive's beta Project A.T.L.A.S. system was revealed during formnext 2017

Arconic and Airbus sign multi-year research agreement to advance AM for aerospace

Arconic, New York, USA, has announced a multi-year cooperative research agreement with Airbus to further advance metal Additive Manufacturing for aircraft components. The companies state that they will develop customised processes and parameters to produce and qualify large structural AM components, such as pylon spars and rib structures, up to approximately 1 m in length.

"This agreement combines the expertise of two of the world's top aerospace Additive Manufacturing companies to push the boundaries of 3D printing for aircraft production," stated Eric Roegner, Executive Vice President and Group President, Arconic Engineered Products and Solutions and Arconic Defense. "Additive Manufacturing promises a world where lighter, more complex aerospace parts are produced cheaper and faster. We're joining forces to make that potential a reality in a bigger way than ever before."

Arconic will develop its processes and manufacture test parts at its facilities in Cleveland, Ohio, USA, and at the Arconic Technology Center outside Pittsburgh, Pennsylvania, USA. The company has a long-standing relationship with Airbus in which its capabilities in materials science and AM, qualification and supply chain management, have seen the companies announce three agreements in the last year. Perhaps most notably, the company's Austin, Texas, USA facility currently produces Airbus's AM titanium brackets, installed on its series A350 XWB aircraft. These brackets entered commercial use in September 2017, and are reported to be the first metal AM parts installed on a series production commercial aircraft.

www.arconic.com
www.airbus.com

BeAM's new Modulo 400 system for industrial-scale metal AM

French-based BeAM Machines, SAS, introduced its new Modulo 400 machine at the recent formnext 2017 exhibition, Frankfurt, Germany. The Direct Energy Deposition (DED) machine is designed to allow industrial-scale metal Additive Manufacturing while reducing the required floorspace for an industrial set-up.

According to BeAM, traditional DED systems place their peripheral equipment (laser, chiller, fume extractor and more), as well as the machine base, outside the main 'envelope' of the system – therefore requiring a large area of floor space. The Modulo 400 is said to integrate all peripherals into the machine cabinet, resulting in a significantly reduced machine footprint.

The new machine is also said to be more portable than traditional DED systems, fitting inside a normal shipping container or box truck for easier transportation and operation in remote locations, such as offshore oil rigs and military bases. Tim Bell, General Manager of BeAM Machines, stated, "Designed and built to operate every day in harsh conditions, the Modulo 400 is truly the future 'factory in the field.'"

The Modulo 400 has a significantly reduced machine footprint compared to traditional DED systems

The Modulo 400 also offers BeAM's standard suite of options including a 2 kW fibre laser, fully controlled atmosphere system, multiple deposition heads, touch trigger probe and light-duty milling spindle for dry machining. In January 2018, the company expects to introduce the Modulo 250, an even more compact version of its DED system designed specifically for small-scale activities such as R&D, training and the AM of small parts.

www.beam-machines.com

HP to launch metal Additive Manufacturing platform in 2018

Following HP's move into Additive Manufacturing with its high-speed polymer Jet Fusion 3D Printing systems, the company has announced plans to launch a new metal Additive Manufacturing platform in 2018.

Speaking at the HP Securities Analyst Meeting in Palo Alto, California, USA, on October 12, Stephen Nigro, HP's President of 3D Printing, announced the development of a novel metal AM approach which he called "a major step for HP 3D printing aspiration."

The company hopes that the release of this new platform will "transform 3D metal printing into more mainstream, high-volume production." Further details of HP's metal AM technology were not disclosed during the presentation, with Nigro stating that HP will make a formal announcement in 2018.

www.hp.com/go/3DMetals

GKN reinforces Additive Manufacturing business with formation of GKN Additive

GKN plc, the global aerospace and automotive engineering group, has announced the formation of GKN Additive, a new division within the company to bring its Additive Manufacturing activity together into one new brand. The company is a leading producer of additively manufactured parts, with aerospace components produced, certified and flying on seven major platforms and AM parts driving in today's cars. GKN is also a specialist metal powder and component producer through its Powder Metallurgy division.

Operating from seven global centres of excellence in four countries, GKN Additive will act as the focal point for all this activity in the future, ensuring the company continues to push the boundaries of the technology and strengthen the Group's position in the market.

Jos Sclater, Head of Strategy at GKN, stated, "GKN Additive is an incredibly exciting venture and the potential applications for the technology are endless. The benefits of AM are significant, both for our customers and the world around us in terms of greener, more efficient production. There is also a tangible feeling that manufacturing is suddenly a very exciting place to be for the brightest and best engineering talent. That is great for the future of the industry and I am delighted that GKN Additive will be at the forefront of this revolution."

www.gkn.com/en/our-divisions/gkn-additive

Adira introduces its AddCreator machine for large-scale metal AM components

Portuguese-based manufacturing company Adira has released a new large-scale metal Additive Manufacturing system, the AddCreator (AC). Displayed at the recent formnext exhibition in Frankfurt, Germany, the AC claims to offer the largest working volume of any metal powder Additive Manufacturing machine.

The system uses Adira's Tiled Laser Melting (TLM) process, which divides the work area of a build into smaller segments or 'tiles' to be processed sequentially. This is said to enable more efficient and flexible production of very large components which it may not be possible to produce using traditional AM.

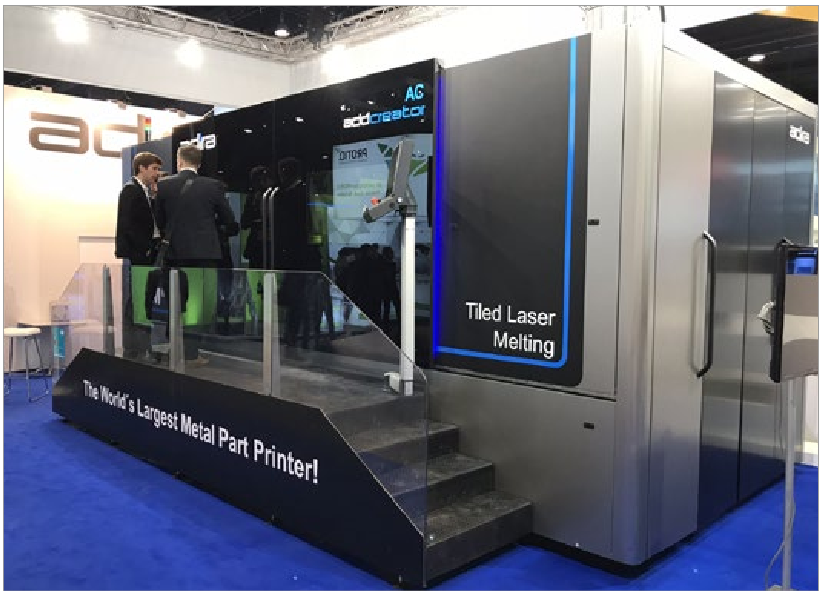
Using TLM, it is also possible to produce parts larger than the AC's build chamber volume. By making use of a moveable chamber, atmospheric conditions can be maintained solely in the working area, allowing as-needed expansion of the build area without compromising system functionality.

The AC system incorporates a number of useful features aimed at making metal Additive Manufacturing more accessible to the market, such as an automated powder cycle for easier cleaning and sieving of used powder, quicker supply and storage.

The machine also offers full production chain integration and an optimised infrastructure for the removal of parts, comprising multiple access areas and the capacity for cooperative interaction with an external robotic handling system. Additionally, integrated laser and process-related equipment is reported to offer end-users a cleaner and more efficient work environment, free of unnecessary peripherals.

Adira was founded over sixty years ago and formerly specialised in the production of its own widely-used press brakes, shears and laser cutting systems for sheet metal processing. The development of TLM and release of the AC mark the company's first entry into Additive Manufacturing and Industry 4.0.

www.adira.pt



The AddCreator was displayed at the recent formnext exhibition in Frankfurt, Germany

AP&C receives ISO13485 certification

Arcam AB's powder manufacturing subsidiary AP&C in Quebec, Canada, has received ISO13485 certification. This certification is designated for the orthopaedic implant industry. In addition to the new ISO13485 certification, AP&C is already certified to ISO9001 and AS9100.

Alain Dupont, President of AP&C, stated, "The ISO13485 certification proves our firm's commitment in producing quality powder to the industries we serve. With the certifications and our recently inaugurated new state of the art powder manufacturing plant we are well positioned to serve our customer's needs."

"The demand for high-end titanium powder is driven by the accelerated growth and industry adaptation of Additive Manufacturing," added Magnus René, CEO of Arcam. "Arcam, AP&C and GE Additive are committed to disrupt conventional manufacturing and help the industry evolve into Additive Manufacturing by offering high quality and cost-effective solutions. This ISO13485 certification is one more step into the future of Additive Manufacturing."

AP&C opened a new powder production facility in Saint-Eustache, Quebec, Canada in September 2017. The new manufacturing plant will employ more than one hundred new staff by the end of the year, making it one of the largest employers in the region and marking a significant growth for AP&C, which has quadrupled in size over the last two years.

With a present total production capacity of 750 tons and planned production capacity of 1,250 tons at full capacity, the new plant is poised to meet the growing demand for titanium powders in terms of quality and capacity.

www.arcam.com
advancedpowders.com

Additive Industries launches Product Removal Module

Additive Industries launched its new Product Removal Module at formnext 2017

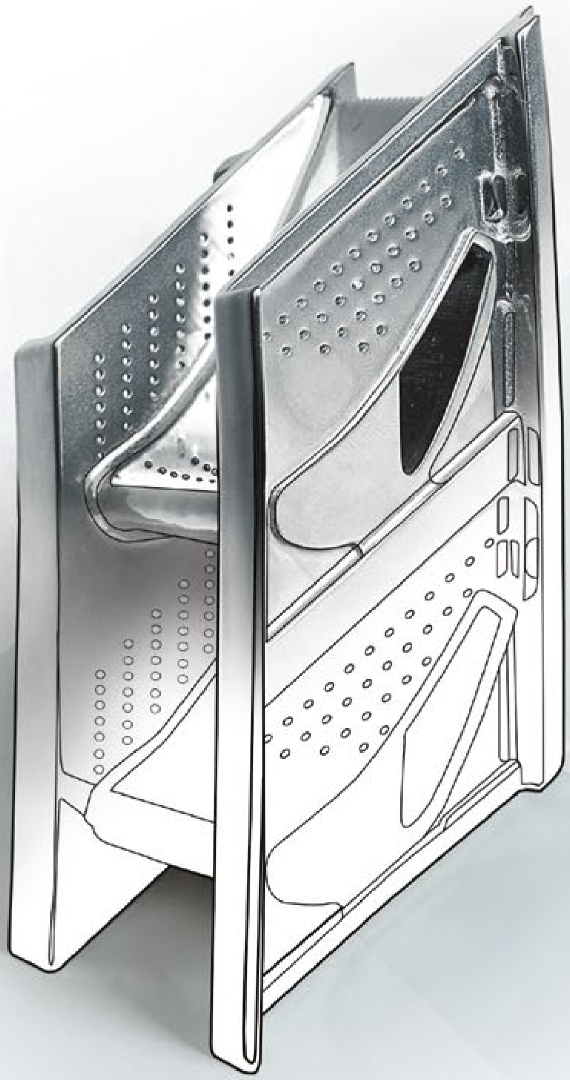
Additive Industries, Eindhoven, the Netherlands, launched a new Product Removal Module at formnext 2017 to allow users of the company's MetalFAB1 system to remove products from the build plate, release any trapped powder and resurface the build plate by three-axis milling for reuse. According to Additive Industries, this will prevent the need for time-consuming logistics and external post-processing.

Additive Industries also presented its Dynamic Laser Allocation software, which is used to control four full-field lasers working on a single part or multiple products. The software contains a smart algorithm which optimises laser allocation for a customer-set balance between quality and productivity. A specific feature of the software is the ability to dynamically prevent lasers from melting in the smoke of another laser, which may help ensure part quality.

During formnext, Additive Industries also announced that it will offer ten potential new users of its technology to enter into an Industrial Additive Manufacturing Program. This programme offers attractive conditions for the purchase of a user's first MetalFAB1 system, in combination with full support for process implementation and application development.

Daan A J Kersten, CEO of Additive Industries, stated, "We want to support professional OEMs and their 1st tier suppliers to scale for production with our integrated metal Additive Manufacturing systems, and recognise that help from our Process & Application Development team will accelerate part identification, design for AM as well as implementation of the technology."

www.additiveindustries.com ■



Trumpf's TruPrint 5000 high speed three-laser AM system

The TruPrint 5000 has three scanner-guided, 500 watt Trumpf fibre lasers

Trumpf, Ditzingen, Germany, introduced its TruPrint 5000 Additive Manufacturing system at the recent formnext 2017 trade fair in Frankfurt, Germany. According to the company, the new machine is "the world's fastest and most productive medium format 3D printing system for metal components."

The TruPrint 5000 is built around a multi-laser principle with three scanner-guided, 500 watt Trumpf fibre lasers. The three lasers are fitted with optics specially designed by Trumpf, enabling them to operate simultaneously at any point in the system's construction chamber. Using the exposure strategies and optimised process parameters developed by the company, the TruPrint 5000 is reported to cut exposure time per job by a factor of three.

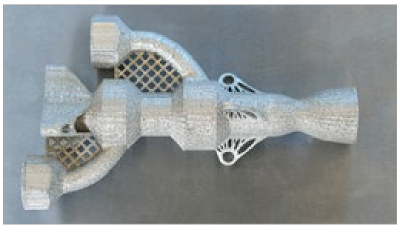
Peter Leibinger, Chief Technology Officer at Trumpf, stated, "All our new 3D printers are selling well, and we're gaining increasing market shares in various sectors. Accordingly, we will most definitely be further investing in this highly promising field." This will include the establishment of a new development unit in Aachen, Germany.

"As a seedbed for technologies of the future and with its proximity to RWTH Aachen University and the Fraunhofer Institute for Laser Technology, Aachen, is an ideal location to further develop our Additive Manufacturing technologies," Leibinger added.

"If the market for 3D printers continues to develop in line with current indications, then we see an opportunity for our company to achieve additional revenues of half a billion euros in a timescale of five to seven years. We want to gain a leading role in the market and secure a market share of around 20% in the medium term," concluded Leibinger.

www.trumpf.com

Xact Metal launches XM300 system for industrial grade metal Additive Manufacturing



Xact Metal systems can process a wide range of materials

Xact Metal, State College, Pennsylvania, USA, has launched the XM300, a mid-sized, industrial grade metal Additive Manufacturing system. The XM300 was launched during formnext 2017 and offers a large build volume of 254 x 330 x 330 mm (10 x 13 x 13 in). According to Xact Metal, it is designed for large-part development and production use.

"The XM300 uses patent-pending Xact Core™ technology, a highly scalable gantry system platform that allows light, simple mirrors to move quickly and consistently above the powder bed on the X-Y axis," explained Matt Woods, CTO of Xact Metal. "It's equipped with two or four high-precision independent fibre lasers, meaning that parts can be printed up to four times faster. The system also has twin feed chambers, which lowers build time and increases productivity."

"Our machine uses two translating mirrors that deflect the beam to different locations without varying the angles of incidence, keeping the beam orthogonal to the entire build surface," he continued. "This generates uniform part properties without compromising on effective fusing speed of up to 1.5 m/sec."

Juan Mario Gomez, CEO of Xact Metal, stated, "Priced between $400,000–$600,000 USD depending on the number of lasers, we are confident that the XM300 will create a new benchmark for price and performance in the metal Additive Manufacturing industry, boosting adoption rate of metal 3D printing across many industries. In addition, the XM300's small size reduces overall space requirements on the manufacturing floor, allowing for easy installation, handling and maintenance."

Xact Metal filed a utility patent for its Xact Core technology in May 2017. Shipments for the XM300 are scheduled to begin in Autumn 2018.

www.xactmetal.com

OR Laser introduces new hybrid platform

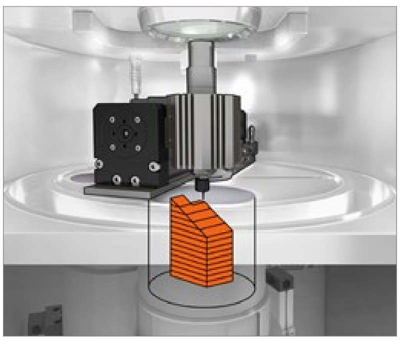
OR Laser, Dieburg, Germany, introduced its new hybrid metal additive and subtractive manufacturing platform, the ORLAS Creator Hybrid, during formnext 2017. According to the company, the ORLAS Creator Hybrid brings together the benefits of both metal Additive Manufacturing and subtractive manufacturing within a single platform, offering a comprehensive manufacturing solution.

The platform, which combines the advantages of AM for complex metal components with advanced milling capabilities for precision finishing, is said to be available at a price affordable to SMEs. In addition, OR Laser states that the new hybrid enables structures and surfaces not normally reachable by traditional milling/machining to be milled effectively.

The ORLAS Creator Hybrid offers the same AM capabilities as the original ORLAS Creator, launched in 2016, including the full laser power of 250 W at a spot of 40 µm; laser processing speeds of 3500 mm/s; and a build platform 110 mm (diameter) with a maximum Z axis of 100 mm.

During formnext, OR Laser also announced that it will launch a new cloud manufacturing service. This cloud manufacturing service will monitor machines in real time as well as providing preventative maintenance reports that aim to avoid downtime by providing monitoring and analysis of multiple systems from one location.

www.or-laser.com



ORLAS Creator Hybrid's milling system

SPEE3D showcases its LightSPEE3D 'supersonic metal printer'

SPEE3D, Melbourne, Australia, showcased its new LightSPEE3D metal Additive Manufacturing system at the recent formnext 2017 event in Frankfurt, Germany. Designed for scalable, just in time production, LightSPEE3D is said to be the world's first metal AM system utilising supersonic deposition technology to deliver manufacturing grade printing at production speeds.

Capable of building metal parts in a matter of minutes, the company's patented technology manufactures fast, low-cost and casting grade parts that are ideal for a range of commercial and industrial applications. Rather than using heat to melt metal powders, SPEE3D's patented technology uses supersonic deposition in which a rocket nozzle accelerates air up to three times the speed of sound. This delivers manufacturing grade metal and high-density parts at speeds that are claimed to be 100 to 1,000 times faster than traditional metal AM technologies.

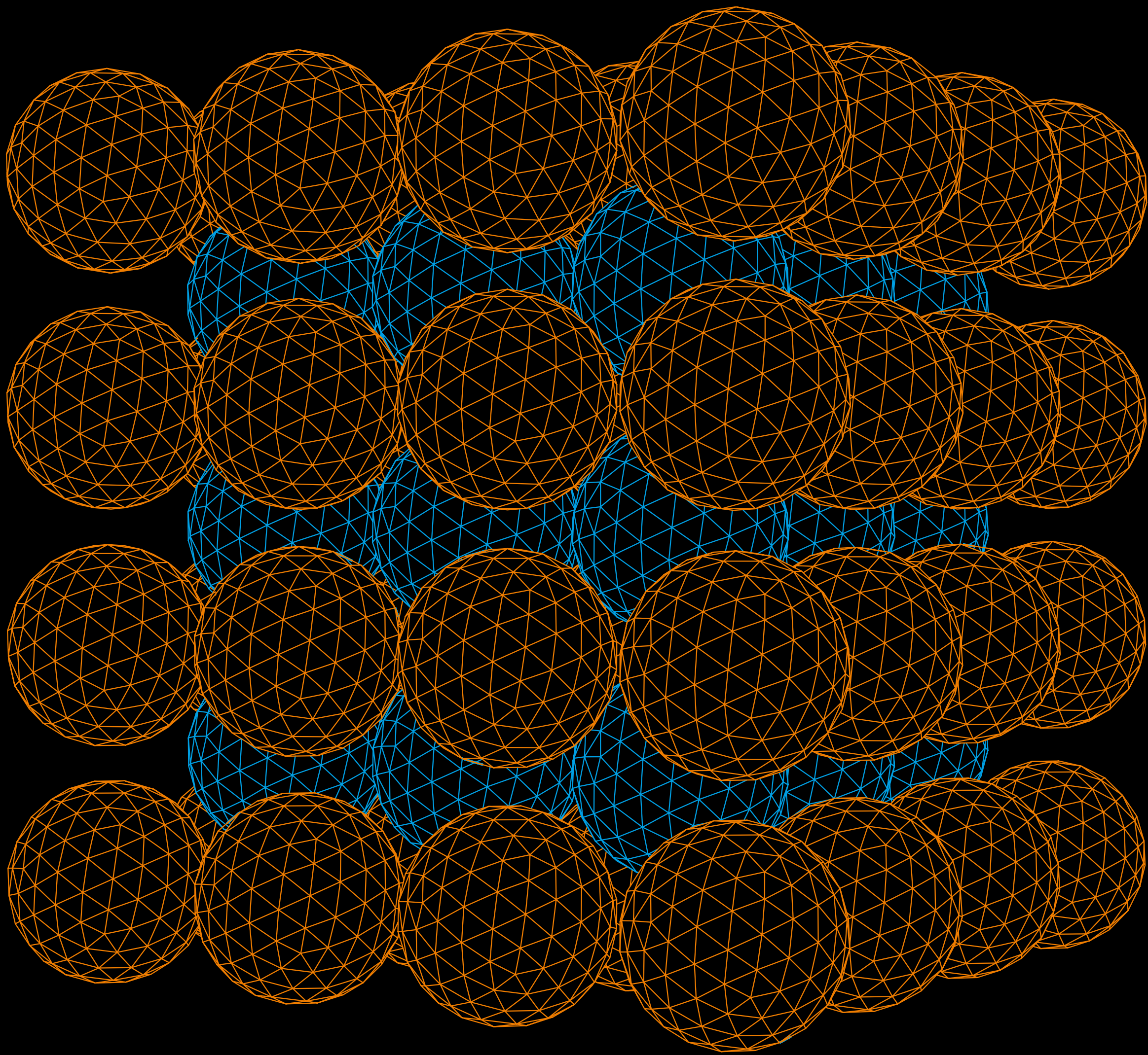
"SPEE3D was started after I experienced the slow pace and lack of rigor in the high cost, traditional metal 3D printing industry," stated Byron Kennedy, Chief Executive Officer and Co-Founder of SPEE3D. "In the past, users had to wait hours or even days to have a standard part delivered to them. Now, SPEE3D can print these same parts in mere minutes, on-site and in real time. This enables the accessibility of just in time production – allowing manufacturers the choice and flexibility of printing 10,000 parts or just a single part with ease."

A LightSPEE3D system is currently installed at Charles Darwin University (CDU) where the institution is researching new applications for the technology. "Being the first organisation to install and run SPEE3D's technology positions Charles Darwin University at the forefront of advanced manufacturing," stated Rebecca Murray, Director of the Advanced Manufacturing Alliance (AMA) at CDU.

Following the formnext exhibition in Frankfurt, the display system was installed at a local technical college, Ludwig-Geissler-Schule (LGS), in Hanau, Germany. The installation will give potential customers in Europe the option to visit, see and test the LightSPEE3D printer. Customers will have the chance to print their own parts for ongoing validation of the printing process and to get a better understanding of the options the printer can offer.

www.spee3d.com

SPEE3D utilises a high speed six axis robot in its metal AM system



Norsk Titanium opens 'world's largest additive titanium factory' in New York

Norsk Titanium US Inc has opened what is reported to be the world's largest facility dedicated to titanium metal Additive Manufacturing. Located in Plattsburgh, New York, USA, the company's Plattsburgh Development and Qualification Center (PDQC) currently houses nine of Norsk's proprietary Rapid Plasma Deposition™ (RPD) titanium AM machines and will produce components for Boeing and other aerospace manufacturers.

In early 2017, Norsk, in commercial agreement with Spirit AeroSystems, Kansas, USA, announced that it had received its first production order from Boeing Commercial Airplanes for the manufacture of AM structural titanium components for the 787 Dreamliner.

Commenting at the PDQC opening ceremony, John Pilla, Senior Vice President and Chief Technology Officer at Spirit AeroSystems, stated, "Spirit is very pleased to be standing alongside Norsk for this very critical milestone in our partnership. Spirit builds thousands of parts every day, and now with this new RPD facility, we will be able to deliver more cost-effective solutions with the highest possible quality to our customers. Spirit will be looking for opportunities to use this new technology and this state-of-the-art facility to deliver world-class aerostructures."

Norsk recently announced a planned 60% expansion of the PDQC facility, targeting an additional 100 new jobs by the end of this year, 250 by the end of 2018, and 400 in 2019. "Growth has been a consistent theme for Norsk Titanium, and today was no exception," stated Warren Boley, President and CEO of Norsk Titanium.

www.norsktitanium.com

FDA issues statement on Additive Manufacturing for medical applications

The US Food and Drug Administration (FDA) has issued a statement concerning the Additive Manufacturing of medical products and devices. In the statement, FDA Commissioner Scott Gottlieb, M.D., commented on recent developments in medical AM and announced the introduction of new guidelines for manufacturers of medical devices using additive technologies.

The agency is reported to be the first in the world to provide a comprehensive technical framework specifically for medical AM. In his statement, Gottlieb said the FDA was "preparing for a significant wave of new technologies that are nearly certain to transform medical practice." The FDA was said to be working to provide a more comprehensive regulatory pathway in order to keep up-to-date with new advances and facilitate "efficient access to safe and effective innovations that are based on these technologies."

According to Gottlieb, the FDA has now reviewed more than one-hundred AM medical devices currently on the market, citing as examples "knee replacements and implants designed to fit like a missing puzzle piece into a patient's skull for facial reconstruction." He stated that the FDA now operates its own state-of-the-art Additive Manufacturing facilities for regulatory purposes, with engineers at the agency's Center for Devices and Radiological Health (CDRH) now using AM to investigate the effects of redesigning devices for AM on their safety and performance and determine how iterative changes alter a device's fit and functionality. "This research helps inform us as regulators to help us understand the policy framework necessary to ensure the quality and safety of 3D printed products," he continued.

The FDA's new guidance aims to advise device manufacturers on technical aspects of AM and clarifies the FDA's recommendations for the submission of additively manufactured medical devices for review. "It includes our thinking on various approaches to 3D printing, including device design, testing of products for function and durability, and quality system requirements," Gottlieb explained.

"Overall, it will help manufacturers bring their innovations to market more efficiently by providing a transparent process for future submissions and making sure our regulatory approach is properly tailored to the unique opportunities and challenges posed by this promising new technology."

However, the FDA was quick to clarify that it expects this technical guidance to be updated as AM technology continues to evolve. "We are already seeing the beginning of this evolution as hospitals and academic centres use their own 3D printers to create innovative dental implants, replacement knee joints and experimental heart valves and bone implants for use in clinical studies," Gottlieb stated.

"We're working to establish a regulatory framework for how we plan to apply existing laws and regulations that govern device manufacturing to non-traditional manufacturers like medical facilities and academic institutions," he concluded. "3D printing is certain to alter the daily practice of medicine where patients will be treated with medical products manufactured specifically for them. The FDA has an important mission to help advance these efforts while also protecting patients who depend on medical products to be safe and effective."

The FDA's 'Technical Considerations for Additive Manufactured Medical Devices' is available to download via the agency website.

www.fda.gov

Heraeus doubles its portfolio of high-tech metals for new industrial applications in Additive Manufacturing

German technology group Heraeus is reported to have nearly doubled its portfolio of special alloys and high-value metals to around 20 metal powders in the last year. The portfolio includes amorphous metals (metallic glasses), precious metals (sterling silver, red gold, and iridium), refractory metals with high melting points such as molybdenum, niobium, and tantalum, and a wide variety of metal alloys.

The preparation of refractory metals for Additive Manufacturing, in particular, is said to be completely new territory for metal-printing technology, as these materials require high temperatures of up to 2500°C. Heraeus develops, supplies, and qualifies appropriate powders for layer-by-layer construction of components for industrial manufacturing. Materials and process expertise are crucial in this regard, as the metal powders and printing process must be perfectly aligned.

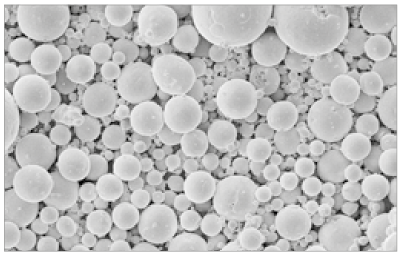
Heraeus also makes it possible to create complex shapes from amorphous metals. Also known as metallic glasses, this innovative class of materials is suitable for an unusually large number of high-tech applications. Amorphous metals are shock-absorbing and scratch-proof while still having very good spring characteristics – making them attractive for injection nozzle diaphragms, cases for consumer electronics, and dome tweeters for speakers, among other things.

Broad variety of industrial applications for metallic powders

The diverse applications range from lightweight end plates for Formula Student race cars, additively manufactured from heat-treatable cast aluminium alloys, to the resource-conserving production of platinum-alloy control nozzles for satellites.

Current Heraeus collaborations include the 3i Print Project, which demonstrates the full potential of industrial 3D printing for the automobile industry, through the example of the front-end structure of an old VW Caddy.

In another project, with the Moog company, hydraulic control blocks for robot applications (such as salvage robots) are produced with Additive Manufacturing techniques. Heraeus supplied and qualified the high-strength aluminium alloy Scalmalloy® for the production of the components.



Heraeus metal powders for AM are atomized crucible-free in a EIGA (electrode induction melting gas atomisation) process and meet all necessary quality requirements

"In the marketing of high-quality powders, Heraeus focuses primarily on the aerospace, automobile, and medical technology industries, while also covering the area that we call 'industrial applications,'" stated Tobias Caspari, head of Heraeus Additive Manufacturing.

"In the future, 3D printing will be the process of choice for many areas of technology. In the aerospace and automobile areas, Additive Manufacturing makes weight savings possible that are not achievable through traditional manufacturing. It is possible to manufacture much lighter and yet stable functional parts with completely new design possibilities. At the same time, we are conserving resources and can recycle excess powder."

www.heraeus.com

Titanium Generation joint venture focuses on titanium processing

Germany's MUT Advanced Heating GmbH and Element 22 GmbH have established Titanium Generation GmbH (TiGen), a joint venture focusing on heat treatment and thermal debinding & sintering for titanium powder processes, such as metal Additive Manufacturing and Metal Injection Moulding.

TiGen will offer its customers equipment for the heat treating, debinding and sintering of AM and MIM titanium components. In addition to equipment, the company will offer engineering support for the development of sintering profiles and settings for titanium products, as well as general engineering support and peripheral devices where required.

Under the joint venture, MUT will utilise its experience as a producer of equipment for thermal debinding & sintering and heat treatment for metals such as titanium, while Element 22 offers thirty years' experience in titanium Powder Metallurgy.

The equipment and engineering solutions offered by TiGen have been developed by MUT and Element 22 with a focus on efficient production with low operational costs. According to TiGen, these solutions also make it possible to achieve superior material properties.

Some of the titanium MIM and AM components made using TiGen furnaces are reportedly in use in medical devices and implants, on commercial aeroplanes and in other components produced at high volumes.

www.mut-jena.de
www.element22.de


ADDITIVE MANUFAC
CNC
EOS M 400-4

Ansys acquires AM simulation company 3DSIM

Engineering simulation software company Ansys, Pennsylvania, USA, has acquired 3DSIM, Utah, USA, a developer of Additive Manufacturing simulation technology. The acquisition of 3DSIM will give Ansys what it states is the industry's only complete AM simulation workflow.

Software for AM simulation offers users the ability to achieve their objectives through simulation-driven innovation rather than physical trial and error. According to 3DSIM, its customers include aerospace and automotive OEMs, parts manufacturers, metal Additive Manufacturing machine producers and leading research labs.

The company's products include ExaSIM, aimed specifically at machine operators and designers for additively manufactured parts. ExaSIM enables the prediction of key features of a build, such as identifying and addressing residual stress, distortion and build failure, and part tolerances and therefore avoid failed builds without costly physical experimentation.

3DSIM also produces Flex, which enables engineers, analysts and researchers to identify the best process parameters for a particular Additive Manufacturing machine and material combination. This enables users to prodict part microstructure and other properties before building, for enhanced part integrity.

"Additive Manufacturing is changing the way companies are bringing products to market, and 3DSIM is helping to lead the way through its innovative solutions," stated Shane Emswiler, Ansys Vice President and General Manager. "By bringing ExaSIM and Flex onto our Workbench platform, Ansys can offer customers the only end-to-end Additive Manufacturing simulation workflow available. That will spark innovation, speed time to market and reduce manufacturing costs for our customers across industries."

"We are excited to become part of the Ansys family with its nearly fifty-year history of helping customers realize their product promise," added Brent Stucker, 3DSIM CEO. "Combining 3DSIM's leading Additive Manufacturing technology with Ansys engineering simulation solutions will be a win-win for our customers and the entire industry."

www.ansys.com
www.3dsim.com

Markforged raises $30 million funding from Microsoft Ventures, Siemens and Porsche

Markforged, based in Cambridge, Massachusetts, USA, has announced that it has completed a $30 million Series C round of funding. next47, the Siemens-backed venture firm, led the round, with Microsoft Ventures and Porsche Automobil Holding SE also making significant investments. The new investors join existing investors Matrix, Northbridge and Trinity.

Markforged claims to be the only company to offer 3D printers that print the complete range of materials, including plastic, carbon fibre, and metal coupled with a cloud-connected software platform.

"Markforged is making 3D printing simple, repeatable, and fast," stated Lak Ananth, Managing Partner at Siemens next47, who will also be joining the Markforged board. "This has far reaching implications for our target industries, from automotive and aerospace to healthcare and energy. We see customers embedding Markforged into their product development and production processes, tremendously improving speed to market and addressing new opportunities in their industries."

"As cloud services shorten development cycles for software engineers, so too is 3D printing accelerating innovation in the physical world," added Matthew Goldstein, partner, Microsoft Ventures. "Markforged's full-stack offering and innovative materials are game-changing for 3D printing, opening up incredible new opportunities for mechanical engineers."

"Start-ups are an important source of innovations. In order to advance and capitalise on such innovations we have to invest in technologies at an early stage," said Philipp von Hagen, member of the executive board of Porsche Automobil Holding SE, responsible for investment management. "Our investment in Markforged is a perfect example of this approach. Its additive manufacturing technology has the potential to massively change different segments along the automotive value chain."

Markforged has reportedly raised a total of $57 million to date and achieved profitability in Q2 of 2017 having grown revenues by 300%.

www.markforged.com

Rheinmetall Automotive launches Solidteq start-up for metal AM

German-based auto-industry supplier Rheinmetell Automotive AG's metal Additive Manufacturing spin-off is reportedly entering the market under the new name of Solidteq GmbH. Under its new title, the company will also offer its expertise to third-party customers, in particular from the automotive and mechanical engineering sectors.

Rheinmetall Automotive, through its subsidiary Pierburg, has specialised in Selective Laser Melting (SLM) for six years during which it states that it has accumulated experience of over 66,000 operating hours. Last year, the company launched Solidteq as a start-up to enable it to market its products to external customers.

This year, Solidteq commissioned the installation of further SLM units at its facility in Neuss, Germany, in order to address the rising demand for its Additive Manufacturing services. The company offers support across the four project phases from planning, to the development of a 3D model, to the Additive Manufacturing and finishing of work pieces. Materials offered by the company include aluminium, stainless steel and tool steel.

Solidteq has numerous SLM units at its facility in Neuss, Germany

Thomas Bartels, CEO at Solidteq GmbH, stated, "Above all we would like to get across to potential customers the design latitude, time savings and cost reductions resulting from additive production in this key technology. We see ourselves as a pioneer and driver of this innovative printing technology which can be used profitably above all in the automotive sector besides other industries."

"Our profound know-how has grown over years of practical experience," he continued. "It is very important for us to be able to advise and accompany our customers in such a way that they can cope swiftly and readily with potential design obstacles."

www.rheinmetall-automotive.com

www.solidteq.com

PyroGenesis signs NDA with Rolls-Royce for AM powders

PyroGenesis Canada Inc., a manufacturer of plasma atomised metal powders, has announced today that it has signed a non-disclosure agreement with the UK's Rolls-Royce plc. The purpose of the NDA is to encompass the evaluation and discussion of business opportunities, including proposal or offer generation, submission and evaluation, for the provision of providing powders to Rolls-Royce.

"We are very happy to be in discussions with Rolls-Royce and look forward, now that the NDA has been signed, to have more substantive discussions on the production of powder for Rolls-Royce," stated P Peter Pascali, President and CEO of PyroGenesis. "I must caution readers however, not to draw any premature conclusions from this announcement. Though it does signal the interest in our product, and that the interest comes from a very discerning, demanding, and sophisticated party, we are still at the very preliminary stages and there is no guarantee that anything, of any commercial value, will materialise form these efforts."

PyroGenesis is the inventor of plasma atomisation, a plasma-based process that produces small, spherical, metal powders for the Additive Manufacturing industry.

www.pyrogenesis.com

SLM Solutions partners with Rosswag and Cronimet to develop steel alloys for high temperature applications

SLM Solutions Group AG, Lübeck, Germany, has agreed a new partnership with Rosswag GmbH and Cronimet Holding GmbH to jointly develop special and high-performance alloys for Additive Manufacturing. In particular, the partners aim to develop steel alloys for high-temperature applications.

Rosswag GmbH brings to the partnership more than one hundred years' metal materials handling experience. The company employs more than two hundred and is reported to be South Germany's largest open-die forge. Cronimet Group states that it is a specialist in stainless steel scrap, superalloys, ferroalloys and primary metals, and has been supplying raw materials to the manufacturing industry since 1980. The company employs approximately 5,400 staff at sixty-one locations globally.

Uwe Bögershausen, Management Board member of SLM Solutions Group AG, stated, "We're very pleased to announce this partnership with Rosswag and Cronimet. Both companies are proven specialists in their respective areas. This partnership supports us on our continued path to becoming an integrated solution provider in the field of Additive Manufacturing."

According to the partners, Rosswag will take over production and optimisation of the jointly developed metal powders, while Cronimet will supply the processed raw materials for atomisation from its Cronifond product line. SLM Solutions will offer its Additive Manufacturing experience to the development process and subsequently assume responsibility for the exclusive distribution of the metal powders developed.

"We decided in favour of this close collaboration with SLM Solutions – ranking as a market-leading solutions provider in the Additive Manufacturing area – as they supplement our process expertise, and understand users' requirements," added Dr.-Ing. Sven Donisi, CEO of Rosswag GmbH.

Gregor Zenkner, Business Development Manager at Cronimet Holding GmbH, added, "SLM Solutions also has the right network and dedicated capacities to distribute the developed and produced metal powders in large volumes on a targeted basis."

www.slm-solutions.com
www.rosswag-engineering.com
www.cronimet.de

Concept Laser breaks ground on new AM centre

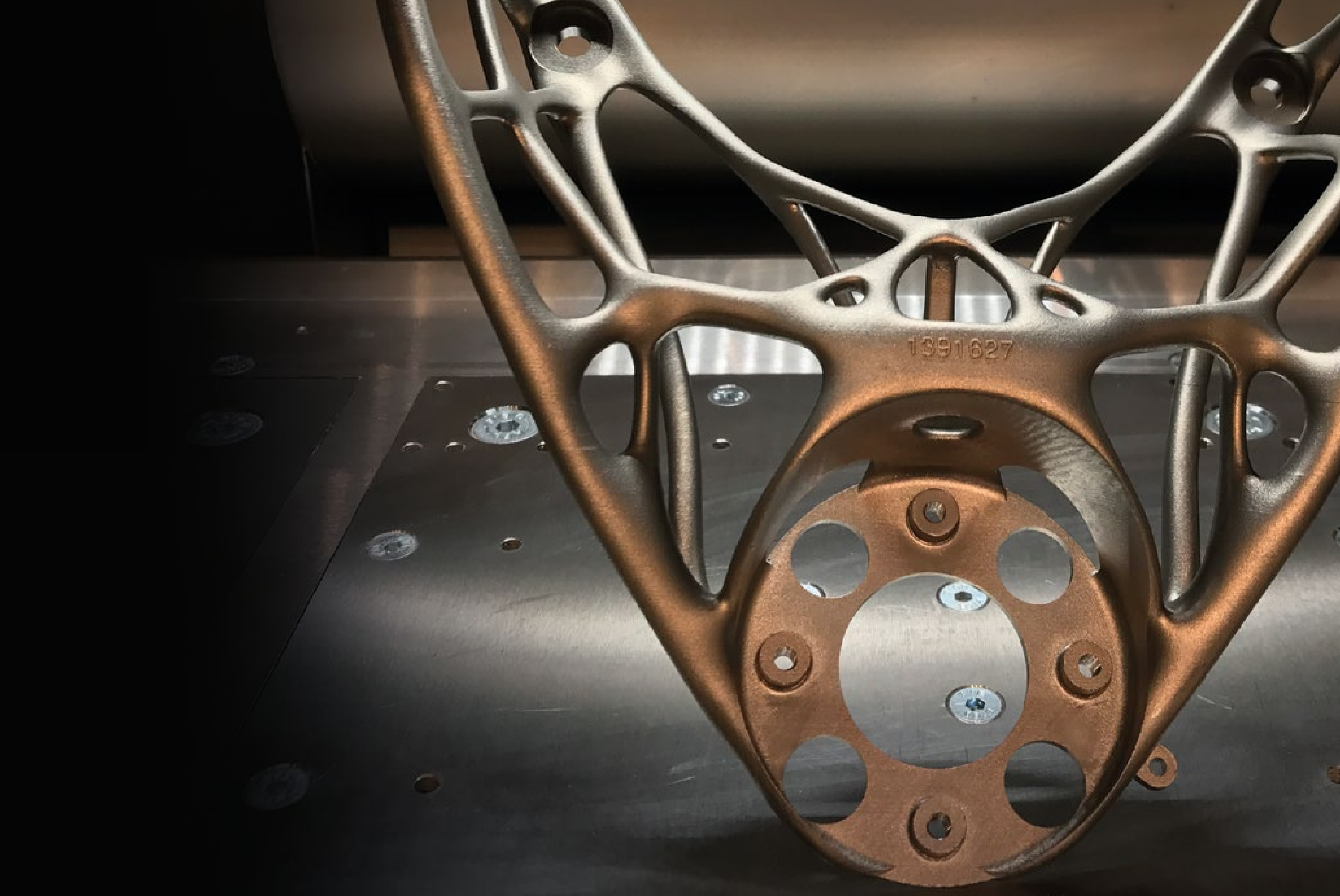
GE and Concept Laser have broken ground on a new '3D Campus' in Lichtenfels, Germany (Courtesy GE)

GE and Concept Laser have broken ground on a new '3D Campus' in Lichtenfels, Germany. According to the companies, the 3D Campus will unite research and development along with production, service, and logistics. The new offices are expected to be ready for move-in in early 2019, and will offer 40,000 m^2 of working space for about 500 employees.

Future machine production capacity is expected to be four times higher than today, making Concept Laser's Lichtenfels facility a global GE centre for the production of metal Additive Manufacturing systems. It was stated that around €105 million will be invested into the location. The 3D Campus is expected to accommodate the strong growth of Concept Laser in recent years and make room for further expansions. Frank Herzog Founder and Chairman & CEO of Concept Laser, stated, "We are not only laying the foundation for a new facility, but also creating skilled jobs in the region. Lichtenfels will become a global beacon for industrial 3D printing as the new GE centre".

Ilse Aigner, Bavarian Minister of Economic Affairs and Media, Energy, and Technology, commented during the groundbreaking, "The 3D Campus will create a centre for 3D metal printing that offers real added value for the whole of Bavaria. 3D printing is becoming more prevalent in almost all sectors because it allows lighter, more variable and more stable components to be produced using fewer resources."

www.ge.com/additive
www.concept-laser.de



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Titomic granted US patent for cold-spray titanium Additive Manufacturing

Titomic Limited, Melbourne, Australia, has been granted a US patent for the metal Additive Manufacturing process it uses, known as Titomic Kinetic Fusion (TKF). The process involves the cold-gas dynamic spraying of titanium or titanium alloy particles onto a scaffold to produce a load-bearing structure.

The US patent, titled 'A process for producing a titanium load-bearing structure', is expected to provide the company with the foundation to expand its reach into the USA. Jeff Lang, Titomic CEO, commented, "This US application has been pending since March 2013, so to date we've only slowly progressed any discussions with potential major US customers until our intellectual property was protected. We're excited that this patent has now been granted in the US, enabling us to advance our initial discussions with potential US customers in what is one of the largest Additive Manufacturing markets in the world," he concluded.

The cold-gas dynamic spraying of titanium or titanium alloy particles onto scaffolds to produce load-bearing structures is a proprietary process of the Commonwealth Scientific and Industrial Research Organisation's (CSIRO), which Titomic has exclusive rights to commercialise as part of its TKF offering.

Titomic states that the new process is able to use powders costing approximately one fifth to one tenth that of traditional AM powders, resulting in components up to 50% cheaper, and that it can produce large scale parts thirty times faster than other metal Additive Manufacturing processes. The company has already secured patents for the technology in Japan and New Zealand, with patent pending approval in Australia, China, Europe, Hong Kong and South Korea.

A new Titomic facility is scheduled to open in December 2017, with production trials beginning in the first quarter of 2018. The Melbourne-based site will house a TKF system with a 40.5 m^3 build area, reportedly making it the largest Additive Manufacturing machine in the world.

www.titomic.com

BeamIT opens Additive Manufacturing Competence Centre

BeamIT SpA, Fornovo Taro, Italy, has opened a new Additive Manufacturing Competence Centre (AMCC). The specialised technology centre will aim to support its customers as they explore the field of metal AM.

Mauro Antolotti, BeamIT's President, stated, "Customers from different industrial sectors are asking BeamIT to assist them in growing this technology knowledge and support them in new products development."

"We grant OEMs, AM system manufacturers, powder producers, research centres and universities our support with a complete training for design engineers, mechanical engineers and systems operators in order to achieve a significant result in terms of manufacturing cost reduction by creating customised business cases," he concluded.

According to the company, AMCC's staff will offer customers their support to develop and put into practice reliable, repeatable and affordable processes and competences in AM, including processes such as heat treatment, Hot Isostatic Pressing, surface finishing and machining.

Founded in 1997, BeamIT supplies components produced using metal Additive Manufacturing to the biomedical, motorsports, aeronautical and aerospace, and energy industries, as well as developing, studying and qualifying metallic materials.

www.beam-it.eu

Titanium Beta 21S powder from GKN Additive

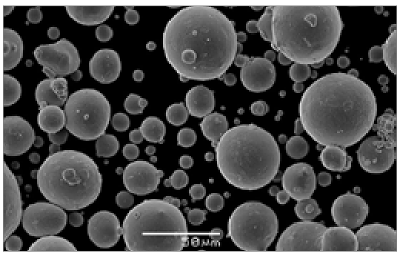
GKN Hoeganaes Specialty Metal Powders, the advanced materials division of GKN Additive, has added AncorTi™ Beta 21S to its portfolio of AncorAM™ powders for metal Additive Manufacturing. Beta 21S titanium (UNS R58210) is a high strength, heat treatable, metastable beta titanium alloy.

It is designed to improve resistance to oxidation and creep, as well as offering enhanced strength and stability in elevated temperatures. According to GKN Hoeganaes, these properties make the alloy a perfect candidate for the manufacturing of parts for aerospace, medical, chemical and marine applications. AncorTi Beta 21S is available in particle sizes optimised for Electron Beam Melting (EBM) and Selective Laser Melting (SLM) AM machines.

AncorAM metal powders are produced on full production scale processing equipment and engineered with alloy chemistry and powder characteristics specifically designed for AM, focusing on final product consistency. AncorTi Beta 21S joins AncorTi CP and AncorTi 6Al4V, as well as a number of nickel and ferrous based powders in the AncorAM product line.

GKN Additive stated that it will continue to develop new powder alloys for AM, including advanced titanium powders, specialised nickel-based alloys, and nickel-titanium powders engineered for use in advanced medical devices.

www.gkngroup.com/hoeganaes



Beta 21S titanium (UNS R58210) is a high strength, heat treatable, metastable beta titanium alloy

Additive Industries and SMS group team up for industrial AM serial production

Handshake after signing of the cooperation. From right to left: Guido Kleinschmidt (Member of the Managing Board of SMS group); Norbert Gober (Vice President Research and Development, SMS group); Daan A J Kersten (CEO, Additive Industries); Markus Hüllen (Vice President 3D Competence Center, SMS group) and Bernhard Steenken (Corporate Development, SMS group)

Additive Industries and SMS group have announced the joining of forces to develop and market a production system that will enable manufacturing companies break through into industrial scale serial production of metal AM components. The two companies will bring together their specialist knowledge of the manufacture of metal powders and Additive Manufacturing systems. The production concept will not just encompass powder manufacturing and AM, but include other stages right up to delivery of the finished component.

"The entire process is designed for maximum productivity, with the result that Additive Manufacturing can finally enjoy competitive success in serial production," stated Guido Kleinschmidt, Member of the Managing Board of SMS group.

"As one of the world's leading machine and plant builders for the metallurgical industry, we have extensive design know-how and process engineering expertise in the field of vacuum melting plants. We are now transferring this expertise to powder production plants," added Norbert Gober, Vice President Research and Development at SMS group.

The process starting point is the manufacture of powder. To ensure maximum purity, the alloys are induction-melted under vacuum in the crucible. The liquid metal is atomised using pure argon in an oxygen-free atmosphere. "The quality of the powder manufactured is crucial for the quality of the finished product. To enable us to make faster progress in powder production, we are building an industrial-scale pilot system, which is scheduled to go live at the end of the year," stated Markus Hüllen, Vice President 3D Competence Center at SMS group.

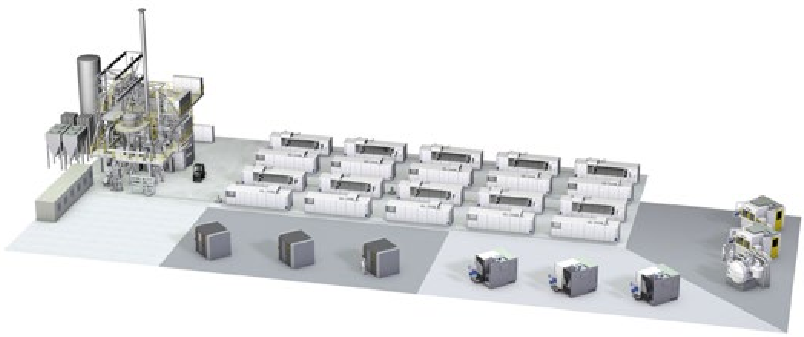
The powder manufacturing process is followed directly by Additive Manufacturing. In the integrated MetalFAB1 system, the metal powder bed fusion process is applied to melt the powder in a reproducible and efficient way. After additively manufacturing the parts, the build plate with parts is automatically transported to the heat treatment furnace for a stress relief cycle before storage by a robot. The MetalFAB1 system is designed to run autonomously 24/7 without the need for multiple shifts, substantially reducing cost.

SMS group is also responsible for the heat treatment of the printed components for setting of improved material characteristics. Within the group, SMS Elotherm is the company with the induction heat treatment expertise, and one of the markets it supplies these machines to is the automotive industry. After the components have been machined and undergone quality control checks, they are ready to be shipped.

The first visible sign of this collaboration will be the Democenter, which is to be set up at SMS's facility in Mönchengladbach, Germany, in the next few months. Additive Industries will supply a MetalFAB1 printer, on which the powder produced by the plant is processed, and this will be installed right next to the pilot unit to work fully integrated.

"This Democenter will allow us to align the powder plant with its process guidance system perfectly with the printer and its parameters. We will then be able to apply this practical experience on an industrial scale and offer this as a turnkey solution to high-end users," added Gober.

www.additiveindustries.com
www.SMS-group.com



Plant concept of SMS group and Additive Industries for industrial Additive Manufacturing serial production

Formalloy releases new L-series Additive Manufacturing machine

Formalloy's Laser Metal Deposition technology is suitable for use in a number of industries

Additive Manufacturing company Formalloy, LLC, San Diego, California, USA, has released its L-222 Laser Metal Deposition machine, which includes an inert gas build chamber, scientific monitoring capability and the latest Blue Laser technology.

The new machine's Blue Laser technology is from Nuburu Inc., Denver, Colorado, USA, and can reportedly be used to additively manufacture, repair and clad metallic parts more quickly and accurately than comparable processes. Formalloy is the said to be first company to perform Laser Metal Deposition with the new Blue Laser technology.

Compared to industry-standard IR wavelengths, Blue Laser absorption is said to be 3-20 times better, resulting in process speed gains of around 2-10 times. Blue Lasers enable material processing capabilities which would either not be possible or produce low yields with IR. In addition, the 'spot size' of the laser is over 5 times smaller than IR, enabling greater precision, resolution and higher finish quality.

Formalloy's Laser Metal Deposition technology is suitable for use in a number of industries including aerospace, oilfield, defence, automotive, chemical and heavy industry. Its L-series machines can be used with titanium, Inconel, stainless steels and other metals.

www.formalloy.com
www.nuburu.net

Chinese hospital implants additively manufactured tantalum knee joint

A hospital in Chongqing municipality, China, has become what is believed to be the first in the world to perform a 'knee revision' surgery using a metal additively manufactured joint, reports *China Global Television Network*. In the surgery, an eighty-four year old man with severe arthritis had large sections of the bones in his knee replaced with tantalum implants.

With the incidence of arthritis among people aged 50-59 now at 62%, the hospital stated that it performs roughly four-hundred knee replacement surgeries annually. However, in conventional knee replacement surgery, bone defects can occur around the joint due to post-operative infections.

In addition, the shape of bone defects varies greatly from person to person; using 'off-the-shelf' implants, surgeons are required to take time during the surgery to shape the implant to match the patient. As a result, hospitals have for some time recognised the potential of additively manufactured knee replacements – which allow implants to be custom-shaped to the recipient – with polymer versions having been implanted successfully in the past.

This marks the first knee replacement surgery using a joint produced by metal AM. Tantalum is typically used in dental and surgical implants; for this implant, porous tantalum was used, to allow future bone in-growth.

An AM tantalum implant was used to fill defects in an 84 year old man's knee (Courtesy China Global Television Network)

According to the hospital surgeons, the patient regained mobility a day after receiving the tantalum implant and was expected to be discharged from the hospital in just four to five days. ■■■

GE Additive opens $15 million international Customer Experience Center in Munich

GE Additive has opened its first international Customer Experience Center in Munich, Germany. The 2,700 m² facility, co-located with GE's European Technology Center, is designed to enable customers to accelerate their adoption of AM by learning about the entire Additive Manufacturing process, from design to prototyping to operations. The opening of the centre was attended by Mohammad Ehteshami, Vice President & General Manager of GE Additive, as well as figures from business, politics, technology and academia.

The centre was launched with an investment of $15 million and will employ up to fifty staff, including technicians and engineers specialising in additive design and production. Ten AM systems from Germany's Concept Laser and Sweden's Arcam EBM have been installed at the centre which also offers an educational facility for its Additive Academy - GE Additive's customer training team.

The Customer Experience Center will provide GE Additive's customers:

- Machine Access: Access to use the latest metal AM systems
- AddWorks: Collaboration with GE's staff on product identification, design, material selection and additive facility setup
- Prototyping: The opportunity to build prototypes
- Low-rate initial production: The opportunity to build multiple parts and develop operations processes prior to full rate production
- Additive Academy: Training from the GE team of additive experts in all aspects of Additive Manufacturing
- Spare parts and powder: Access to GE's team who can provide field service knowledge, spares and operational support to customers

Over 150 guests came to Munich for the opening and got a chance to tour the facility after a ribbon cutting ceremony. Guests also heard from different speakers, including representatives from BMW and Oerlikon, on how they see the future of Additive Manufacturing.

"The opening of our Customer Experience Center here in Munich marks a great milestone for us," stated Robert Griggs, Customer Success Leader at GE Additive. "Germany is the global innovation hub for Additive Manufacturing. Right here, at the heart of the additive revolution, the centre will operate as the interface between customers and our teams, combining the strengths of Germany's Concept Laser and Sweden's Arcam, both leading providers of additive machines and services. We look forward to working closely with European companies and institutes, allowing them to fully realise the transformative potential that additive design and manufacturing can bring. We're excited about the types of products they will design and the improvements they can make to their operations using additive."

The Munich centre is the first of GE Additive's Customer Experience Centers outside of the US. Further GE Additive centres are planned worldwide to boost the use of Additive Manufacturing in different regions.

www.ge.com/additive

Mohammad Ehteshami, Vice President & General Manager of GE Additive (centre), opened the new Customer Experience Center

GE Additive's Customer Experience Center is co-located with GE's European Technology Center in Munich, Germany

Fraunhofer working to develop large scale SLM system

Fraunhofer Institute for Laser Technology (ILT), Aachen, Germany, has announced the development of a new, large scale SLM laboratory system with a usable build volume of 1,000 mm x 800 mm x 500 mm. The new Additive Manufacturing system highlights the institute's work on innovative strategies for exposure and shielding gas flow, allowing the manufacture of large metal components quickly and with high process reliability.

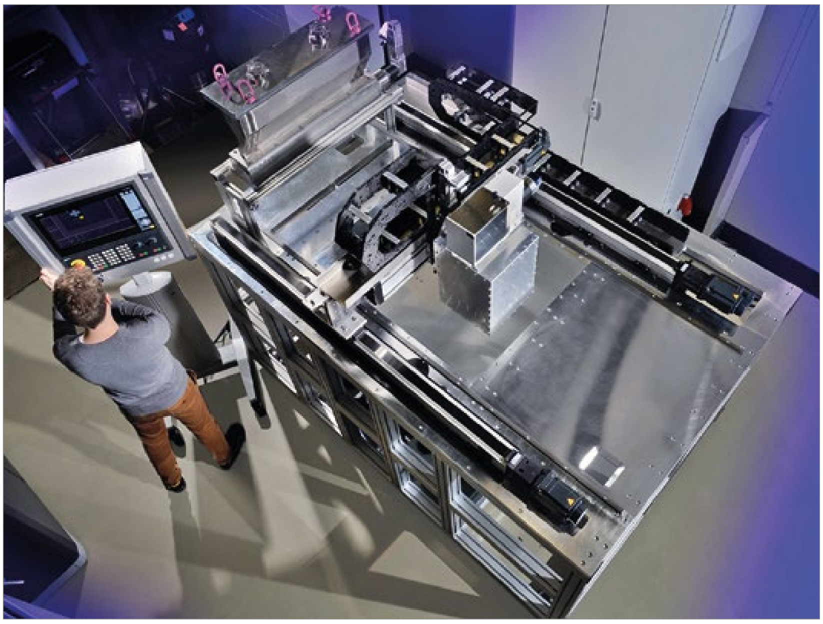
It is stated that established inert gas suction strategies are no longer effective for a very large build volume. Scientists at Fraunhofer ILT are therefore basing their approach on small, movable processing heads with a local shielding system, which ensures a constant stream of inert gas at every processing point for build volumes of any size.

Researches are reported to be testing systems with fibre lasers as well as exposure concepts with cost-effective diode lasers. In addition to research into established scanner systems with mirrors, they are also investigating a moving processing head with highly dynamic linear axes and several individually controllable diode lasers.

The advantage of this multi-spot processing is the ability to significantly and cost-effectively increase the system's build-up rate by increasing the number of beam sources. The new system concept reportedly makes it possible to increase the build volume solely by extending the travel length of the axis system, without changing the optical system.

The research findings are said to give machine manufacturers a foundation upon which to develop and build the next generation of SLM systems. "We hope that the system concept will lead to a breakthrough in the successful use of this technology in series manufacturing," stated Christian Tenbrock, scientist in the Rapid Manufacturing group. "We create process conditions that are constant and easy to control, thereby improving process robustness."

www.ilt.fraunhofer.de



Fraunhofer ILT is developing its technology for the production of large metal components (Courtesy Fraunhofer ILT)

Sintavia becomes one of the first aerospace manufacturing companies to achieve the latest AS9100 standard

Sintavia, LLC, Davie, Florida, USA, has received AS9100 Revision D certification, becoming one of the first aerospace manufacturing companies to achieve the latest AS9100 standard. By meeting these new requirements, Sintavia reports it will improve its quality system by including, among other things, risk-based thinking and maintaining organisational knowledge.

"New requirements were added to the standard," stated Doug Hedges, Sintavia's President and COO. "Some of these requirements we have always done since the beginning because they are simply good business practices. Now we are one of only a handful of aerospace companies in the world that has the new Revision D certification."

The new AS9100 wording lends itself towards methods for institutionalising and maintaining critical organisational knowledge, for which Sintavia uses Granta software. In addition to assessing risk at contract review or quoting, Sintavia also assesses process risk, corporate risk and opportunities within every process in the company.

"Although passing the audit with zero findings was a rewarding accomplishment, we will strive for continuous improvement," added Alex Bencomo, Sintavia's Quality Manager, "It's important that we stay focused on remaining the quality leader in the world of metal Additive Manufacturing."

In addtion to AS9100, Sintavia holds, ISO17025 and ANAB accreditation, as well as being OASIS and ITAR registered.

www.sintavia.com

Granutools offers metal AM process optimisation through powder characterisation

Granutools, Awans, Belgium, aims to help optimise the Additive Manufacturing process with its set of physical characterisation tools for metal powders. The tools help users understand the macroscopic behaviour of metal powders for Additive Manufacturing, and can reportedly be applied to any application which uses metal powders.

Granutools was founded in 2015 to address the industry's need for simple, precise and repeatable measurement techniques for powders. According to the company, powder properties are key to accelerating the adoption of AM in volume manufacturing. In order to obtain a thin layer in Additive Manufacturing, the powder must be as fine as possible. Unfortunately, when the grain size decreases, the cohesiveness increases and the flowability decreases. Moreover, the powder becomes more and more sensitive to moisture. Therefore, a compromise between grain size and flowability has to be found. The quality of the part's build with AM is directly related to the powder flowing properties; the flowability must be good enough to obtain homogenous successive powder layers.

For all processing methods dealing with powder, the measurement method used to characterise the powder should be as close as possible to the process. In particular, the stress state and the flow field of the powder should be comparable in the measurement cell and in the process.

To optimise the AM workflow, Granutools recommends the use of Granudrum, which assesses powder spreadability to select precursors and optimise recoater speed, Granupack, as a quality control which is related to part porosity and surface roughness, and Granucharge for powder reusability.

Granudrum works on the rotating drum measurement principle

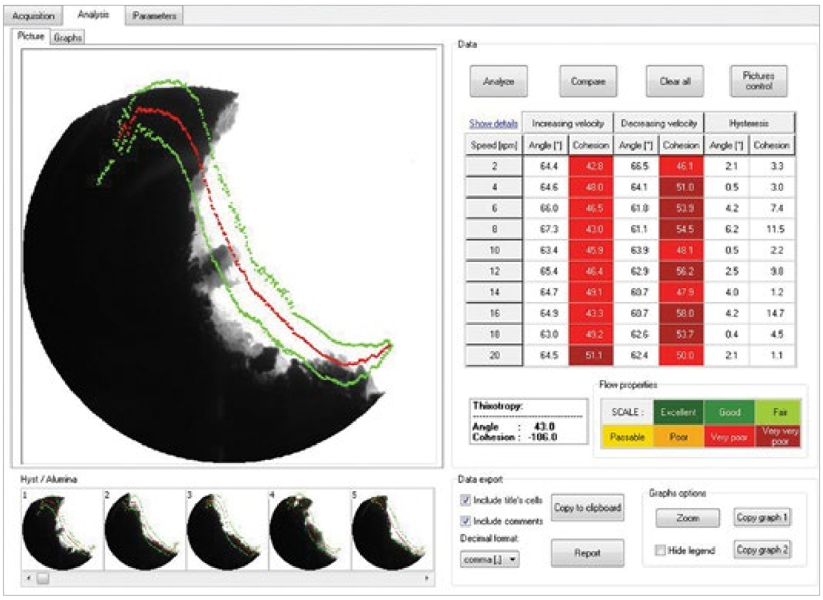
Powder flow properties

The company's Granudrum is a dynamic angle of repose analyser. The automated instrument provides quick and precise measurements of granular materials' flowing properties. It works on the rotating drum measurement principle associated with a customised image treatment algorithm, and provides cohesive index and flowing angles for different shearing rates.

In traditional flowmeters such as shear cell testers and rheometers, Granutools states that the existence of a compressive load on the powder being measured contradicts the free surface flow of powder in an AM device, meaning measurements taken using traditional methods are not relevant for AM.

The rotating drum measurement method used in the Granudrum enables the analysis of powder flow precisely at the powder/air interface, without any compressive load. In addition, the rotating drum's geometry allows users to study the natural aeration of powder during flow.

By measuring the cohesive index of a powder, users can avoid the formation of waves on the powder bed and predict optimal recoater speed to obtain a homogenous layer.



The software provides cohesive index and flowing angles for different shearing rates

Powder density

Granupack provides rapid, precise measurements on the density curve of a granular material versus the tap number. The parameters obtained from these measurements can provide information about both powder density and powder flowability.

Contrary to classical manual tapped density measurement, Granupack is said to measure powder compaction curve – powder density plotted as a function of the tap number – very precisely, thanks to

Granupack is a high resolution tapped density analyser for precursor quality control

Stefan Ritt, SVP Global Marketing of SLM Solutions (left) met with Filip Francqui, Managing Director of Granutools, during a recent visit to the facility in Awans, Belgium

measurement automation (ruling out user error) and an initialisation protocol.

From this compaction curve it is possible to analyse the optimal density, the compaction range and the compaction speed of the powder, enabling users greater control over the porosity and surface roughness of the final AM part. Due to its high accuracy and repeatability, Granutools states that this instrument is the best candidate for precursor quality control.

Electrostatic charge measurements

Granucharge is an automated instrument able to measure the build-up of electrostatic charge inside a powder while flowing on surfaces of various nature. The electric charge density of a powder is measured using a customised Faraday cup, after a controlled flow inside a vibrating V-shaped conduit. The charge time evolution is then plotted and analysed within a dedicated software.

The presence of electric charges in a powder induces cohesive forces, leading to the formation of undesirable agglomerates. Measuring the electrostatic charges created by a powder enables users to predict flowability deterioration during processing, for example during layer formation in AM, to analyse the surface state of grains for oxidation, contaminants and roughness, and to quantify the ageing of a reused powder precisely.

Process optimisation for industrial and research applications

Granutools now supports a number of industrial customers globally, in North America, Asia and throughout Europe. The company was recently visited at its factory by Stefan Ritt, SVP Global Marketing of SLM Solutions. Speaking on Granutools' technology, Ritt stated, "As manager of standardisation work groups in ASD-STAN and DIN I appreciate the work of Granutools to make equipment for standardised tests on metal powders. This will help establish standardised processes in future manufacturing."

McGill University, Canada, is involved in a research partnership with Granutools for the analysis of the dynamic behaviours of aluminium, titanium and superalloy powders. Professor Mathieu Brochu, head of the university's P2AM2lab, stated, "Both Granutools and McGill are developing key knowledge in this field and pushing further the advances on powder optimisation for AM application. Our Granudrum is the first one in Canada, and is having traction with national and international key players in the AM field."

ENGIE Laborelec has selected Granupack and Granudrum to complement the capabilities of the ENGIE Powder Lab, which aims at characterising metal powders and fostering prequalification activities of material feedstock for powder bed fusion processes. "Granudrum and Granupack provide a quick and automated solution to deliver accurate data on powder rheology for a better understanding of flowability and spreadability behaviour that metal powders can encounter during shipment, storage, or powder delivery and spreading during powder bed fusion processing," stated Steve Nardone, Project Manager Metal Additive Manufacturing.

The SIRRIS research centre in Belgium also uses Granutools instruments. Olivier Rigo, Senior Engineer Additive Manufacturing, added, "We are now implementing the use of these instruments in our Additive Manufacturing lab for periodic quality testing in order to detect quality drifts throughout the AM process steps. We have chosen Granutools for both the precision and repeatability of their instruments, and the applicability of their technology for AM."

www.granutools.com

VTT offers Powder Piloting Service for powder-based materials and components

VTT Technical Research Centre of Finland Ltd (VTT), Tampere, Finland, a facility specialising in powder-based materials technology, now offers a Powder Piloting Service for the design and pilot scale processing of powder-based materials and components.

The service provides users with an easy way to check the feasibility of ideas and innovations in a confidential setting, without large investments in machinery, and covers the whole production chain from raw material synthesis to component performance testing.

VTT claims to be one of the leading research and technology organisations in Europe and has a national mandate in Finland. The centre serves clients in the private and public sectors, both domestically and internationally, and has over 75 years' experience supporting client growth with top-level research and science-based results.

The organisation's Powder Piloting Service is focused on the key areas of:

Coatings

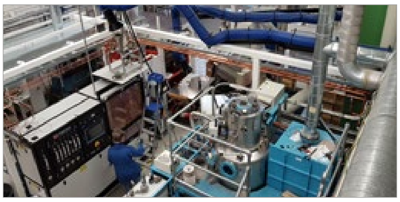
- Cost efficient solutions against wear, corrosion and high temperatures
- Tailoring of material properties to fulfil performance criteria for harsh operating environments

Components

- High-performance components using cost-efficient and sustainable manufacturing
- Tailoring of components to meet high demands and standards

Powder-based additives

- Graded or locally reinforced structures
- Structures with added functionality such as integrated catalytic or electro-magnetic properties



VTT Technical Research Centre of Finland is offers tailored PM material compositions for extreme applications with its new Powder Piloting Service (Courtesy VTT)

Circular economy

- Alternative raw materials based solutions
- The utilisation of secondary materials and industrial side-streams

Pilot facilities are available at almost all levels of powder manufacturing, consolidation, post-treatments and characterisation, from gas atomisation and plasma spheroidisation to heat and surface treatments. VTT's equipment includes Additive Manufacturing, Hot Isostatic Pressing (HIP) and Powder Injection Moulding machinery.

www.vtt.fi/powder

Registration opens for AMUG's 30th Education & Training Conference

Registration is now open for the Additive Manufacturing Users Group (AMUG)'s 2018 Education & Training Conference, to be held in St. Louis, Missouri, USA, from April 8–12, 2018. This will mark the 30th year of the conference, which is open to owners and operators of industrial Additive Manufacturing technologies used for professional purposes.

The conference brings together engineers, designers, technicians, supervisors, plant managers and educators from around the world to share AM expertise, best practices, challenges and application developments. Paul Bates, AMUG president, stated, "It is my pleasure and honour to lead AMUG in the milestone year of its 30th anniversary."

"Way back in 1987, our organisation hosted its first conference. It was a small gathering of early adopters of rapid prototyping, which we now call Additive Manufacturing," he continued. "Over the past thirty years, the technology has become mainstream, the options have expanded and the applications have progressed beyond simple models. More individuals are doing more with the technology, often in surprising ways."

The AMUG Conference includes technical sessions and hands-on workshops designed to help users get more from AM. Through its Innovators Award, Technical Competition and Awards Banquet, AMUG also recognises excellence in applying AM and contributions to the industry. The five-day event also includes the two-night AMUGexpo, networking receptions and catered meals.

The conference agenda is expected to comprise more than two-hundred presentations and hands-on workshops. The 2018 conference will also host the fourth annual Innovators Showcase, with Wilfried Vancraen, Founder and CEO of Materialise, sharing his experiences and insights in innovating for AM in an on-stage interview.

"It is the mission of AMUG to help our members understand how they can do more with the available AM technologies," Bates concluded. Attendees can register for a discounted early-bird rate until January 13, 2018 – registration includes entry to the conference, AMUGexpo and all keynote presentations, general and technical sessions, workshops and networking lunches, as well as entry to all workshops, the AMUG Awards Banquet and Technical Competition.

www.amug.com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SPHERICAL • PURE • DENSE • HIGH FLOWABILITY POWDERS

First plant in Europe to produce aviation-grade titanium by recycling

A new plant in Saint-Georges-de-Mons, France, will be the first in Europe to produce aviation-grade titanium by recycling. The EcoTitanium project makes alloys from titanium solid scrap and chips collected from the major aircraft makers and their subcontractors, and is said to provide Europe with a titanium supply source which is independent of the major global producers.

The €48 million project has three shareholders: UKAD with 43.5% (a 50/50 joint venture between France's Eramet Group subsidiary Aubert & Duval and UKTMP International based in Kazakhstan), ADEME with 41.3% (the French environment and energy management agency under its Investissements d'Avenir programme) and Crédit Agricole Centre France with 15.2% (through its investment subsidiary CACF Développement). The European Investment Bank (EIB) granted a €30 million loan to fund the project, with further financial support coming from the European Regional Development Fund, the French Commissariat for Equality of Territories, the Auvergne-Rhône-Alpes Region, Puy-de-Dôme département council, the Loire-Bretagne water agency and Banque Publique d'Investissement.

Speaking at the inauguration of the new EcoTitanium site in Puy-de-Dôme, Christel Bories, Chairman & CEO of the Eramet Group, stated, "The Eramet Group is proud to support the EcoTitanium project for the creation of a recycling stream that will provide Europe with a titanium supply source which is independent from the major global producers. EcoTitanium is a milestone in Eramet's constant commitment to environmental and social responsibility, as well as industrial innovation."

At full capacity, EcoTitanium will produce several thousand tons of titanium alloy ingot per year to meet high growth in demand for titanium on aviation markets. Titanium and its alloys provide this industry with valuable properties: lightness (44% lighter than steel), excellent corrosion resistance and advanced mechanical characteristics. It is said that EcoTitanium's recycling route will prevent the emission of 100,000 tons of CO_2 by consuming four times less power than the conventional, ore-based production supply chain. .

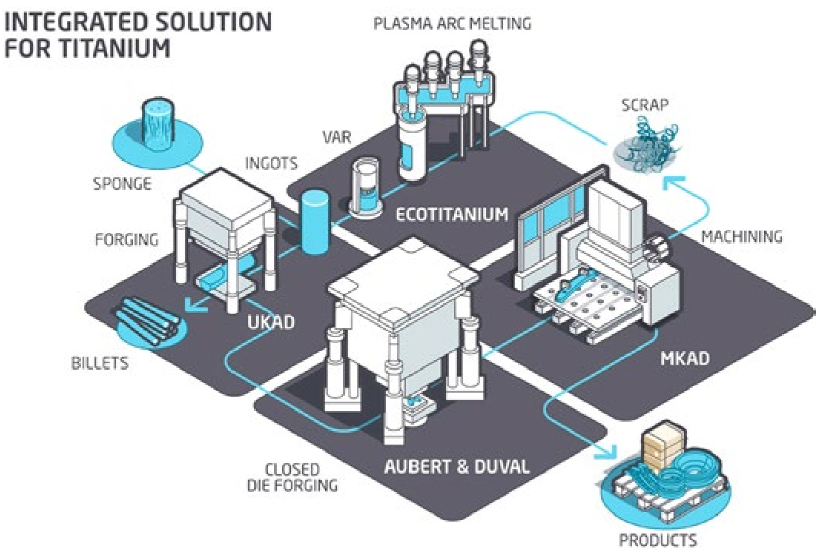
"I thank our partners UKTMP, Crédit Agricole Centre France, ADEME, and the European Investment Bank for their involvement in this pioneering project. With EcoTitanium, the Eramet Group and its subsidiary Aubert & Duval are reasserting their attachment to the Combrailles activity area, which will benefit from the creation of around sixty direct jobs, shoring up its industrial vocation," stated Denis Hugelmann, CEO in charge of the Alloys Division, Eramet and Chairman of EcoTitanium.

"EcoTitanium is a highly ambitious project that supports the competitiveness of a strategic sector, while substantially reducing the industry's impact on the environment," added Bruno Lechevin, Chairman of ADEME. "It is, therefore, perfectly in line with the goal of the Investissements d'Avenir programme."

The EcoTitanium site in Saint-Georges-de-Mons, Puy-de-Dôme, France

Discussing the importance of such a project in the region, Sylvain Gehler, Chairman of the Board of Directors at UKTMP, stated, "The creation of Ecotitanium is a major step in the development of the titanium industry in Europe, and in France in particular. As an integrated titanium producer in Kazakhstan, UKTMP is proud to take part in the creation of EcoTitanium and to contribute its expertise in the supply of titanium sponge."

www.ukadforge.com
www.uktmp.kz
www.eramet.com



EcoTitanium's recycling process uses scrap to produce titanium components

Bionic Smart Factory for Additive Manufacturing to be established in Lüneburg

German based Additive Manufacturing company Bionic Production AG, a spinoff of Laser Zentrum Nord GmbH in Hamburg, will move to a new location at the former Leuphana Campus Volgershall in Lüneburg, Germany, early 2018. The company plans to create a 'Bionic Smart Factory', which it states will offer a new manufacturing concept for complex 3D printing.

"Additive Manufacturing methods gain importance in the industry, as new and more individualised products have to be produced more efficiently, with less material and in even lesser time. Additive Manufacturing, digital business models, and Industry 4.0 offer additional potential to save costs," stated Wolfgang Bülow, CEO at Bionic Production AG.

"With the Bionic Smart Factory we have created a factory structure that enables design inspired by nature and hence, offers tremendous cost savings. As a combination of Additive Manufacturing, bionic optimisation, and digitalisation along the process chain our factory enables new approaches for an economical production of individualised products."

The Bionic Smart Factory is reported to be a highly efficient production site for digital production and manufacturing, equipped with AM machines for various materials and systems for post production steps. At its final stage of expansion, the facility will have around 20 AM machines at its site in Lüneburg.

The Bionic Smart Factory will have around 20 AM machines at its site in Lüneburg

The new factory will not only be a production site, integrating Additive Manufacturing into the entire development, manufacturing and logistics chains, it will also be the base for innovative research and development projects, which will be conducted jointly with Laser Zentrum Nord GmbH. Designed as a Campus, the Bionic Smart Factory offers future engineers the opportunity to work on and research innovative concepts jointly with developers and researchers.

www.bionicproduction.com

XJet launches Carmel line of AM systems

XJet Ltd., Rehovot, Israel, has launched a new line of systems for metal and ceramic Additive Manufacturing. The company showcased its XJet Carmel AM System product line, comprising the Carmel 1400 and the Carmel 700 AM systems, at the recent formnext 2017 exhibition in Frankfurt, Germany.

The Carmel line features XJet's patented NanoParticle Jetting™ technology, and the company states that it has the potential to 'transform' the metal and ceramic Additive Manufacturing industries by printing separate nanoparticle 'inks' or fluids for the build and support materials. This is expected to allow manufacturers to produce ceramic or metal parts with the ease and versatility of inkjet printing.

"NanoParticle Jetting technology is a unique 3D inkjet technology that redefines Additive Manufacturing for metals and ceramics," stated Hanan Gothait, CEO and Founder of XJet. "Other Additive Manufacturing technologies use powders, but we offer a real breakthrough by leveraging our know-how as pioneers of both inkjet printing and 3D printing industries."

"Our solution prints very fine layers of both build materials and a support material to enable the creation of complex geometries in a very simple and very safe process," he continued. "While we are currently printing only one build material, we could theoretically print multiple build materials."

The XJet Carmel 1400 features a 1,400 cm^2 build tray and can manufacture both ceramic and metal parts

Dror Danai, XJet CBO, added, "The XJet Carmel 1400 features a 1,400 cm^2 build tray, one of the industry's largest, for high-capacity production and a unique ability to print both ceramics and metals."

www.xjet3d.com

Aurora seeks to certify metal AM parts for oil & gas industries

Metal Additive Manufacturing machine producer Aurora Labs, Bibra Lake, Australia, has reportedly formed a non-binding agreement with Norwegian certification group DNV GL to produce metal AM parts on Aurora machines which can be independently certified for oil and gas, renewables and marine industry applications.

In a report by *Offshore Engineer*, Aurora Labs stated that, as AM parts cannot be used in these areas without certification, it expects independent certification of its AM parts to accelerate the adoption of its metal AM system, the S-Titanium Pro, in these target markets.

Brice Le Gallo, Regional Manager for SEA & Australia, DNV GL – Oil & Gas, stated, "While AM is raising more and more interest in various industries, the adoption level in the oil and gas and maritime industries is still slow due to challenges in qualification and certification."

According to *Offshore Engineer's* report, the two companies will collaborate to create a process whereby parts additively manufactured on Aurora machines can be independently certified by DNV GL, and whereby the end to end certification process, including the use of Aurora's management software, allows for parts to be certified whilst being printed and then independently verified by DNV GL.

www.auroralabs3d.com | www.dnvgl.com

3D Systems announces its next generation metal AM production platform

3D Systems, Denver, Colorado, USA, has announced its next-generation metal Additive Manufacturing production platform, designed to allow manufacturers to easily scale their AM production and integrate seamlessly into the factory floor. Based on the company's Direct Metal Printing (DMP) technology, 3D Systems claims that the DMP 8500 Factory Solution is the first truly scalable, automated and fully integrated metal Additive Manufacturing system. It features an efficient and fully integrated workflow, from powder in to part out, to produce repeatable, high-quality parts with a lower total cost of operation (TCO).

With a build size that is able to produce metal parts up to 500 mm x 500 mm x 500 mm, the system is engineered to open up new applications in Additive Manufacturing for companies in aerospace, industrial and automotive industries. 3D Systems stated that the modular design of this metal AM solution reduces required capital equipment and ensures maximum utilisation as manufacturers scale production.

The DMP 8500 Factory Solution is comprised of function-specific modules designed to maximise efficiency by optimising the utilisation of each module, including:

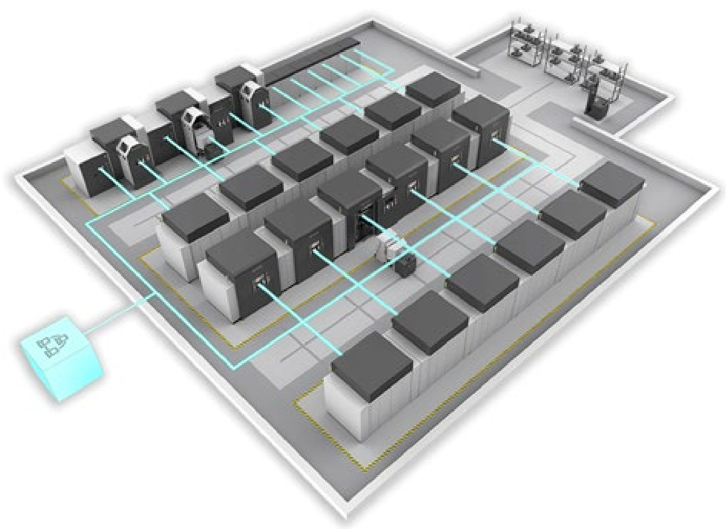
- Removable Print Modules (RPMs):These sealed modules for powder and part transport between printer, powder, and transport modules enable a continuous production workflow and maximises powder quality throughout the process.
- Printer Modulesare designed to withstand the rigors of 24/7 production cycles enabling maximum printer uptime and output.
- Powder Management Modules (PMMs) efficiently de-powder parts on build platforms, automatically recycle unused powder materials, and prepare the RPM for the next build.
- Transport Modulesenable efficient movement of the RPMs between printer and powder modules – reducing production time.

"The industry is at a point where companies are looking to scale up their metal 3D printing production, bridge the chasm, and move onto the factory floor," said Vyomesh Joshi, President and CEO, 3D Systems.

Each module within the factory solution is fully integrated with a Removable Print Module

"The DMP 8500 Factory Solution was developed by experts with deep knowledge and experience in factory solutions and takes metal printing technology to a new level of economic efficiency for our customers."

The DMP 8500 Factory Solution will integrate 3D Systems' innovative 3DXpert™ software. This all-in-one software efficiently prepares and optimises parts for streamlined direct metal production of functional parts. The new platform is planned for availability in Q4 2018.



3D Systems' ProX DMP 8500 modular AM factory solution

LaserForm® materials portfolio expanded

3D Systems has also expanded its portfolio of ready-to-build precision alloys with the introduciton of LaserForm Maraging Steel (A), a metal that can be machined, welded and hardened. The new material is ideal for injection molding and tooling applications.

The company also introduced an upgrade to customers with an existing parameter set license for specific LaserForm metal materials which helps them achieve faster build times. The new Extra High Productivity Parameters for LaserForm Ti Gr5 (A) and Ti Gr23 (A) enable users to achieve high-speed metal printing with proven DMP quality. A high level of consistent, repeatable part quality is maintained, while build time is reduced by more than 30% resulting in lower part cost.

www.3dsystems.com

US Air Force integrates Senvol Database into HyperThought

Senvol has reported that the US Air Force recently licensed its Senvol Database for integration into HyperThought, the Air Force Research Laboratory's (AFRL) premier enterprise software platform for Materials Research. HyperThought is a digital workspace and integration suite that allows AFRL researchers to record, share, access and manage data. The arrangement will put Additive Manufacturing data at the fingertips of nearly one thousand AFRL researchers.

Matthew Jacobsen, Materials & Manufacturing Directorate for AFRL, stated, "HyperThought is our answer to the demand for a single system for data creation, exchange, and consumption, eliminating the inefficiencies associated with traditional data management solutions. The Senvol Database is the de facto standard database for industrial Additive Manufacturing, so it's a perfect addition to our growing suite of repositories that give researchers on demand access to the data they need."

Jennifer Fielding, Technical Advisor at the Propulsion, Structures, and Manufacturing Enterprise Branch of AFRL added, "HyperThought is a powerful platform that's used by our AFRL researchers every day, and Additive Manufacturing is a topic of great interest. We're excited to have access to the Senvol Database within HyperThought."

www.senvol.com

3YOURMIND raises $12M to aid expansion in US and Asian markets

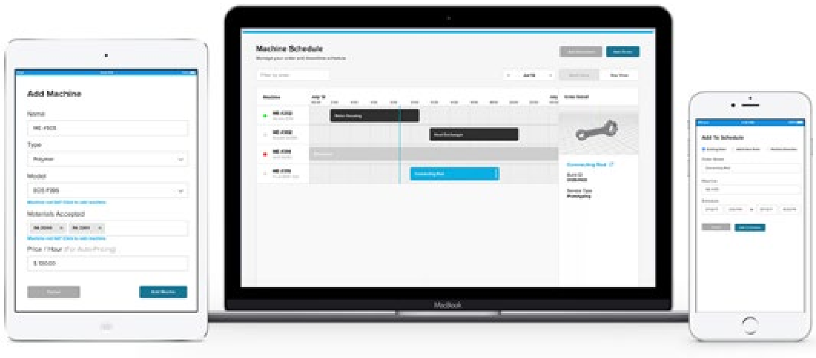
3YOURMIND, a provider of software for Additive Manufacturing processes, has reported the closing of a $12 million Series A funding round. The funds raised will be used to further expand into the US market, following the company's successful market entry which resulted in the addition of major aerospace and engineering customers.

Money will also be earmarked to drive initial entry into the Asian market as well as the development of further, innovative software tools for industrial 3D printing. The company also announced the opening of its East Coast office, based in New York City, USA.

"The strong demand we are seeing from large, established businesses for our industrial 3D printing solutions confirms this is the future of high-tech manufacturing in the US and globally," stated Aleksander Ciszek, 3YOURMIND's CEO. "We are committed to shaping the production processes of digitised factories, and are delighted to have four outstanding strategic partners investing in our vision, including EOS and TRUMPF which are global leaders in the industrial 3D printing market."

www.3yourmind.com

LINK3D enables workflow automation for Additive Manufacturing



LINK3D's Digital Factory is an end-to-end solution designed to enable the flow of Additive Manufacturing orders from product development, order placement, production scheduling, to delivery and traceability (Courtesy LINK3D)

LINK3D, New York, USA, has launched its Digital Factory, a project management system designed to enable the automation of Additive Manufacturing workflows. The software allows engineering companies to create a virtual 'digital factory' to manage their Additive Manufacturing processes, and reportedly brings security, automation, accessibility and traceability to every connecting point within an organisation's AM ecosystem.

Digital Factory includes features such as a project collaboration tool, API integration for internal and certified vendors, an automated file repair tool, intelligent order routing and assisted or automatic pricing simulations. According to its developers, it is the first product to allow industrial Additive Manufacturing 'in real-time.'

LINK3D has also announced a production scheduling tool designed to enable the most effective running of Additive Manufacturing machines. SCHEDUL3D will be integrated into the company's Digital Factory workflow software and is designed for application engineers, facility planners and supply chain managers to optimise their lead times, digital supply chain and better understand their machines. The technology uses AI-based algorithms to make recommendations for placing part orders on the correct and available machines to achieve real-time distributed manufacturing.

When LINK3D was launched earlier this year, Co-founders Shane Fox and Vishal Singh stated that they had discovered an increasing demand for an integrated software as a service to simplify manufacturing automation. According to the company, Digital Factory was launched to connect key parts of the additive workflow, from initial product development through end production.

"SCHEDUL3D is the next step toward truly optimising and automating Additive Manufacturing," explained Fox. "By linking software with hardware, we believe that companies will start to unlock the true potential of Additive Manufacturing as it relates to shortening supply chain and reducing our carbon footprint," added Singh.

www.link3d.co

Fomas and Inteco to manufacture metal powders for Additive Manufacturing

Fomas Group, Osnago, Italy, has formed a joint development agreement with Austria's Inteco Group to produce metal powders for Additive Manufacturing. Metal powder production will begin at Fomas's plant near Osnago and Inteco group member Thermal Technology's plant in Santa Rosa, California, USA.

Both sites incorporate Inteco's 'next generation' powder production plant, which it states enables new possibilities in terms of powder production compared to existing technology. The partners state that their plants will ensure the constant availability of back-up; a shared and qualified sourcing point; advanced technologies for process and product control; reduced batch sizes to guarantee process stability and, accordingly, constant powder quality and predictable part properties; and the capacity to develop tailored alloys and supply different batch sizes offering a complete flexibility to customers.

Besides the production of already established powder grades, the main focus of the new plants will be on highly specialised powders, customised and developed in close cooperation with the customer.

Dr Jacopo Guzzoni, VP & CEO of Fomas Group, stated, "This agreement will be instrumental in entering the Additive Manufacturing markets. It will exploit synergies between our two companies and bring to the market a worldwide offer, it will be a structured process, powered by the achievements shared between us. We are pleased to join forces with Inteco Group (to us a very valuable and reliable partner since 2007) in our mutual vision to develop a new market".

Fomas will distribute its metal AM powders under the brand name Mimete, beginning 2018. The new brand will target various markets, primarily biomedical, power generation, aerospace and racing.

www.fomasgroup.com
www.inteco.at

Simufact introduces the next generation of its metal AM simulation software

Simufact, Hamburg, Germany, an MSC software company, has announced the release of the third generation of its software solution for the simulation of metal-based Additive Manufacturing processes, Simufact Additive 3. The software now provides a thermo-mechanical method which allows users to have a clearer overview of the effects of thermal energy by providing insights for the global temperature of the component. Users can use this data to determine both deformation and the influence of the base plate. Simufact Additive 3 offers a Linux Solver, for users with Linux computers, in addition to the Windows Solver for Windows users.

Analysing the entire build process

Simufact Additive 3 focuses on analysing the layered calculation of the build process with the new thermo-mechanical simulation method. Users can now receive global statements about the heat behaviour in the component, such as thermal peak loads, in order to identify overheated areas at an early stage.

The thermo-mechanical method takes into account much more physical parameters and boundary conditions than the Inherent-Strain method that include thermally relevant variables, such as laser power, laser speed, and pre-set temperatures. By using the thermo-mechanical calculation method, users do not need to perform a calibration beforehand. Through the implementation of the thermo-mechanical calculation method, users can take into account the essential parameters of the printer in the software during model building.

Influences of the base plate

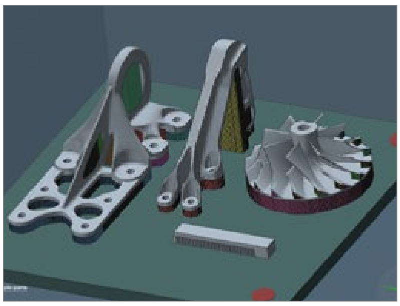
During the production of additive components, not only does the work piece undergo distortions and stresses; the base plate also influences the printing process and subsequent steps. Distortions and stresses can occur in the base plate during the actual printing process, which can then have an effect on the supporting structures and component. In Simufact Additive 3, engineers can examine these and other influences of the base plate on the component.

Frequent use of the base plate can lead to additional problems because it is a wearing part. After each production, a layer of material is removed, which makes it ever thinner. In the run-up to the next printing projects, the user can assess the distortion of the base plate and determine when an exchange of the base plate is required.

Multiple parts with the best-fit method

With Simufact Additive 3, the printing process of several geometries can be modelled easily and quickly in the build space. The simulation of the thermal construction process can then reveal possible influences of the components among one another. Users can also compare simulation results and reference models, for example CAD data, by using "best-fit" positioning. In the best-fit method, the software automatically determines the position at which the deviations are lowest. The visual presentation of the results, allows the user to quickly assess whether the deviations are within the permissible tolerances. For this function, Simufact has integrated Hexagon's 3DReshaper technology.

www.simufact.de



Simulation of multiple parts in the build space

ASTM International seeks partners for AM centre of excellence

ASTM International, West Conshohocken, Pennsylvania, USA, has announced plans to establish a centre of excellence in the field of Additive Manufacturing. The organisation is now calling for industry-university proposals aimed at creating a global innovation hub that advances AM technical standards, related R&D, education and training and more.

Katharine Morgan, President of ASTM International, stated, "Over the last decade, hundreds of the world's top experts in Additive Manufacturing have pioneered the development of new standards through ASTM International. We are thrilled to take this next bold step to bridge standards development with R&D, while also meeting the growing demand for related services in this field."

The new centre aims to be a global hub for innovation and to serve as a consortium in attracting stakeholders from the aviation, automotive, medical and other industries increasingly engaged in AM applications. It will be supported with up to $250,000 annually from funds and in-kind contributions for up to five years. In-kind support could increase the award amount beyond $250,000.

ASTM International's committee on Additive Manufacturing technologies (F42) was formed in 2009. The committee, in conjunction with the International Organization for Standardization's (ISO) Technical Committee 261, has worked and continues to work closely with the Additive Manufacturing Standards Collaborative to identify and fill a variety of gaps across multiple industry sectors. ASTM International could select up to two awardees as part of this initiative.

www.astm.org

APWorks partners with Toyal on Scalmalloy for metal AM

Germany's Airbus APWorks GmbH has signed a strategic partnership with Toyal, a global producer of aluminium based products. The companies will partner on the development, production and distribution of Scalmalloy®, APWorks's patented high-strength aluminium-magnesium- scandium alloy.

Scalmalloy is reported to be the world's first material developed specifically for AM and, due to its high cooling rates and rapid solidification, possesses a unique microstructure which remains stable at high temperatures. It offers exceptionally high fatigue properties, weldability, strength and ductility compared to other aluminium alloy powders, which makes it particularly well-suited to aerospace, transportation and defence applications, among many others.

Toyal will now produce Scalmalloy as part of its materials range, and partner with APWorks for further developments in the composition of the alloy and the optimisation of its production process. In addition, Toyal will distribute the alloy through its own distribution network.

"We are convinced that Toyal is a cooperation partner with whom we can ensure a continuous development of the material composition and the production process of our unique material for our customers," stated Sven Lauxmann, Head of Sales and Marketing at APWorks.

"The close collaboration creates an excellent synergy between Toyal's decades of experience in the production and global marketing of aluminium based products and APWorks' more intensive experience in processing Scalmalloy in 3D printing. Our common goal is to market Scalmalloy by the global presence of TOYAL for numerous customers and a wide range of applications ranging from aerospace to automotive up to robotics."

www.apworks.de/scalmalloy

www.toyalgroup.net

Short course on Atomisation for Metal Powders returns

Atomising Systems Ltd and Personal Development Advanced Courses (PERDAC), a division of CPFResearch Ltd, will hold their popular short course on atomisation for metal powders for the eleventh time in 2018. The two-day course will take place from March 8-9 in Manchester, UK.

Developed for engineers working in metal powder production and/or R&D, the programme combines up-to-date practical information with theory. On the agenda are all current atomiser types and uses, key instrumentation, essential theory and computer modelling, and plant design, operation and economics.

www.atomising.co.uk | www.perdac.com

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Latest version of Siemens NX expands toolset for digitalising the machine shop

Siemens has released the latest version of its NX™ software, which incorporates tools for Additive Manufacturing, CNC machining, robotics and quality inspection. The updated software is reportedly designed to enable the digitalisation of part manufacturing within a single, integrated end-to-end system.

The software is said to offer advanced automation capabilities for computer-aided manufacturing (CAM), including robotic programming, adaptive milling and tooling design and to provide industry-specific technology to help deliver high-quality products to the market in less time. In addition, the NX Machining Line Planner tool, combined with integrated NX CAM software, provides new capabilities for industries with high-volume production of complicated parts, such as automotive and industrial machinery.

Siemens stated that it designed the new version of NX in response to the added pressure part manufacturers now face from changing market expectations, with many customers requiring improved accuracy and faster response times. In order to remain competitive, Siemens said, many part manufacturers look to digitalisation to connect all of the steps of part manufacturing, planning and production with a single source of information, or a 'digital thread'.

The company believes that implementing a digital strategy can enable part manufacturers of all sizes to take greater advantage of automation, adopt Additive Manufacturing for production and ultimately expand into new market opportunities and reduce time to delivery.

"In order to grow their businesses and expand into highly competitive markets like the aerospace and semiconductor industries, machine shops need to offer Additive Manufacturing combined with a highly automated process chain that digitally connects design, print preparation, NC and quality inspection programming to production," explained Christoph Hauck, Managing Director of New Technologies and New Markets, MBFZ toolcraft GmbH, an early adopter of Siemens' AM technology.

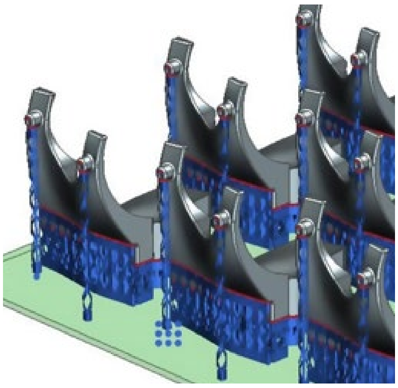
"Siemens offers all of these capabilities in one complete and integrated system for part manufacturing. This allows us to link each step in our digital process chain, providing critical process control, associative data flow and traceability – which are important for our customers," he concluded.

The new version of NX also incorporates automation enhancements aimed at expanding production efficiency and reducing cost. The software's robotic programming technology provides the ability to automate complete manufacturing cells, including programming robots to perform machining and pick-and-place operations. In addition, it now offers adaptive milling and tube milling capabilities, enabling users to automate CNC machine programming and accelerate the cutting of complex parts.

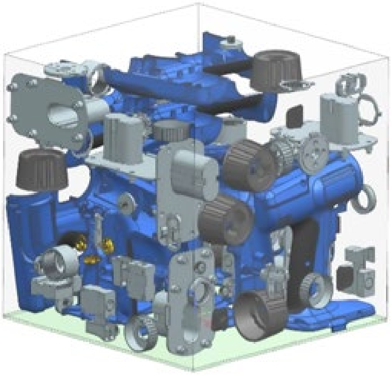
"Transformative technologies like Additive Manufacturing and advanced robotics offer tremendous potential for manufacturers of all sizes to gain an advantage in today's competitive market," stated Zvi Feuer, Senior Vice President of Manufacturing Engineering Software for Siemens PLM Software. "NX provides a fully integrated solution for part manufacturers to utilise these powerful technologies, creating the ability to improve overall business performance and helping to create a truly digital machine shop."

Siemens also develops applications for Additive Manufacturing process simulation in Simcenter 3D, a tool designed to help manufacturers industrialise AM by manufacturing components 'first-time-right'.

www.siemens.com



Siemens NX can automatically create various support structure types for use with powder bed AM systems (Courtesy Siemens)



Siemens NX allows multiple parts to be nested in the build area of an AM system to optimise efficiency (Courtesy Siemens)

An example lattice structure created using the NX Lattice Structures Design module (Courtesy Siemens)

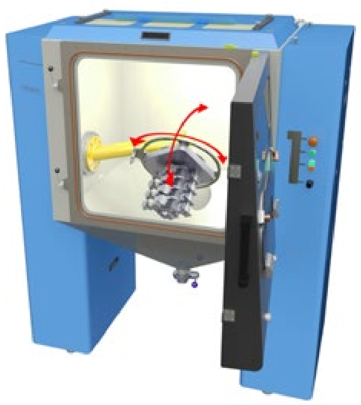
Solukon launches automated depowdering solutions for AM metal parts production

SFM-AT800 depowdering systems for cleaning metal parts up to 500 x 500 x 500 mm in size and weighing up to 300 kg

Solukon Maschinenbau GmbH, Stadtbergen, Germany, formally launched its line of depowdering systems for metal Additive Manufacturing systems at this year's formnext 2017 exhibition in Frankfurt, Germany. The systems automate the process of removing excess unmelted metal powder in powder bed fusion systems through systematic rotation and controlled vibration of the laser melted metal parts, releasing powder trapped in voids and internal channels around and inside the parts.

"Metal AM systems have grown in their capabilities and the breadth of application in recent years, but peripheral processes to speed up the industrialization of these technologies has been lagging," stated Solukon Co-founder Andreas Hartmann. "Studies by leading users of AM indicate that more than 70% of the costs of producing metal parts is attributed to pre- and post-processes. Solukon's mission is automate and simplify the additive process, and by so doing to expand the industrial viability of these technologies."

Co–founder Dominik Schmid added, "Customers tell us that they want to reduce the costs and simplify the process of part manufacture, and manage the occupational and environmental risks of metal additive manufacturing. Our systems set new standards in the industry for the achievement of these goals."



Solukon systems automate the cleaning of metal parts

As the design of additively manufactured parts has increased in complexity to take advantage of the possibilities of the additive process, so too has the challenge of removing unfused powder from inside these complex structures. "Solukon systems have been designed to maximize the reclaiming of unused powder through processes that minimise the need for manual intervention," added Hartmann.

The systems are supplied in two sizes and each size comes in two versions. The large size SFM-AT800 depowdering system is designed for the processing of large parts with maximum dimensions of 500 x 500 x 500 mm (19.7 x 19.7 x 19.7 inches), and up to a weight of 300 kg (661 lbs). In 2018 the SFM-AT800 will also be available for larger part dimensions of 800 x 400 x 500 mm (31.1 x 15.8 x 19.7 inches). The SFM-AT300 system is designed for smaller parts of up to 300 x 300 x 350 mm (11.8 x 11.8 x 13.8 inches) weighing up to 60 kg. Both systems come in a standard version for the removal of hazardous metal dust by extraction, and an inert gas version that facilitates the safe processing of powders with a high explosive risk, such as titanium and aluminium.

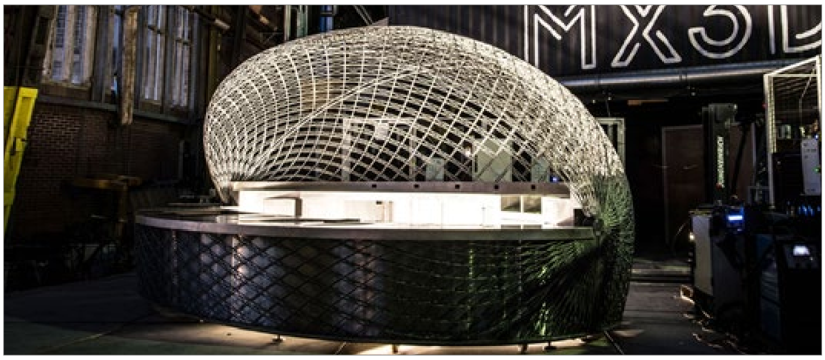
AM parts, including build plates, are fixed onto the processing table of the machine. The process table rotates the parts in a pre-planned path to release unused powder from around and within the printed parts, including from inside inner channels for parts such as conformal channels, and from complex shapes such as heat sinks and heat exchangers. At the same time, a controlled variable-frequency vibration device targets the release of even stubborn and compacted powder from inside the parts.

The rotating device for the large format SFMAT800 operates in two axes to free powder from the most inaccessible areas of the parts. The machine also features an automatically opening roof that allows crane-loading of heavy parts. The rotating device for the SFM-AT300 operates in a single axis, suitable for smaller parts. Unfused powder is collected for further processing or re-use in a specially designed container, or connected to an external sieving device.

For processing of problematic materials such as titanium and aluminium, both systems come equipped with a nitrogen or argon gas infusion system for powder processing in an inert atmosphere.

www.solukon.de

MX3D opens Cucuyo – the metal additively manufactured café



Cucuyo is believed to be the world's first metal AM café (Courtesy MX3D)

MX3D, a Dutch company focused on the research and development of robotic Additive Manufacturing technology, has delivered a metal additively manufactured café to STARR Catering Group for installation at the Perez Art Museum Miami (PAMM), Florida, USA. The stainless steel structure was produced in collaboration with Miami-based architectural firm Berenblum Busch Architects (BBA) and opened for business in late September, 2017.

The cocoon-shaped café is named Cucuyo, after the Spanish name for a firefly-like beetle, and is reported to be the first of its kind. MX3D used an industrial robot, equipped with an advanced welding machine and controlled by newly developed software, to produce the structure's exterior shell using a framework of thin, intricate crossbeams. According to MX3D, the resulting 700-pound stainless steel structure proves that the freedom of form and design offered in the Additive Manufacturing of small objects can be applied on a larger architectural scale.

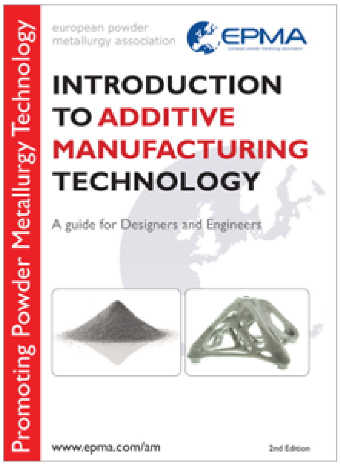
"It was a challenge to design a piece that was not only lightweight and easily disassembled for relocation, but also fully functional," noted Claudia Busch, Founding Principal of BBA. "That is why we decided to work with MX3D on manufacturing this project. Their unique technology allowed the construction of this site-specific piece that meets all structural requirements while seamlessly fitting into the PAMM environment."

"The cutting-edge and sculptural design of Cucuyo complements PAMM's Herzog & de Meuron-designed building with its shaded verandas and plazas built for public engagement and interactions with works of art. It will create another meeting point for conversation for our visitors," added Franklin Sirmans, Director of PAMM.

Cucuyo is divided into three major components: the front counter, the back counter and the door. The final assembled piece is reported to stand at 20 ft long, 9 ft high and 12 ft wide with an advanced counter design, electrical configuration and plumbing.

www.mx3d.com
www.pamm.org

EPMA launches Second Edition of its Introduction to AM Technology



The European Powder Metallurgy Association (EPMA) has launched the Second Edition of its Introduction to Additive Manufacturing Technology brochure. The new edition, produced in collaboration with the EuroAM Sectoral Group, was launched at Euro PM2017 Congress & Exhibition in Milan and looks to expand on the original edition by providing updated and enhanced case studies from a range of different industries.

The First Edition of the brochure was originally launched in 2013 by the EuroAM Group and has since been widely distributed and downloaded from the EPMA's website, as well as being distributed at a number of promotional events throughout Europe and beyond.

The new 56-page edition includes content from over ninety contributors and contains more than fifty case studies. The following new chapters have also been added:

- HIP post processing
- Non-destructive testing for AM parts
- Powder handling & safety areas of focus

Andrew Almond, EPMA Marketing Manager, stated, "This is a great booklet for potential users of the Additive Manufacturing process, as it provides a neutral view of the main AM processes available to date. It is with great thanks to Adeline Riou, Claus Aumund-Kopp, the original authors of the first edition, that the newly revised edition has been able to be produced. Without the EuroAM's commitment and enthusiasm the first edition would not have been made, or even updated!"

The brochure can be downloaded in PDF format via the EPMA website.

www.epma.com

Vancraen to receive AMUG 2018 Innovators Award

The Additive Manufacturing Users Group (AMUG) has announced that Fried Vancraen, CEO and founder of Materialise, is to receive its 2018 Innovators Award. The AMUG Innovators Award is presented to individuals who have cultivated innovative ideas that in turn have advanced the Additive Manufacturing industry.

Fried Vancraen, CEO and founder of Materialise

After finishing a Masters in Electro-Mechanical Engineering in 1985, Wilfried Vancraen worked as a Research Engineer and Consultant at the Research Institute of the Belgian Metalworking Industry, which is where he first discovered Additive Manufacturing. Passionate about this new technology and firm in his belief that it could help create a better and healthier world, Vancraen started Materialise in July 1990, where he remains CEO to this day.

Vancraen will be presented with the award at the AMUG Conference in St. Louis, Missouri, USA, April 8 – 12, 2018. He will partake in a 'fireside-chat-styled' interview with the goal of getting to know the man behind Materialise and gain guidance from his experience in developing the software and services that many use throughout the AM industry.

Previous recipients of the AMUG Innovators Award have included technology creators Chuck Hull, Scott Crump and Carl Deckard, innovators of the stereolithography (SLA), Fused Deposition Modeling (FDM), and Selective Laser Sintering (SLS) processes, respectively.

www.amug.com
www.materialise.com

International metalworking show Metalloobrabotka set for Moscow 2018

Metalloobrabotka, Russia's 19th International Exhibition on Equipment, Instruments and Tools for the Metalworking Industry, is set to take place at the Expocentre Fairgrounds, Moscow, Russia, May 14-18, 2018. Organised by Stankoinstrument Russian Association of Machine-Tool Manufacturers, the event is Russia's largest metalworking show and aims to offer a platform for networking between Russian and international companies.

The exhibition hall offers 80,000 m^2 of floor space and, in 2017, hosted 1,042 exhibitors from 33 countries and 31,300 visitors. Product sectors from across the metalworking industries are represented, including areas relevant to Powder Metallurgy, Metal Injection Moulding and metal Additive Manufacturing. More than twenty-five supporting events will take place alongside Metalloobrabotka, organised by Russian companies and academic organisations.

Denis Manturov, Russian Minister of Industry and Trade, stated, "Metalloobrabotka is a key event in the field of material processing technology. It greatly contributes to the implementation of relevant national programs and investment projects. I am positive that the show will foster expansion of international trade, study and introduction of innovative technologies and signing of contracts for supply of state-of-the-art equipment."

www.metobr-expo.ru

Oerlikon: Swiss industrial group positions itself as a leading developer of AM components and materials

Over a period of just twelve months, Switzerland's Oerlikon Corporation AG has made a major move into the world of Additive Manufacturing. Through a combination of acquisitions and new facility investments, the company has established itself as a leading international developer of both AM materials and components, offering its customers the complete process chain, from new alloy development to component post-processing and testing. *Metal AM* magazine's Nick Williams reviews the company's progress to-date.

The metal Additive Manufacturing industry is growing at a rapidly increasing rate. Interest among end-users is at an all-time high and an ever-broadening range of production applications is being reported on a regular basis. There are, however, a number of routes that a company can take to embrace AM technology. Just a few years ago, a company that had an application that it was looking to develop would probably have taken the obvious route of investing in a small production-scale AM machine and experimenting in product development, most probably with a team that had little experience of AM and a finite budget.

Many of the companies that took this route quickly discovered that the knowledge required to embrace all that Design for Additive Manufacturing offers – along with the technical complexity of the metal AM process and its associated post-processing steps – led to a long and expensive learning curve, punctuated by numerous build failures and increasing budgets.

This scenario developed into what is now a mainstay of the AM machine builder's portfolio – consultancy services that offer to guide potential end-users through all stages of the development of an AM application, from design through to the commissioning of a dedicated in-house AM facility.

A further route by which a company can embrace AM, however, is in many ways the most conventional: partner with a specialist AM service provider to develop an application and then outsource production or, on a larger scale, form a production joint venture. The outsourcing of production is of course commonplace in the world of

Fig. 1 An additively manufactured AlSi10Mg distributor housing produced by Oerlikon's AM facility in Barleben, Germany

Fig. 2 A large additively manufactured heat sink from AlSi10Mg

industrial manufacturing, for example for the manufacture of machined or cast components.

Working with an external partner for a product's development and manufacture is by no means new in metal Additive Manufacturing – service bureaux have existed in the world of metal and plastic prototyping for many years. However, as demand for AM components for critical, high-value applications has grown, the concept of the AM service bureau has radically transformed into a far more sophisticated and industry-focused business model that is designed specifically for the volume production of aerospace, medical, automotive and power generation components - as examples - to the necessary international standards. Such partners must of course also be able to handle all of the necessary materials development, post-processing and quality monitoring that is required in metal Additive Manufacturing. It is within this space that Swiss engineering leader Oerlikon has positioned itself.

Oerlikon's path to AM

Headquartered in Pfäffikon, Schwyz, Switzerland, Oerlikon is a major industrial technology group with more than 13,800 employees in thirty-seven countries and 2016 sales of CHF 2.331 billion ($2.37 billion). As such, it has the financial resources to support its ambition of becoming a leading player in AM. The group has over the last year steadily expanded its AM-related capabilities to the point where it can now support its customers through the entire AM process chain, from alloy development through to powder production, application development and component manufacturing, post-processing and quality inspection.

The company's new Additive Manufacturing business, led by Florian Mauerer, fits within its Surface Solutions segment, one of three divisions in the Oerlikon group, with the others being Manmade Fibers and Drive Systems.

As a leader in advanced surface solutions, Oerlikon has had an interest in metal powder technologies for many years and this was further enhanced by its acquisition of Sulzer's Metco division in 2014. This business, which specialises in the production of novel, high-performance metal powders such as superalloys for thermal spray applications, saw increasing demand for its products from the growing AM sector.

However, it was Oerlikon's announcement in December 2016 that it was to acquire international AM producer citim GmbH that gave the first clues as to the group's AM ambitions. citim's core expertise lies in metal Additive Manufacturing for small-series production and functional prototypes and the company operates production sites in Europe (Barleben, Germany) and in North America (Kennesaw, Georgia, USA). Its primary markets are high-tech industries such as aviation, automotive and energy and in 2015 it generated sales of CHF 12 million (US $11.8 million) with around 120 employees.

Dr Roland Fischer, Oerlikon's CEO, stated at the time of the transaction, "The competencies and team from citim will serve to consolidate our position in the Additive Manufacturing business, marking the acquisition as an important move for us to drive the industrialisation of Additive Manufacturing and to become an independent service provider for the production of additively manufactured components".

In May this year Oerlikon announced a further acquisition; that of Scoperta Inc., an advanced materials development company with a proprietary process technology that enables the rapid design and development of new materials using computational software.

With these acquisitions, Oerlikon rapidly gained expertise in all areas of the AM process chain and successfully positioned itself as a leading player in the AM industry, with its services supported by its global network of service and production centres.

The story of citim

citim is without doubt the 'jewel in the crown' of Oerlikon's Additive Manufacturing business unit. Founded in 1996 as a spin-off from Otto von Guericke University in Magdeburg, Germany, the company first focused on prototype tooling. In the following years the company's portfolio of production technologies steadily grew to include Selective Laser Sintering technologies in 2004 and Selective Laser Melting in 2009.

Today, citim operates twenty-seven AM machines across its sites in Germany and the US, with the latter site established in 2013. In 2016 the German operation moved into a new 7,000 m^2 state-of-the-art production facility on a 25,000 m^2 site. The knowledge and experience that its staff gained over more than twenty years of AM production of course not only brings expertise, but a high degree of credibility in an industry that is still seen by many as young and unproven.

In addition to metal AM technologies for prototype and series production, citim also offers precision sand casting, die casting with rapid tooling and HSC/CNC machining and milling - all with a focus on the rapid turnaround of low-volume production runs for small-series applications or prototyping.

citim also retains its founding expertise in plastic prototyping and low volume production using Selective Laser Sintering and injection moulding. For the latter, prototype tools can be rapidly manufactured from aluminium, with manually operated inserts where needed, to produce prototype components that can be regarded as 'series-identical'.

XJet's new AM production system installed in Barleben

In November, Oerlikon announced that XJet's new Carmel 1400 Additive Manufacturing system was being installed at the Barleben facility. This was the first international installation of XJet's inkjet-based technology for the additive production of ceramic parts. The NanoParticle Jetting™

Fig. 3 A view of citim's Additive Manufacturing operation in Barleben, Germany. In 2016 the operation moved into a new 7000 m^2 state-of-the-art facility

Fig. 4 An operator cleans a machine in preparation for a new build. citim operates twenty-seven AM machines across its sites in Germany and the US

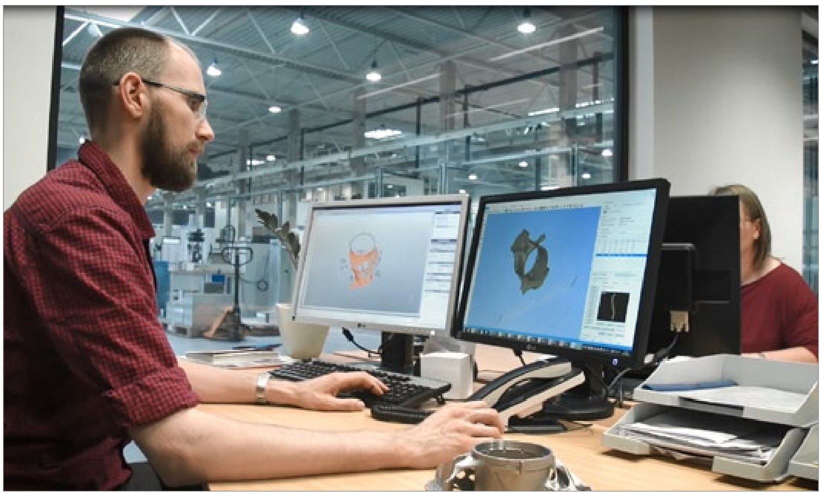


Fig. 5 Oerlikon partners with customers in the complete AM component cycle, from concept to production and post-processing

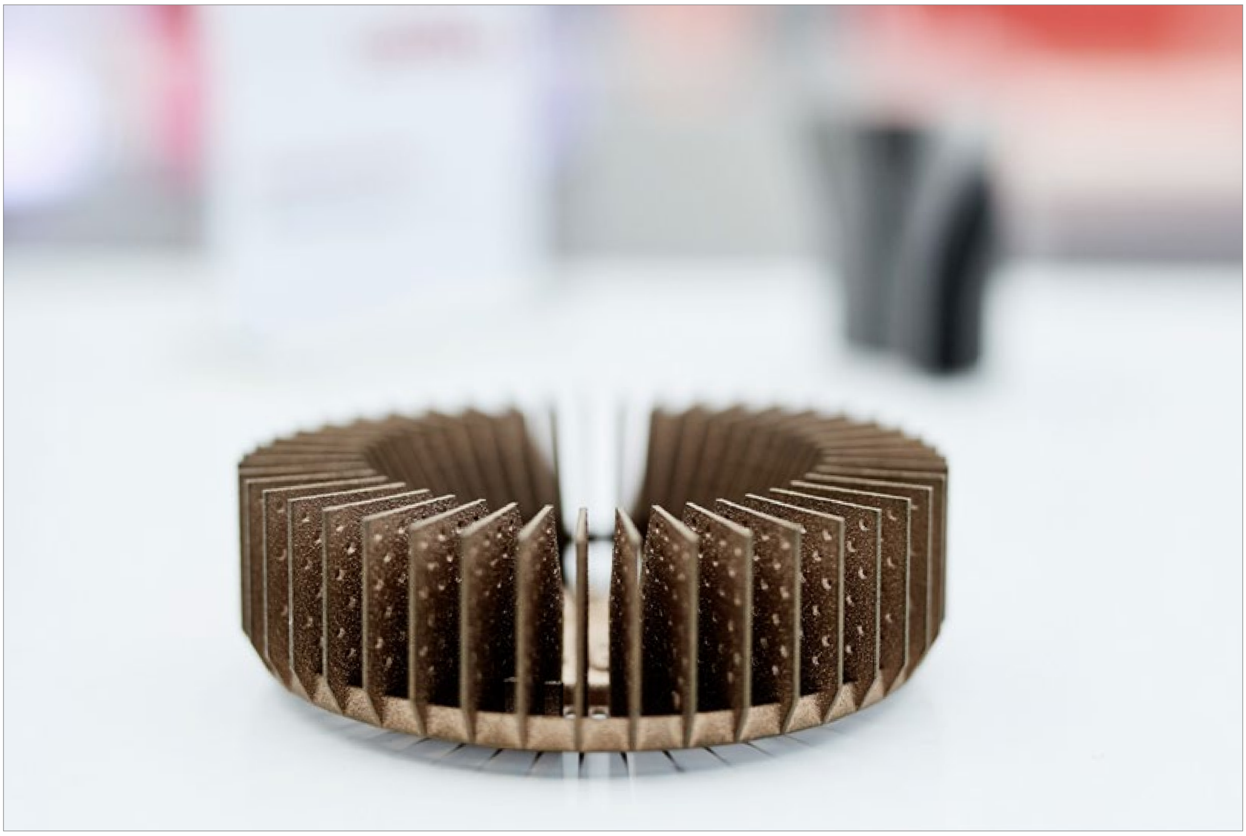


Fig. 6 An additively manufactured CuNi2SiCr cooling element

(NPJ) system featured in the machine uses separate nanoparticle 'inks' or fluids for the build and support material. This enables ceramic or metal parts to be produced with the ease and versatility which one associates with inkjet printing. The parts are then debound and sintered.

The system is configured to manufacture ceramic parts from zirconia, however at a later stage it can also be used to manufacture metal components that require the very fine resolution details that the Carmel system can offer.

"The cooperation with XJet is an exciting opportunity for us to expand our AM offering beyond metals and into ceramics," commented Andreas Berkau, Head of AM Service Europe. "With over twenty years in the industry, citim has established itself as a leading international supplier of AM parts that meets evolving industry needs and remains at the forefront of AM technology. This collaboration enables us to stay ahead of technology developments and maintain our technology leadership."

"With an investment of around $55 million in the facility, the company is anticipating the creation of over a hundred new jobs when fully operational in 2018."

Florian Mauerer added that this collaboration with XJet is a natural extension of Oerlikon's existing activities and, "further strengthens our technology offering and leadership position in the field of AM."

New US Additive Manufacturing facilities bring additional AM and powder production capacity

In July 2017, Oerlikon announced that it would further expand its Additive Manufacturing business in the US with a new state of the art R&D and production facility for AM components in Charlotte, North Carolina. With an investment of around $55 million in the facility, the company is anticipating the creation of over a hundred new jobs when fully operational in 2018.

"Charlotte is an important step in our plans to grow our Additive Manufacturing business and our investment in key technology areas. The investment underlines our intention to become a leading independent global partner in the industrialisation of Additive Manufacturing," stated Fischer.

Oerlikon also announced that it would be building a new $50 million state-of-the-art manufacturing facility in Plymouth Township, Michigan, USA, dedicated to producing advanced materials for Additive Manufacturing and surface coatings. This facility will develop and manufacture a range of metal powders for AM, including titanium alloys. The site features the latest generation of vacuum inert gas atomisation (VIGA) technology, combining vacuum induction melting with inert gas atomisation systems.

In addition, the facility houses a state-of-the-art research and development lab for further alloy developments of titanium and other alloys (e.g. nickel, copper, iron and cobalt) for joint R&D projects with customers and will have the capacity to produce custom powders in small batches.

AM-grade metal powders currently offered by Oerlikon include nickel-, cobalt- and titanium-based alloys as well as stainless steels and maraging steels.

Fig. 7 An automotive piston demonstration part that highlights the weight saving potential of AM

Innovative alloy development

Oerlikon's acquisition of Scoperta has put the company in a leading position to develop the next generation of material solutions for industrial applications, with powerful 'big data' analytical software used to design new alloys in a matter of months rather than years. The result is that new alloys can be commercialised much more effectively, thereby giving customers the materials needed for their applications far faster than through conventional empirical material development methods.

Such an alloy development solution is of particular interest for the metal AM industry, as there are cases where a brand-new AM-tailored alloy system may be a far better solution for specific applications, in terms of performance, cost and processability, than conventional cast alloy compositions. For example, new alloys can be developed to match the specific performance criteria of an existing alloy, but with a completely different composition.

Fischer stated, "The expertise and team from Scoperta adds great value and complements well with Oerlikon's existing strong materials heritage and competence. With industries seeking solutions to improve performance and sustainability, the need for advanced materials and products is continuously growing. This investment underscores our aim to stay at the forefront of the new era of innovating for advanced materials, which will be used in surface solutions and also in Additive Manufacturing."

"In our transition to become a powerhouse in surface solutions and advanced materials, such targeted and selective investments will reinforce our in-house capabilities and provide additional growth opportunities for Oerlikon."

The acquisition of Scoperta undoubtedly strengthens Oerlikon's position in the market for metallic and ceramic materials and extends the scope of services to customers in terms of developing individualised materials in significantly reduced development times and costs.

Munich as a centre of AM excellence

In October this year, Oerlikon formally opened a new Additive Manufacturing Technology & Innovation Centre in Munich. The centre will allow existing and potential customers to see and experience first-hand the design and production of metal components by AM along the process chain, from design and simulation to production and post-processing.

The centre will leverage its partnership with TU Munich, and its proximity to leading global industrial companies in the aerospace, automo-

Fig. 8 Guests at the opening of Oerlikon's new Additive Manufacturing Technology & Innovation Centre in Munich, Germany

Fig. 9 The official cutting of the ribbon. Left to right: Dr Bernhard Schwab (Director, Bavarian State Ministry of Economic Affairs and Media, Energy and Technology) with Oerlikon's Dr Roland Fischer, CEO, Prof Dr Michael Süss, Chairman of the Board, and Florian Mauerer, Head of the AM Business Unit

Fig. 10 An exterior view of Oerlikon's new Additive Manufacturing Technology & Innovation Centre in Munich

tive, power generation and medical devices sectors in the Munich region, to drive forward research and innovation in AM. The company states that it has made "a high single-digit-million Swiss Franc investment" in the centre, which will house over fifty AM engineers, technicians and application specialists.

Mauerer commented at the inauguration, "We are excited to open the AM Technology & Innovation Centre in Munich to drive the integrated development of new materials, production capabilities and processes, software, automation and post-processing solutions. Bringing all the different aspects of the AM value chain under one roof is central to our contribution to industrialising AM and to offering our customers comprehensive and fully integrated AM services. The Munich Centre uniquely connects the dots between our material science, component design, production and post-processing engineering capabilities."

Partnerships to support R&D

Earlier in the year, Oerlikon entered into AM-focused research partnerships with the Technical University of Munich (TUM), Germany, and Russia's Skolkovo Institute of Science and Technology, Moscow. These partnerships are designed to support the company's strategy to extend its leading position in surface solutions into Additive Manufacturing. In anticipation of the expected growth in demand for advanced component production by Additive Manufacturing, these collaborations will also address some of the most pressing research and development challenges in the field.

Roland Fischer stated, "Innovative technology is key to our growth strategy and gives Oerlikon a distinct advantage. These partnerships mark yet another important milestone in our efforts to take a leading position in Additive Manufacturing. Our goal is to deliver innovative products and services in surface coatings and advanced materials to meet customers' growing demand for advanced components that are lighter and with embedded functionalities. Additive Manufacturing offers cost-effective production solutions coupled with increased design freedom for even more highly complex geometries. With our leading expertise in advanced materials and surface technologies, we are ideally positioned to be a driver of this technology."

Markets and collaborative agreements with industry

Oerlikon's AM business is primarily focused on industrial and medical applications. Industry sectors covered include aerospace, automotive, power generation and tooling.

Within the aerospace sector in particular, applications for AM can generally be seen as falling into three types; complex engine parts, structural components and replacement parts. AM technology enables the production of aerospace parts at a lower weight, significantly reducing life-cycle costs, and for aircraft applications such as brackets, ducting and seat belt buckles, Oerlikon states that AM can be leveraged for weight and flow optimisation, sound reduction and near-net part substitution. AM is also being used in aero engine applications to integrate components, reducing part counts and mass for compressor vanes, diffusers, acoustic attenuation, heat exchangers and more.

It was therefore a natural fit when Oerlikon signed a Memorandum of Understanding at the 2017 Paris Air Show with GE Additive and its Concept Laser and Arcam businesses. The agreement included the provision of additive machines and services to Oerlikon, while Oerlikon became a preferred component manufacturer and materials supplier to GE Additive and its affiliated companies. GE and Oerlikon also agreed to collaborate on AM machine and materials research and development over the five-year period of the agreement.

Oerlikon and LENA Space collaborate on AM for space launch technology

Fig. 11 Florian Mauerer presents an AM propulsion system impeller developed in collaboration with LENA Space

In an example of the way in which Oerlikon's AM business is working with users of AM technology, the company recently began a collaboration with LENA Space, a rocket propulsion start-up based in the UK, to develop optimised AM components for propulsion systems. These systems are used in small launch vehicles to launch payloads in low Earth orbit.

This partnership combines LENA's experience and vision for fast-to-market, high-performance, low-cost launch propulsion technology with Oerlikon's end-to-end services in Additive Manufacturing to drive wider adoption of the technology in the space industry.

All parts, components and systems used in space need to meet highly stringent requirements in terms of weight, power and structural design and they need to function optimally in demanding space conditions. Additive Manufacturing, states Oerlikon, can help deliver new and cutting-edge technologies and solutions to satisfy such demands.

This collaboration serves to bring innovative approaches to addressing such manufacturing challenges for space. LENA Space designs and develops turbines, impellers, pumps, combustion chambers, regenerative cooling systems and more.

Dan Johns, Global Head of R&D - Additive Manufacturing at Oerlikon, explained, "We look forward to partnering with LENA Space to develop truly innovative products using our Additive Manufacturing capability. In particular, we will bring into the collaboration our differentiating capabilities in four areas: design for additive engineering, rapid alloy development (RAD), additive process knowledge to create high quality, repeatable components and our advanced coatings. Through our expertise, we aim to expand the operational envelope."

Natasha Allden, Chief Commercial Officer at LENA Space stated, "At LENA, we continually challenge and innovate technology and processes. Additive Manufacturing allows us to make step changes in producing complicated designs not possible with traditional machining, improving the performance whilst reducing the mass of our products. We look forward to our partnership with Oerlikon and shaping the future of space propulsion technology."

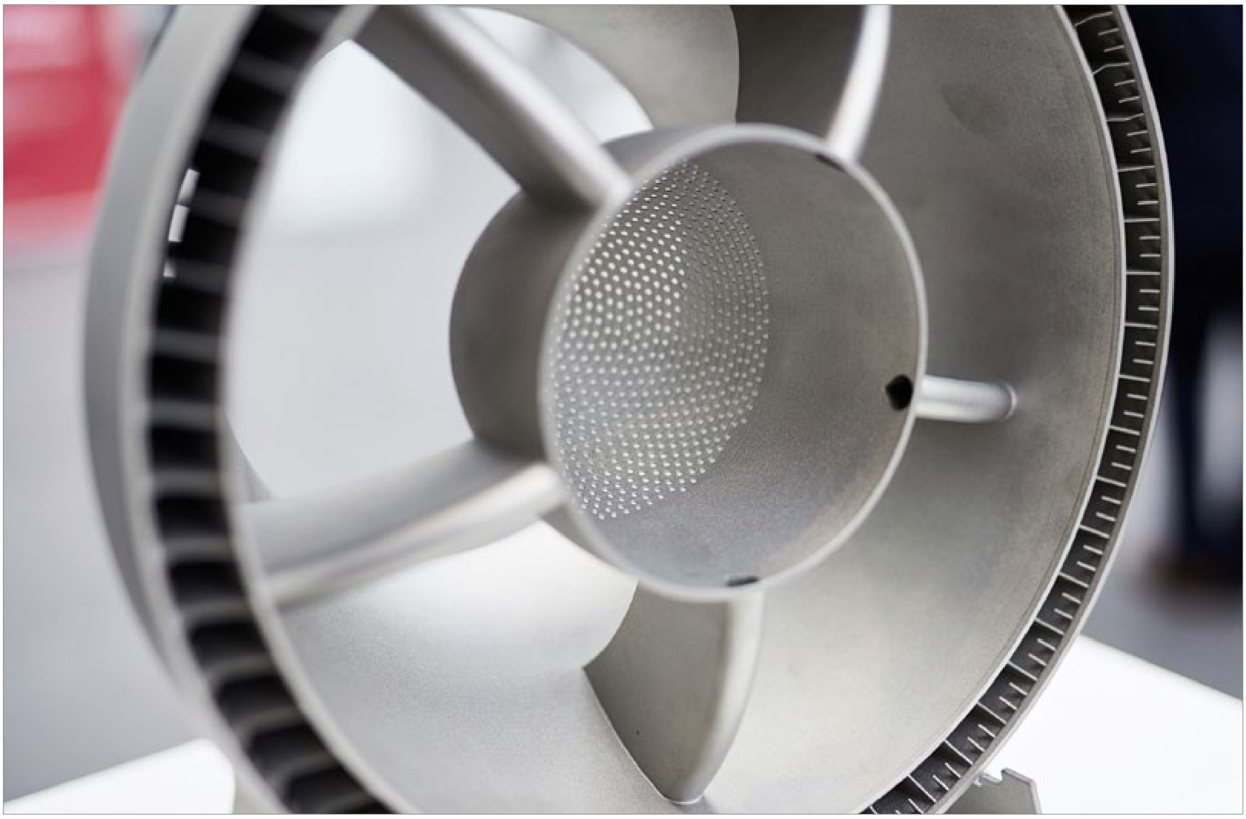


Fig. 12 This double nozzle, manufactured from Inconel 625, is a demonstration part for the aerospace sector

At the time of the agreement, Mohammad Ehteshami, Vice President and General Manager of GE Additive, commented, "GE Additive and Oerlikon both understand the transformative power of Additive Manufacturing. This is further proof that the adoption rate of additive is growing rapidly and we're proud to partner with Oerlikon." From Oerlikon's perspective, this arrangement will significantly strengthen its ability to meet the growing demand for additive components and materials for a variety of industry sectors.

Conclusion

Oerlikon believes that success will come from offering the complete AM process chain to its industrial and medical customers, becoming a single source for a full suite of integrated services for end-to-end component manufacturing, from materials, design and applications engineering to series production and post-processing. This, it states, will help customers reduce product development times and production costs, shorten their supply chains and increase the reliability, performance and sustainability profile of their AM activities.

In order to place themselves in a position to deliver on this, the company has moved quickly and decisively. In a period of just twelve months, it has become a leading player in the international AM industry through significant investments and acquisitions. There is no doubt that such developments will positively contribute to the continued growth of AM as the industry moves towards series production at a rapid pace.

The company has already demonstrated, through its organisation of the impressive 1st Munich Technology Conference (covered elsewhere in this issue), that it is open to working in collaboration with the wider community to collectively drive forward the growth of Additive Manufacturing.

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The 1st Munich Technology Conference: AM is on course for broad industrial use

More than 600 international metal AM professionals gathered in October for the 1st Munich Technology Conference. Organised and sponsored by Oerlikon, the aim of this unique event was to provide a dedicated platform for the discussion and sharing of best practices in AM production and applications, along with the business models needed to drive the industrialisation of AM. We invited Prof Dr-Ing Michael Zäh, Chair of Machine Tools and Production Technology at the Technical University of Munich, to consider the status of metal AM as revealed over the event's two days of presentations and discussions.

"A few decades from now, we will 3D print everything." Today, this is a frequently uttered platitude that at once reflects the hype and the misunderstandings that surround Additive Manufacturing technology. Undoubtedly, AM has huge potential as a replacement for conventional technologies in a large number of areas. However, we must not forget that AM is looking to compete with established technologies which can rely upon centuries of research, development and experience. As a consequence, in order to make a realistic judgment about future scenarios, we have to take a closer and more balanced look at the current status of the industry.

Oerlikon, the Swiss-based multi-technology corporate group with a long history in advanced engineering, recently provided a platform for a closer evaluation of the state of Additive Manufacturing during the 1st Munich Technology Conference. The event was held from October 11-12, 2017, at the Technical University of Munich (TUM), Germany. More than 600 AM industry professionals, from both business and academia, attended the event, as well as guests from politics and finance. Conference sessions were followed by panel discussions expertly moderated by prominent international journalist and political commentator, Dr Melinda Crane.

The conference followed the inauguration of Oerlikon's new Additive Manufacturing and Technology Centre in Feldkirchen near Munich on October 11. As highlighted previously in this issue of *Metal AM* magazine, the new technology centre aims to position Oerlikon as a

Fig. 1 The 1st Munich Technology Conference took place at the Technical University of Munich (TUM) and was dedicated to understanding the latest advances in metal Additive Manufacturing

Fig. 2 The conference attracted more than 600 international experts from the field of Additive Manufacturing

leading supplier and service provider for AM. According to the company, the centre's location will enable it to benefit from close contact with TUM and the associated Fraunhofer Institute IGCV in Augsburg, as well as with industrial leaders in the area such as BMW, Audi, Siemens, MTU Aero Engines, Airbus and General Electric, all of which are pursuing applications for Additive Manufacturing within their operations.

TUM itself was among the first academic institutions in Germany to explore additive technologies, beginning with the foundation of its Technology Transfer Centre in Augsburg in 1994, which has since been home to a successful team of scientists and specialists in AM.

The current status of metal AM

Based on the presentations at the 1st Munich Technology Conference and the lively panel discussions that followed, the current status of metal Additive Manufacturing can be characterised by the following statements:

The technology is readily available
There are today a large number of AM machine builders, all of whom appear to be successfully and continuously increasing their machine sales.

The technology has moved from prototyping to production
While in the late 1990s AM technology was predominantly known as Rapid Prototyping, with Rapid Tooling and Rapid Manufacturing also becoming common terms, it has gained ground since the 2000s and been adopted for value-added applications in many areas, even where rapidity is not really the driving factor.

There are still challenges to overcome
AM still suffers from many shortcomings, including issues relating to heat-induced distortion, poor part resolution due to the layer-based manufacturing process, potentially lower strength compared to some conventional processes, the risk of porosity and the potential for anisotropic material properties where they are not desired. FEM based simulation models also lack accuracy and validation.

Strengths and weaknesses of AM

Thanks to the impressive range of leading international figures from the world of AM in attendance, the panel discussions at the first Munich Technology Conference presented the opportunity to take a fresh look at the current status of metal Additive Manufacturing and to make a fair judgement concerning its current strengths and weaknesses.

Material efficiency
AM works without any tools or physical models and thus has an

Fig. 3 Lively panel discussions took place throughout the event, expertly moderated by Dr Melinda Crane

a-priori cost advantage over most conventional technologies. Material usage is extremely efficient: with the exception of the structures that are required to support any overhanging areas of the part during a build - and to help manage heat build-up during manufacture - there is no material wastage.

Is it correct, therefore, to say that AM is far more resource efficient than conventional technologies, as we only consume the material for building the part, thereby eliminating machining chips and other kinds of waste? Not necessarily, because manufacturing the raw material – in the majority of cases, as powder - requires an energy consuming process, and the AM process itself is energy-intensive. Materials used in metal AM will see melting temperatures at least three times during their life cycle: first in the raw material factory, second during powder production and third during the AM process. The powder required for powder bed fusion processes is also expensive when compared to material for casting or machining.

Of course, one cannot directly compare AM with conventional processes based solely on the efficiency of their materials usage. One of the key messages from the conference was that it will never make sense to simply take a part produced using a conventional manufacturing process and convert it to AM. AM thrives where there is an opportunity to add value through, for example, combining multiple components into one, designing features that have never before been possible to manufacture.

Health and safety considerations

We also must not forget about laser safety issues for laser-based AM processes and the hazards that go along with the handling of fine metal powders. The latter has risks in terms of the inhalation of carcino-genic materials, for example nickel and cobalt, as well as the significant risk of explosions when dealing with more reactive metals such as titanium and aluminium.

Parts manufactured in a powder bed require a labour-intensive removal from the working chamber and removal of adhering remainders of the powder. Managing these issues requires a considerable investment in safety measures, which poses an entry threshold for those thinking about entering AM.

Process simulation

Many AM technologies simply are not yet mature because of high heat-induced distortions. Models – predominantly based on FEM - used to predict these distortions so that countermeasures can be taken lack reliability and validation.

Design freedom

On the other hand, AM opens up completely new possibilities and features and an almost unlimited diversity and complexity of manufacturable geometries. We saw the first approaches to conformal

Fig. 4 Mohammad Ehteshami, Vice President and General Manager, GE Additive, stated at the conference, "Additive Manufacturing is still a young technology. But we've come a long way. And we are already printing things that people had predicted would only be printed in 2025. I hope that Additive Manufacturing mass production is not ten years from now, but two years from now."

cooling channels quite a while ago, honeycomb structures incorporating complex curved surfaces, movable joints manufactured in one build and topology optimised parts, to name but a few examples.

Consider the entire process chain

Is AM as simple as just one process yielding the finished part? Perhaps, in some cases. Many technologically advanced applications, however, require more accurate parts with more precise surfaces than AM alone can guarantee. Thus, finishing operations (such as milling, grinding, lapping, polishing, etc.) are necessary. So how 'rapid' is it in reality? It is rapid in the sense that we can go from CAD to process via just a few automated data manipulation steps - but the process chain can be laborious.

New markets for AM attract industry's giants

Industrial applications for AM are diverse and already numerous:

- Jet engine construction: lightweight design, complex internal features, reducing manufacturing complexity by combining multiple components into one
- Aircraft construction: bionic lightweight structures, fixation devices, interior panelling, cabin equipment such as seats and seat belt buckles in lightweight designs
- Automotive manufacturing: parts for prototypes and pilot lots, custom-designed components and low-series components for high-performance applications
- Medical technology: implants, dental prostheses, osteosynthesis-elements, hearing aids, illustrative models for surgery
- Industrial engineering: lightweight tools, conformal cooling in moulds and dies, gripper jaws
- Civil engineering: individualised components of buildings
- Furnishing: customised furniture designs
- In all industry sectors: any kind of filigree structures not economically manufacturable by other methods

It is a huge challenge to convey the new freedom in part design offered by AM to engineers in design departments; namely, the practically unlimited geometrical degrees of freedom, the ability to grade material properties within a part and even the capacity to manufacture joints within one build job. In embracing AM, we all have to rethink design from scratch.

The annual Wohlers Report indicates sound AM market growth of more than 25% per annum on average since the early 1990s. It has now reached sales of well over $5 billion per annum. Meanwhile, many enterprises are acknowledging the potential of AM and intensifying their activities in this field. The expansion of Oerlikon's activities in relation to metal AM is by no means unique, and the technical media appear to report new stories on the AM activities of enterprises on a weekly basis.

ThyssenKrupp AG, for example, the German steel and technology provider, recently opened a Tech-Center for Additive Manufacturing and considers the technology mature for industrialisation. The company mentions a number of workpieces realised on the basis of AM. Laser deposition using metal powders ranks high on ThyssenKrupp's agenda.

Half a year earlier, the entry of Voestalpine into Additive Manufacturing was also reported. Voestalpine is ThyssenKrupp's Austria-based competitor, and considers AM technology to be disruptive because of the multitude of new applications that it will make possible. Buzzwords of special interest are conformal cooling and shortened cycle times.

General Electric is currently undergoing a reorganisation of its research activities, which will have an impact on its Technology Centre in Garching, near Munich. While reallocating most of its research work to the business units, research on AM will remain a centralised activity in Garching. A new building, reserved just for AM, is nearing completion and is expected to employ more than one hundred staff in the long term. Not to be forgotten is GE's recent acquisition of machine builders Concept Laser and Arcam – extremely important acquisitions in the AM sector and a milestone in the development of the industry. So, GE has cutting-edge machine competence aboard.

Fig. 5 Dr Hans J Langer, Executive Chairman, EOS Group, put into perspective the recent rapid growth in AM, stating, "It took EOS twenty years to sell the first 1,000 systems [1990-2010], another five years to sell the second 1,000 systems, and the last two and a half years to sell the third 1,000 systems. Today we have a worldwide installed base of around 3,000 systems. As of 2018, we'll be able to produce and install 1,000 systems per year."

Fig. 6 Prof Johannes Schleiffenbaum (right), from RWTH Aachen University, stated, "The beauty of Additive Manufacturing is that you can directly transform ideas into reality. This will enable engineers to be more creative and develop completely new things."

MTU Aero Engines has been working on AM for aviation for many years, in cooperation with Technical University of Munich at its Competence Centre for Construction Techniques. Some parts are already flying. In collaboration with TUM, a small jet-engine inspection opening was designed and optimised by taking advantage of AM's capabilities, in particular the geometric design freedom the technology offers.

BMW and Audi both have ample laboratory space for the technology and see application potential in tool and die making, for the building of prototypes and pilot lots, for filigree structures and for low volume

Fig. 7 Michael Schreyögg, Chief Program Officer, MTU Aero Engines AG, stated "AM achieves improvements through weight reductions of bionically designed parts. A bracket on an Airbus A350 that flight attendants use to steady themselves can now be additively manufactured with titanium – and weighs 500 g less. Extrapolating that over the 30 year life of an aircraft, this will result in a reduction of 300,000 tons of CO_2."

Fig. 8 Dr Karsten Heuser, Competence Center AM, Siemens AG, commented during his presentation, "Additive Manufacturing is a big investment for Siemens. But it's also a necessary investment."

applications. Both have recently intensified their cooperation with academia.

Last but not least, Deutsche Bahn, Germany's railway company, will reorganise its strategy for spare parts by making use of on-demand Additive Manufacturing to produce them as needed instead of storing them.

The impact on business models

With the advent of AM in industrial environments, it is very likely that a change in business models will take place – both in terms of the customer interface and changing internal procedures. Internal procedures will focus more on part design, on topology optimisation and on process simulation in order to benefit from AM's strengths. On the other hand, process planning will lose importance and become a standard procedure.

For suppliers in the field of conventional technologies, the question is whether there is a risk of becoming obsolete over time.

One successful business model we have seen is to offer the Additive Manufacturing of parts in the sense of a job shop. So AM is a technology which one would typically expect to be adopted by small- to medium-sized enterprises (SMEs), which have the flexibility and agility to enter AM. On the other hand, workplace safety and laser safety are more of an obstacle for SMEs compared to large industrial conglomerates, with the resources to allocate to new technologies.

Another challenge is to encourage designers to rethink design by taking the new possibilities offered by AM into consideration. German universities and colleges have only recently begun to educate the new generation of engineers, and coursework offered on AM is not yet substantial.

During Oerlikon's Munich conference, BMW's Dr Susanek presented a sober approach to a technology that has been subject to so much hype. According to Susanek, apart from building prototypes and low volume runs, not much application potential has been exploited yet within BMW. His application examples in production are few, and are more or less limited to custom-made design elements.

The medical industry has seen some of the greatest advances. Dental implants made by AM are state of the art, and the same holds true for knee and hip implants as well as many other devices, requiring a high degree of geometry optimisation and individualisation.

In recent years, magnesium has been discovered as a promising chemical basis for implants for bone repair. Magnesium and some of its alloys are biodegradable; meaning the human body dissolves them within months and without any harm to the patient. As a result, bone repair can be done using brackets made from magnesium and a second operation to remove the brackets becomes obsolete. A challenge to be mastered is the high reactivity of magnesium powder, and the working chamber of the AM machine has to be filled with shielding gas to avoid explosions.

Outlook

Additive Manufacturing is among the youngest of all production technologies. Will we print everything one day? I do not think so. This article is supposed to give a fair and realistic perspective on AM. There is a stable and above-average growth of the market, with good reason; AM will certainly capture its place on the palette of all manufacturing technologies and reach a broad industrial use. What can we contribute? Work hard, research relentlessly, educate our students well and, above all, remain optimistic and open minded.

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2nd Munich Technology Conference

It has been announced that the Second Munich Technology Conference (MTC2) will take place from October 10–11, 2018. For more information visit the event website:

www.oerlikon.com/am/#!mtc-event.php

Fig. 9 Dr Roland Fischer (left), CEO Oerlikon, with Dr Melinda Crane (centre) and Florian Mauerer (right), Head of Oerlikon's Additive Manufacturing Business Unit. Fischer stated at the close of the conference, "Looking at the industrialisation of AM, there is still a lot of work to be done. However, it is not a question of 'if' but 'when'. Once it happens, AM will bring massive changes in industry."

Fig. 10 A conference reception was held at the Residenz in central Munich, the former royal palace of the Wittelsbach monarchs of Bavaria. The Residenz is the largest city palace in Germany.

Combining Metal AM and Hot Isostatic Pressing (HIP): Application and process innovations

A technical session at the Euro PM2017 conference, held in Milan, Italy, October 1-5, 2017, investigated three different concepts in processes that combine metal Additive Manufacturing with Hot Isostatic Pressing (HIP). In the following report, Dr David Whittaker reviews three papers that consider the use of SLM for the manufacture of HIP capsules, HIP as a final densification process in AM, and finally HIP as a process to join EBM processed components into larger structures.

Selective Laser Melting for thin-walled HIP capsule manufacture

A paper from Sebastian Riehm, Anke Kaletsch and Christoph Broeckmann (RWTH Aachen, Germany) and Sandra Wieland and Frank Petzoldt (Fraunhofer IFAM, Bremen, Germany) investigated the use of Selective Laser Melting (SLM) for HIP capsule manufacture, as an alternative to the expensive and time-consuming approach of fabrication from sheet metal. The investigated approach was to build open capsules by SLM and fill them conventionally with powder for HIPing.

In the reported study, the production of monolithic components through this combination of SLM and HIP was presented. As a further variant of this route, the outer capsule could be made from a wear- or corrosion-resistant material, with the inner bulk material offering high toughness and strength. For this approach, the capsule was manufactured as an open hollow body. Building components by SLM is a time-consuming process and, therefore, the thickness of the capsules was kept to an absolute minimum. After SLM-building, a filling pipe was conventionally welded onto the capsule, allowing filling and closing of the capsule. This combined process allows the production of complex net-shape composite components.

Table 1 shows four combinations of materials: two monolithics, where capsule and bulk were from the same material, and two composites, where a capsule of stainless or wear resistant steel was to be filled with powder of tool steel. The chemical compositions of the investigated powders can be seen in Table 2. While the goal of this project was to build complex composite components

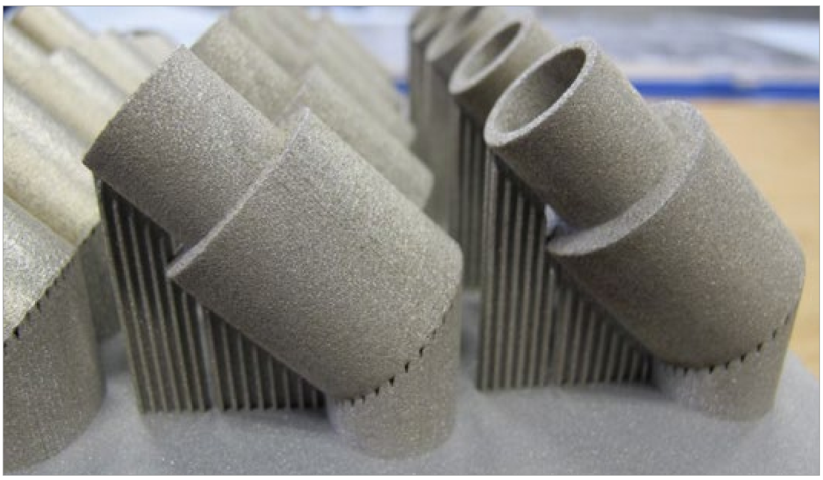

Fig. 1 316L cylinders produced by SLM [1]

	Capsule	Bulk
Monolithic	Martensitic tool steel 56NiCrMoV7 (1.2714)	
	Austenitic stainless steel X2CrNiMo17-13-2 (1.4404 / 316L)	
Composite	Austenitic stainless steel X2CrNiMo17-13-2 (1.4404 / 316L)	Martensitic tool steel 56NiCrMoV7 (1.2714)
	Carbide rich, wear resistant steel X245VCrMo8-5-1 (DEW FeCrV10)	Martensitic tool steel 56NiCrMoV7 (1.2714)

Table 1 Materials for monolithic and composite components [1]

	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	N	B	O	Fe
56NiCrMoV7	0.52	0.28	0.96	< 0.01	0.002	1.22	1.99	0.5	0	0.11	0	0	0	Bal
316L	0.021	0.8	0.95	0.009	0.004	17.3	13.2	2.5	0.05	0	0.14	0.001	0	Bal
FeCrV10	2.45	0.98	0.42	0.02	0.087	5	0	1.49	0	8.28	0.098	0	0.035	Bal

Table 2 Chemical compositions of the investigated powder materials [1]

by SLM and HIP, some initial basic experiments were conducted with simple cylindrical capsules. Fig. 2 shows the geometry and the first batch of SLM-manufactured cylinders with outer diameter of 25 mm and height of 25 mm. The wall thickness of the cylinders varied from 0.3 mm to 2.0 mm. The cylinders were produced at IFAM using an EOS M270 Dual Mode SLM machine.

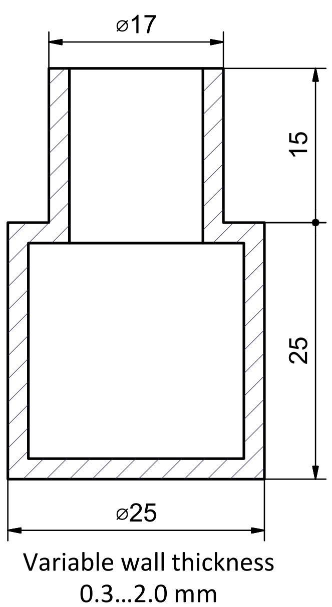

Fig. 2 Geometry of the first batch of SLM-made cylinders [1]

After the SLM build, the cylinders were removed from the building platform and the support structure was removed from the cylinders by wire erosion. Afterwards, a longer filling pipe was TIG welded onto the short SLM-made lug. Every capsule was filled with 316L powder to a relative density of around 50 to 60%, evacuated and sealed.

Capsules with a wall thickness of less than 1 mm had defects, in that they either had holes from the wire erosion or the welding of the pipes was not successful. For this reason, only three capsules with wall thicknesses of 1.0 mm, 1.5 mm and 2.0 mm could be prepared for the first HIP cycle.

The deformation and shrinkage during HIP can be numerically simulated by FEM-based methods. In order to design a net-shape component, the necessary geometry of the capsule prior to HIP can be optimised by using this numerical simulation routine.

In this study, a macroscopic simulation model was used, based on a yield criterion and particularly formulated for porous continua. The simulation routine was implemented as a user sub-routine in the commercial FEM software package Simulia Abaqus.

Prior to the first HIP cycle with SLM-built capsules, an experimental cycle was conducted to investigate the influence of HIP on the microstructure of carbide rich steel samples made by SLM. Samples of around 5 x 5 x 5 mm were built from a powder mixture of 82.5 w% FeCrV10 + 17.5 w% X6Cr17. The HIP parameters used were: Temperature = 1100°C, Pressure = 100 MPa, Holding time at temperature = 120 min.

Fig. 3 shows micrographs of the SLM samples of the FeCrV10 mixture: (left) before HIP and (right) after HIP. In the as-built state, the melting traces of the laser beam were clearly visible and pores and voids could be seen. In the as-HIPped state, nearly all voids had been closed and the material was homogenised; the laser beam tracks were no longer visible.

The SLM-made capsules were subsequently filled with powder, evacuated, gas-tightly closed and hot isostatically pressed using the following HIP parameters: Temperature = 1125°C, Pressure = 110 MPa, Holding time at temperature = 120 min. The capsules with a wall thickness of 1.5 mm and 2.0 mm were densified. Only the capsule, with wall thickness of 1.0 mm, did not densify, because it was not gas-tight.

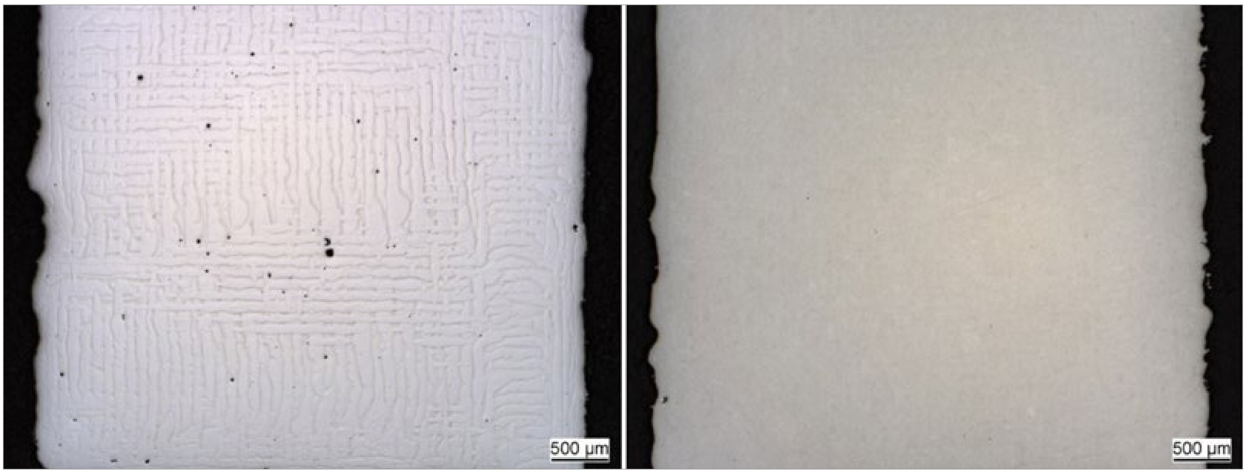

Fig. 3 Micrograph of FeCrV10 before (left) and after (right) HIP [1]

Fig. 4 (left) shows a cross section of the capsule with 1.5 mm wall thickness. The densification and high homogeneity are obvious. In Fig. 4 (right), a detailed view of the upper left corner is shown. While there are only very few pores and voids in the capsule, the inner bulk exhibits a high number of irregularities. This is now the subject of further investigations to determine which of these voids are real pores and which are merely artefacts of metallographic preparation. The interface region between capsule and bulk powder can still be easily identified.

In this early state of the project, the geometry of the capsules has not been optimised by numerical FEM simulation. Instead, the initial geometry of the capsules was numerically modelled in order to compare the calculated and the real dimensions after HIP. In a further step, capsule geometry will be optimised to obtain the desired shape after HIP. The results of the current FEM simulation are shown in Fig. 5 and indicate full densification of the entire sample. Fig. 5 also shows the results of the simulated contour of the capsule after HIP (red solid line) and the experimentally determined contour after HIP (black solid line). The model is clearly already well capable of predicting qualitatively the shrinkage during HIP, but, in terms of quantitative accuracy, there is potential for improvement. Particularly at the bottom, the simulation routine seems to overestimate the shrinkage. It was noted that simulation results of conventionally produced capsules, made by the welding of sheet metal, yield a much better quantitative accuracy.

As SLM components are built layer by layer, they exhibit anisotropic material parameters. Therefore, properties depend on the building direction.

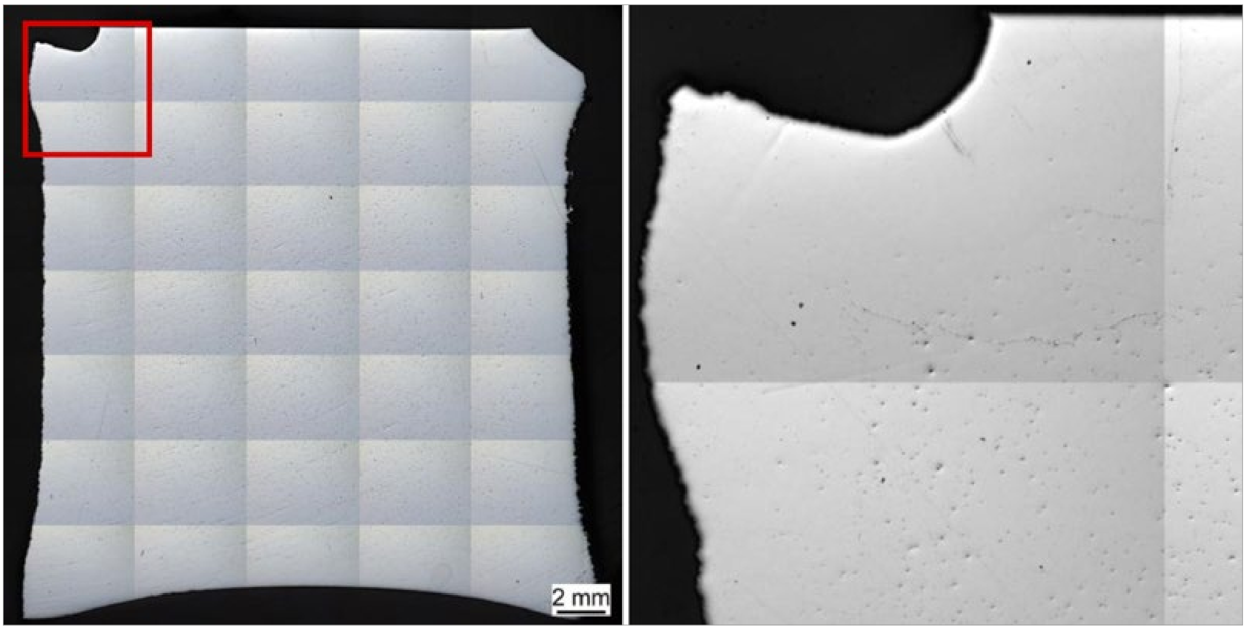

Fig. 4 Cross section of capsule with wall thickness 1.5 mm (left) and detail of upper left corner (right) after HIP [1]

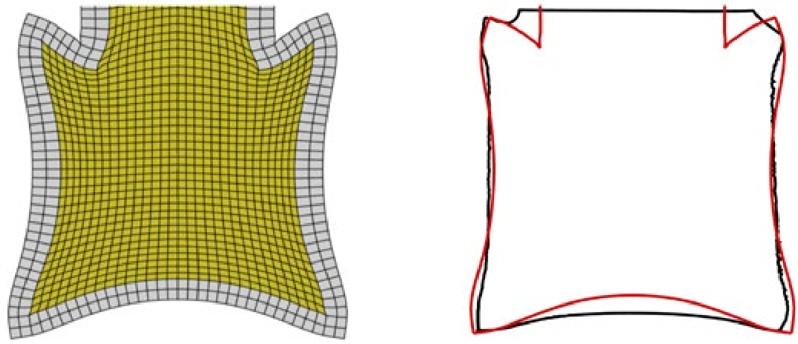

Fig. 5 FEM simulation of capsule; left: after simulation; right: comparison of simulation with real capsule after HIP. (all wall thicknesses 1.5 mm) [1]

It remains to be investigated the extent to which material properties of conventional material can be used for additively manufactured material.

Two other mechanisms that could have an impact on the component after HIP are friction and gravity: The base components of the HIP unit cause a counterforce to the shrinkage of the body. This counterforce impedes the shrinkage. Also, gravity acting on the powder particles influences the deformation. These results are strong evidence that gravity and friction need to be taken into consideration in HIP simulation.

HIP as post-build densification treatment in Additive Manufacturing

A paper, from Johannes Kunz, Anke Kaletsch and Christoph Broeckmann (RWTH Aachen University, Germany), then focused on the more "standard" combination of the two technologies, with HIP being used as a post-build densification treatment. The reported study was aimed at assessing the influences of both the HIP treatment and build position on the SLM platform on the derived mechanical properties.

Elements	Fe	C	Si	Mn	Cr	Ni	Mo
wt.%	Balance	0.018	0.63	1.47	16.5	10.2	2.1

Table 3 Chemical composition of the 316L powder [2]

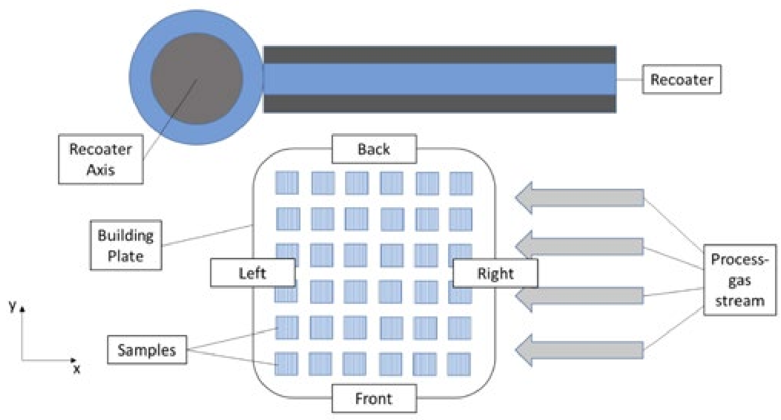

Fig. 6 Schematic setup of the building chamber in the SLM process [2]

In the study, the powder used was a type 316L stainless steel with a material density of 7.91 g/cm^3 and a chemical composition as shown in Table 3. This powder was manufactured by gas atomisation by Carpenter Powder Products Inc. The powder particles had spherical or nearly spherical shapes with some satellite particles. The powder size distribution was determined and exhibited d_{10} = 30.9 µm , d_{50} = 42.2 µm and d_{90} = 60.2 µm, thus showing a shifted and closer particle distribution than that commonly used in SLM powders. A bulk density of 4.15 g/cm^3 was determined. In an earlier study by the same authors, the fatigue strength was determined by rotating bend fatigue testing. The staircase procedure with a surviving level of 10^7 cycles was applied. The fatigue strengths were determined for a fracture probability of 50%. The fatigue strengths, $\sigma_{A,50}$, were around 305 MPa in the as-built condition and around 338 MPa after HIP.

In this further study, SLM was carried out using a SLM 100 machine (Realizer GmbH), working with a Ytterbium 200 W fibre laser and a layer thickness of 50 µm. Scanning parameters, such as laser power, laser focus, scanning speed and hatch strategy, were defined for the support structure, outer boundaries and inner areas. These parameters were optimised with respect to density. The density-optimised set of parameters led to a sample density of 7.91 g/cm^3. During the process, argon was used as the process gas. Fig. 6 shows the schematic setup of the building chamber in the SLM process.

For the mechanical test programme, highly filled building plates were produced, with 36 cylinders or 25 cuboid samples produced on each building plate. The post-build HIP cycle was carried out at a temperature of 1125°C, a pressure of 100 MPa and a dwell time of 3 h.

Tensile tests, rotating bend fatigue tests and Charpy impact tests were performed. As the focus of this study was on the influence of building position and HIP post treatment on

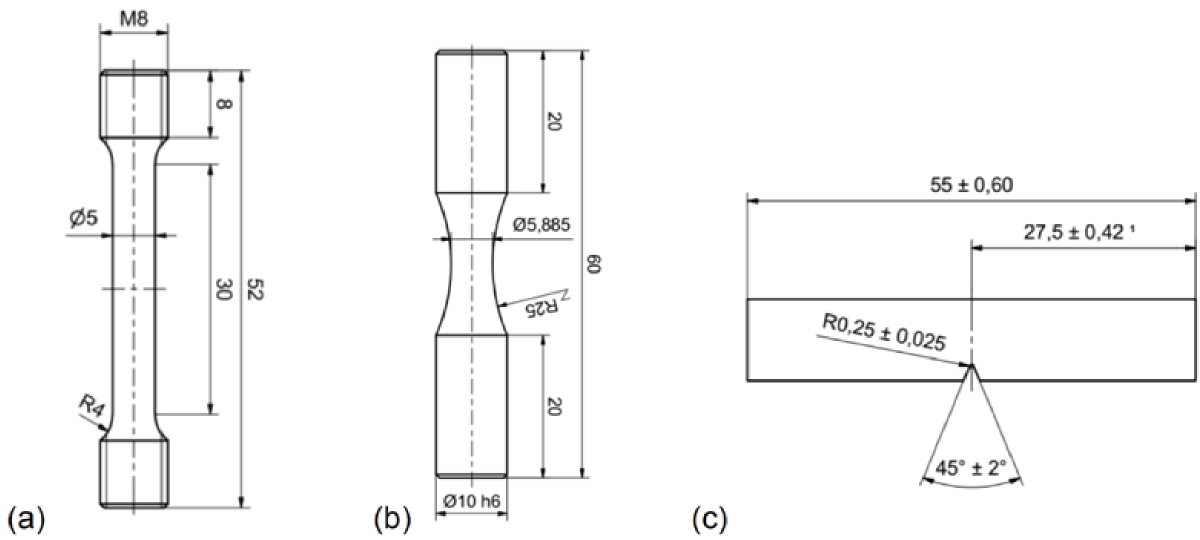

Fig. 7 Sample geometry for tensile tests (a), rotating bend fatigue tests (b) and Charpy impact tests (c) [2]

the bulk material properties, the original SLM specimen surfaces were removed by machining. The cylinders manufactured by SLM were machined to the sample geometry, shown in Fig. 7 (a).

In the SLM condition, the average tensile strength of all samples was determined as 583.6 ± 46.2 MPa and the average uniform elongation as 24.2 ± 11.4%. Fig. 8 shows the tensile strength and uniform elongation as a function of the position on the plate. The lines represent samples at the back, middle and front from left (position 1) to right (position 3) on the plate. In the middle and back positions, only small variations are visible. The front line positions 2 and 3 show the lowest values of elongation. The tensile strength drops significantly in position 3. This position is characterised by having the largest distance from the rotation axis of the recoater.

Table 4 shows proof stress $R_{p0.2}$, ultimate tensile strength R_m, uniform elongation A_g and fracture elongation A_f of the samples in the as-built and HIPed conditions. After HIP, a tensile strength of 577.5 ± 5.1 MPa, a uniform elongation of 56.2 ± 2.9% and a fracture elongation of 73.7 ± 5.6% were measured. It was therefore evident that the large scatter in properties could be reduced by HIP.

For the determination of the fatigue properties, rotating bending tests were carried out with a stress ratio of R = -1. The cylindrical samples were machined to the sample geometry as shown in Fig. 7 (b). The tests were performed with a frequency of about 100 Hz. The stress amplitude was set at 310 MPa for the as-built condition and 340 MPa for the HIPed condition. These values were slightly above the fatigue strengths determined in the prior study. The survival level was set at 10^7 cycles. Surviving samples were tested again at a higher stress level. The fracture origins were identified by Scanning Electron Microscopy (SEM) analysis.

In the fatigue testing, only one sample in the as-built condition fulfilled the survival level of 10^7 cycles.

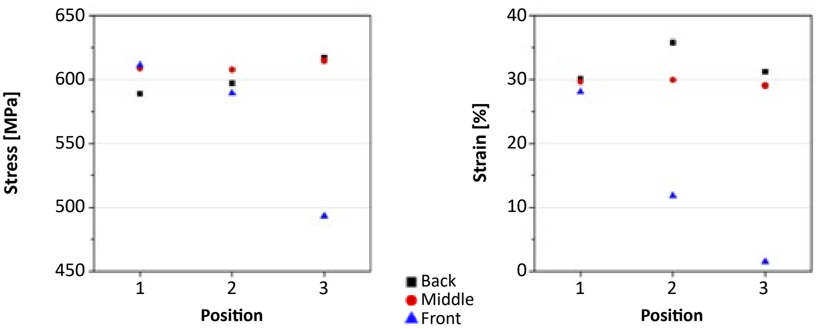

Fig. 8 Ultimate tensile strength and uniform elongation as a function of the position on the plate [2]

	$R_{p0.2}$ [MPa]	R_m [MPa]	A_g [%]	A_f [%]
As-built	492 ± 20.4	583.6 ± 46.2	24.2 ± 11.4	34.9 ± 15.6
HIP	312 ± 9.2	577.5 ± 5.1	56.2 ± 2.9	73.7 ± 5.6

Table 4 Tensile test data of the samples in the as-built and HIPed conditions [2]

	Surviving cycles	Number of samples
Center (2x2)	1 732 667 ± 863 448	3
Center (4x4)	1 620 636 ± 1 397 910	11
All	1 099 391 ± 1 151 983	23

Table 5 Surviving cycles in the as-built condition at the stress level of 310 MPa [2]

	Left	Number of samples	Right	Number of samples
Back	1 498 500 ± 558 500	2	2 502 500 ± 2 064 500	2
Front	657 000 ± 335 055	3	92 000 ± 38 893	3

Table 6 Surviving cycles of areas located at the corners in the as-built condition at the stress level of 310 MPa [2]

	As-built	Number of samples	HIP	Number of samples
Inner Area [J]	116 ± 12	9	77 ± 7	9
Outer Area [J]	111 ± 28	16	72 ± 9	16
All [J]	113 ± 23	25	74 ± 9	25

Table 7 Impact toughness in the as-built and HIPed conditions [2]

	Left		Right	
	As-built	HIP	As-built	HIP
Back	88 ± 31 J	85 ± 6 J	143 ± 8 J	75 ± 7 J
Front	112 ± 10 J	68 ± 3 J	108 ± 20 J	64 ± 3 J

Table 8 Impact toughness of areas (2x2) located at the edges in the as-built and HIPed conditions [2]

Table 5 and Table 6 show the average surviving cycles of premature failures in different areas of the building plate. The values were taken from the centre 2 x 2, the centre 4 x 4 area and the 2 x 2 corners. Additionally, an average over the entire building plate is given, excluding those locations that were used in the tensile tests. Closer to the outer area, the average surviving cycle number is reduced. The front right corner exhibits a tendency to low cycle numbers.

After HIP, at a stress level of 340 MPa, five samples broke before fulfilling the survival level demand. The broken samples had an average cycle number of 1,788,600 ± 936,242. At a stress level of 380 MPa, five samples reached the survival level demand. The average cycle numbers of the failures are 143,000 ± 101,008. After HIP, no obvious dependency between the number of cycles survived and the building position could be observed.

Fracture analysis, using SEM and EDX, on premature failures has attributed the fracture origin to two main defects, pores and oxidation phases. EDX analysis on the oxides showed the constituents to be mainly silicon, chromium, manganese and oxygen.

Charpy impact tests were conducted, with the cuboid samples being machined to the specimen geometry shown in Fig. 7 (c). The as-built samples exhibited an impact toughness at room temperature of 113 ± 23 J. After HIP post-treatment, an average toughness of 74 ± 9 J was measured. An overview of the toughness in the as-built and HIPped states is given in Table 7. By subdividing the plate into inner (3 x 3) and outer area, a tendency can be seen. A toughness of 116 ± 12 J for the inner area and of 111 ± 28 J for the outer area was measured. Table 8 shows the values of the areas (2 x 2 samples) located at the corners in the as-built and HIPed conditions. The area located back left exhibits the lowest impact toughness with the largest standard deviation. The difference between the areas with the highest and lowest values is about 55 J. After HIP, the largest difference in toughness is about 25 J and can be found along the plate diagonal (back left to front right).

The authors drew the following overall conclusions:

- Tensile tests, Charpy impact tests and rotating bend fatigue tests revealed a positional dependence for samples in the as-built condition. In all tests, a regional variation could be observed. In particular, the ductility and the fatigue strength were highly sensitive to the building position.
- Post-build HIP treatment decreased the deviation of properties on a building plate.
- Due to the reduced porosity level, the fatigue strength increased after HIP
- A post-build HIP treatment also increased ductility
- Average toughness decreased after post-build HIP treatment, but the variability was reduced

This study has, therefore, indicated that a HIP post-treatment improves the reproducibility of properties of SLM samples.

For future investigations, the authors plan to examine the influence of HIP treatment followed by solution annealing with rapid cooling on the toughness.

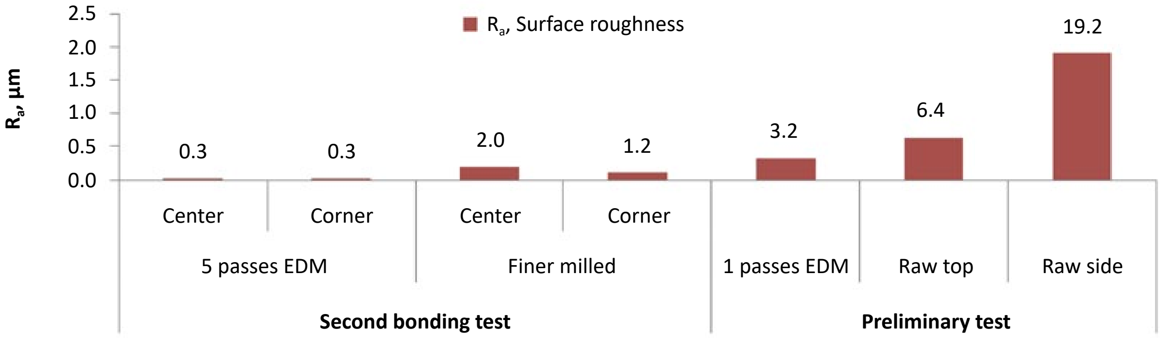

Fig. 9 R_a, by surface, which is the surface roughness. This graph does not display the roughness of the milled surfaces in the preliminary test [3]

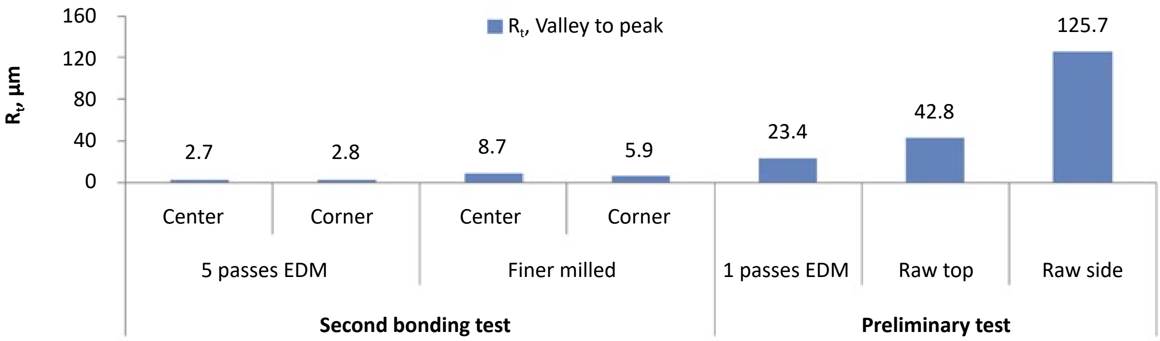

Fig. 10 R_t, by surface, which is the peak to valley distance of a certain measurement. This graph does not display the roughness of the milled surfaces in the preliminary test [3]

HIP bonding of EBM-built blocks

Finally, Pelle Mellin, Hans Magnusson and Joakim Algardh (Swerea KIMAB, Sweden), Peter Harlin (Sandvik Materials Technology, Sweden), Stefan Wikman (F4E, Spain), Jon Olsen and James Shen (Stockholm University, Sweden), Lars-Erik Rannar (Mid Sweden University) and Lars Nyborg (Chalmers University of Technology, Sweden) reported on a study of a process route involving the HIP-bonding of EBM-built blocks of 316L stainless steel, with particular reference to a potential application in an experimental nuclear fusion reactor.

316L stainless steel is the designated material for use in the First Wall Beam in the ITER reactor. In contrast to previous research on HIP-bonding of 316L, the material in this paper was built by EBM. HIP of EBM highly critical components, to heal any defects, such as pores and cracks, is usually advisable, in any case. Using HIP to simultaneously bond several print jobs together into a larger component saves time and reduces manufacturing complexity.

"Using HIP to simultaneously bond several print jobs together into a larger component saves time and reduces manufacturing complexity."

Two attempts to bond blocks were made. In a preliminary test, the surface roughness of the blocks was varied. Secondly, a test using larger blocks was carried out, using the most successful surface preparations from the preliminary test and, in this case, HIP parameters were instead varied.

The preliminary test involved the use of the 'raw' as-built surface finish and the use of milling and electro-discharge machining (EDM) to refine surface finish.

The various surface finishes are characterised in terms of R_a and R_t (peak to valley distance) in Figs. 9 and 10, respectively.

In this preliminary test, slices with the prepared surfaces were put into a HIP capsule as a stack of slices. Fig. 11 shows the iron

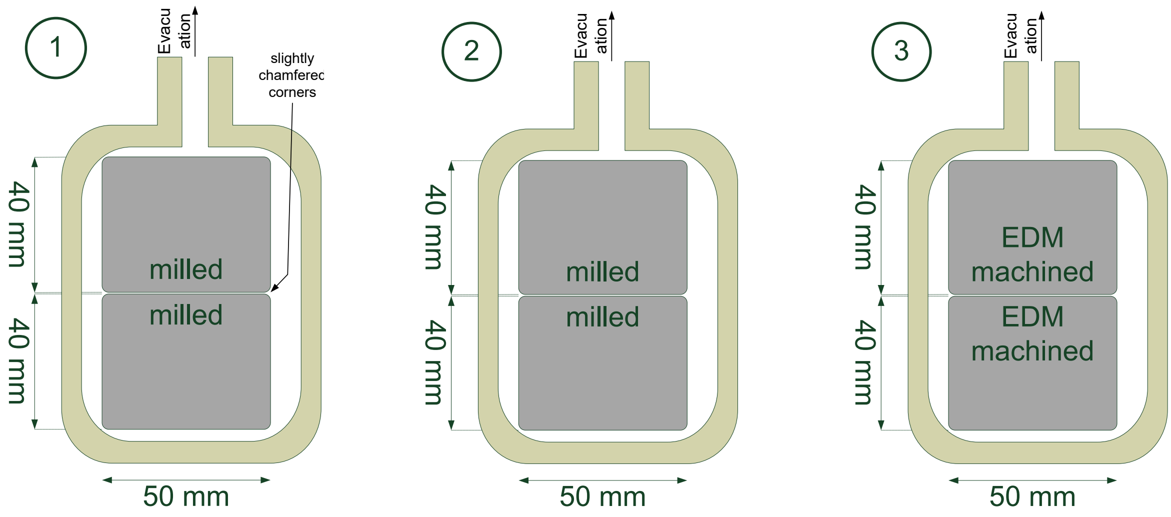

Fig. 11 The capsules that were evacuated and HIPed to bond each pair of blocks together [2]

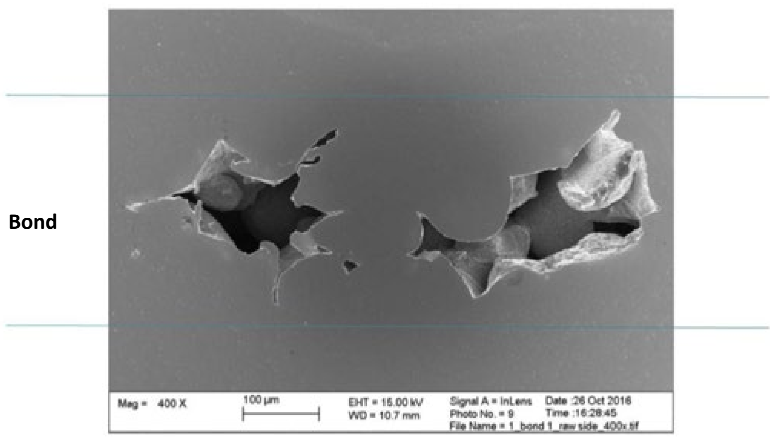

Fig. 12 Incomplete bond (preliminary test). Raw side surfaces (parallel to the build direction, R_a = 19.2 µm) that were bonded together, using 1150°C, 1000 bar, holding time 1 h. Here large pores are visible [2]

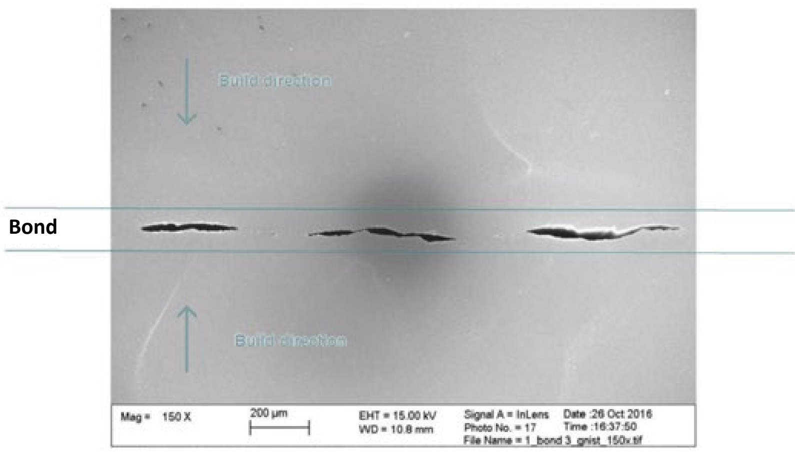

Fig. 13 Incomplete bond (preliminary test). Raw top surfaces (R_a = 6.4 µm) that were bonded together, using 1150°C, 1000 bar, holding time 1 h. Here large pores are visible [2]

capsules that were used to enclose the blocks to be bonded. Evacuation, in order to not trap any gases in the bond, was performed before welding the capsules and pressing them. The HIP cycle applied (by Sandvik Materials Technology) comprised 1150°C HIP temperature, 1000 bar pressure and 1 hour holding time.

SEM was used to investigate the centre of the bonds, with the outcome shown in Figs. 12 and 13. Here, none of the surfaces were completely bonded, although the milled surfaces were much closer to a complete bond.

In the second set of tests, larger blocks were used and milling was selected as the preferred surface finish modification method. HIP parameters were varied, according to the following programs:

- 1150°C, 1000 bar, holding time 2 h (carried out by Swerea KIMAB). This cycle ran 1 capsule for the second test, containing milled blocks and produced a near perfect bond (Fig. 15)
- 1200°C, 1000 bar, holding time 2 h (carried out by Swerea KIMAB). This cycle ran 1 capsule for the second test, containing milled blocks and, again, produced a near perfect bond. Also, 1 capsule for the second test, containing EDM-cut blocks, was run. Incomplete bonding resulted, in this case (Fig. 15).

The conclusion drawn from the preliminary test was that fine surface roughness is an important enabler for a good bond. High HIP temperature, pressure or time could also offset a rougher surface, although more severe HIP conditions can also increase the risk of shape distortion and abnormal grain growth. During the second set of tests, it was demonstrated that finer surfaces (Ra = 2 µm) and longer HIP time (2 h) (without increasing HIP temperature) could be used to achieve a good bond.

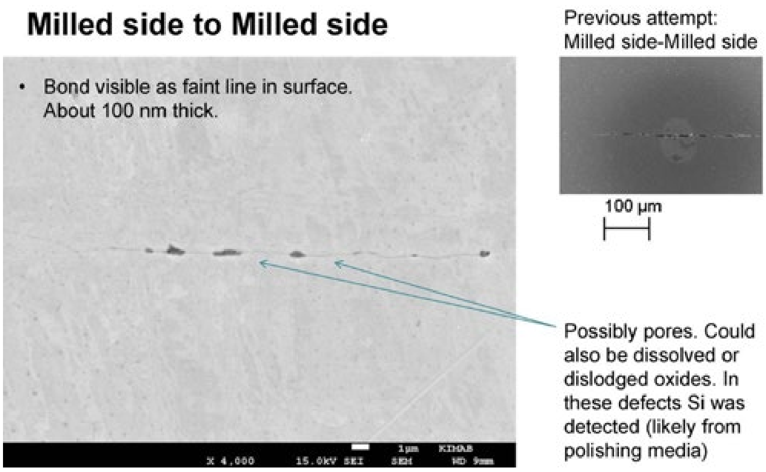

Fig. 14 Near perfect bonding test (second test). Here, two milled surfaces (R_a = 2) were bonded, using 1150°C, 1000 bar, 2 h holding time [2]

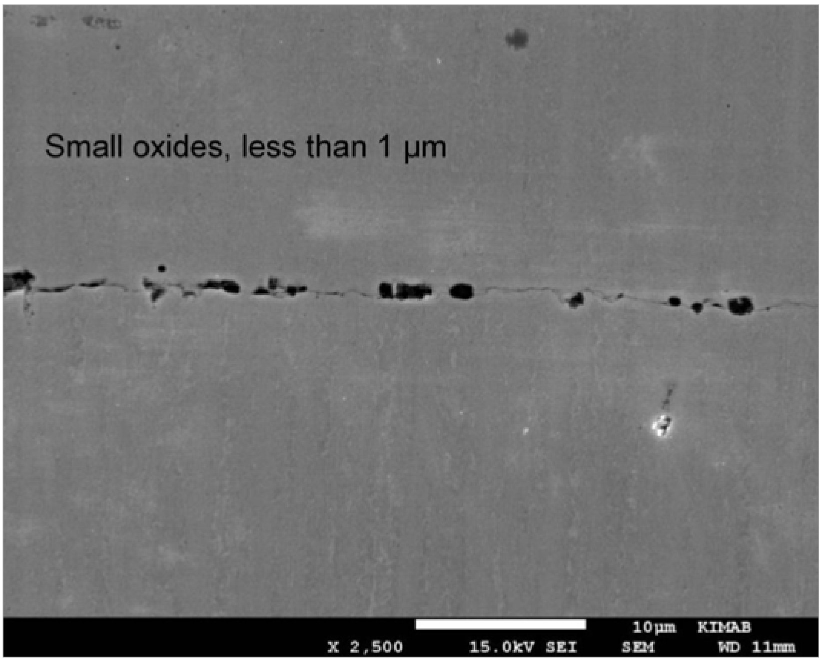

Fig. 15 Incomplete bonding test (second attempt). Here two EDM surfaces (R_a = 0.3) were bonded, using 1200°C, 1000 bar, 2 h holding time [2]

References

[1] Net-Shape Components Produced By Combining Additive Manufacturing And Hot-Isostatic Pressing, S Riehm, A Kaletsch, C Broeckmann, S Wieland and F Petzold, as presented at Euro PM2017 Congress and Exhibition, Milan, Italy, October 1-5, 2017, and published in the Conference Proceedings by the European Powder Metallurgy Association (EPMA).

[2] Influence of the Building Position and Post HIP Treatment on Properties of SLM Components, J Kunz, A Kaletsch and C Broeckmann, as presented at Euro PM2017 Congress and Exhibition, Milan, Italy, October 1-5, 2017, and published in the Conference Proceedings by the European Powder Metallurgy Association (EPMA).

[3] Bonding EBM-built Blocks of 316L Steel, Using Hot Isostatic Pressing, P Mellin, H Magnusson, P Harlin, S Wikman, J Olsén, Z J Shen, L-E Rännar, J Ålgårdh and L Nyborg, as presented at Euro PM2017 Congress and Exhibition, Milan, Italy, October 1-5, 2017, and published in the Conference Proceedings by the European Powder Metallurgy Association (EPMA).

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Costs and considerations when investing in a metal Additive Manufacturing system

Making the investment in a metal Additive Manufacturing machine is, for many, the first step on a journey to truly understanding how the technology can transform a business. There are, however, many considerations when planning such an investment; from essential ancillary equipment and devices, such as sieving stations, to facility changes, software and support. In this exclusive report, Terry Wohlers and Olaf Diegel highlight some of the commonly overlooked costs and considerations when making the move to establish an in-house AM capability.

Growth and interest in metal Additive Manufacturing have never been stronger. Previously, companies might buy one or two systems for qualification and testing. Now, companies are buying many at a time for manufacturing in large quantities. In September 2017, SLM Solutions reported a sales contract of fifty metal AM machines to a customer in China, amounting to €43 million. This was followed at formnext 2017 with the announcement of an order for a further twenty machines to an Asian customer valued at €37 million. Other machine manufacturers are no doubt also doing brisk business.

Most of the metal AM systems on the market are based on Powder Bed Fusion (PBF) technology. Major companies in this business are EOS, GE, Renishaw, SLM Solutions and 3D Systems. Among the lesser known companies that offer metal PBF machines are Additive Industries, AddUp, Bright Laser Technologies, Farsoon and Realizer. In preparing *Wohlers Report 2017*, Wohlers Associates identified twenty-eight companies worldwide that produce metal PBF systems. Fifteen are in Asia and eleven in Europe, but only two in the USA. One US company is General Electric (GE), which entered the business through its acquisition of Arcam and Concept Laser - both European companies. The other is 3D Systems, which entered the metal AM market through its acquisition of Phenix Systems and LayerWise, also two European companies.

Metal AM machines

The list prices of industrial AM machines are not as easy to get as one might think. We have obtained and published base prices of metal AM machines in *Wohlers Report* 2017. They range from about $115,000 for a relatively small and basic configura-tion to nearly $1.9 million for a

Fig. 1 The level of activity at formnext powered by tct 2017 is testament to the rapidly increasing interest in metal AM (Source: Mesago/Thomas Klerx)

Fig. 2 A sieving station (Courtesy Olaf Diegel)

Fig. 3 Gas bottles containing nitrogen and argon (Courtesy Olaf Diegel)

machine that can produce parts as large as a full-scale V6 engine block. With so many companies now offering their own systems, the pricing and number of options is extensive and increased competition are starting to force prices downward.

Sieving equipment for powder recycling is an important part of a metal AM system. Some machine manufacturers will bundle sieving equipment with the price of the machine. To avoid unpleasant surprises after a purchase, it is important to understand what is included with the machine and what isn't. It is not unusual for customers to learn that something is missing only because they failed to ask the right questions. If you are unaware of some of the process steps and 'hidden' costs, it is impossible to know what questions to ask.

Most metal PBF systems operate in an inert atmosphere to reduce the possibility of contamination from gases, such as oxygen and carbon dioxide, in the air. An inert atmosphere helps to ensure that air molecules do not change the physical properties of the parts being produced. Argon gas, nitrogen gas, a vacuum, or a combination of these is used to eliminate the unwanted gases. The cost of argon gas can exceed $12,000 per year for one system; the actual cost depends on the local price of the gas, the way in which the AM machine uses it, and the size and amount of time for which the machine is used. If nitrogen is used, the gas can be obtained either from gas bottles or from a nitrogen generator.

"It is not unusual for customers to learn that something is missing only because they failed to ask the right questions."

Facility costs

Metal PBF systems operate best when ambient temperature and humidity are maintained at the levels recommended by the machine's manufacturer. Air conditioners, humidifiers or dehumidifiers are usually necessary. Their initial cost can be in the range of $10,000, but this amount can vary greatly depending on the size of the space where the machine is being operated.

Your building may require alterations to accommodate a metal AM system. In some cases, doorways may need to be widened or walls removed so that the machine can be moved into place. Proper ventilation is also necessary to reduce hazards associated with materials in the

Fig. 4 A doorway has been widened to move an AM system into place (Courtesy Olaf Diegel)

Fig. 5 A steel plate was used to spread the weight of this machine when it was discovered that the floor was not strong enough (Courtesy Olaf Diegel)

form of fine powders. Machine weight is another consideration. In a recent case, a machine's five-ton weight required structural changes to the factory floor. Here, steel plates were installed to spread the load to an acceptable level.

New gas lines and electrical changes are often required when installing a metal PBF system. If using or storing reactive metal powders, such as aluminium or titanium, sprinkler-based fire extinguishing systems should be disabled because metal powders can react dangerously with water.

If the machine is operating in a relatively small, enclosed space, and argon gas is used, it may be advisable to install sensors that show the level of gases, such as oxygen, in the air. If an argon gas leak occurs, it could quickly suffocate the people in the room.

Accessories and other costs

An industrial compressor is required and can cost $30,000. A sand blaster is needed to clean the powder attached to the parts and can cost $12,000. A shot-peening cabinet is also useful for improving the surface finish of the parts. It is similar to a sand blaster, but uses larger media, often in the form of

Fig. 6 An air filter may be required to safely operate a metal PBF system (Courtesy Olaf Diegel)

Fig. 7 An industrial vacuum cleaner (Courtesy Olaf Diegel)

Fig. 8 A fume filter and collector (Courtesy Olaf Diegel)

small ball-bearings, to flatten the high spots of a rough surface. They can cost $15,000. Industrial vacuum cleaners are required and can cost $18,000. It is very important that they are intrinsically safe and can be used with reactive powders.

A heat treatment furnace can cost in the range of $15,000–$30,000. One used for titanium can cost $100,000. Equipment is needed for removing the parts from the build plate. It can consist of a standard band saw ($10,000–$25,000) or a wire EDM system, which can cost $50,000–$200,000. Electricity can cost $3,000 annually, depending on local pricing. Hot Isostatic Pressing (HIP) is used to eliminate porosity and microcracks in metal parts. HIP is usually outsourced, but it should be budgeted for aerospace and certain other types of structural parts. To buy a HIP system, plan to spend $1.5–$3 million.

Software licensing fees can cost in the range of $3,000 annually, but this too can vary widely, depending on the design and AM machine software modules purchased. Annual maintenance contracts for an AM machine can range from $10,000 to more than $30,000, depending on the level of service required. Maintenance contracts extend the warranty beyond the first year, which is often included in the purchase price. The cost of filters for a metal PBF machine can be $30 each, but they can go as high as nearly $7,000 for the type needed for some production-ready systems. Other consumables include build plates, recoater blade wipers and lasers.

Safety equipment is required to protect the operator from exposure to the metal powders. This can range from a few hundred dollars for gloves and face masks, to several thousands for full body suits with built-in air filtration.

Talent and labour requirements

Operation and part finishing to support one metal AM machine can cost $150,000 annually. Post-processing of parts can be labour intensive and usually begins with the removal of powder surrounding the parts when the build is complete and has cooled. After most of the loose powder has been removed, the parts and support structures - still welded to the build plate - are removed from the machine. Additional powder is removed from holes, cavities, and other areas using hand tools, compressed air and blasting.

The build plate, with parts and support material, is then placed into a furnace for thermal stress relief. Skipping this step can result in the warping of parts when removing them from the build plate due to residual stresses built up in the parts. After stress relief, the parts and support structures are cut away from the build platform. The support material is then removed from the parts using a combination of manual cutting, milling, grinding and other methods.

Some parts undergo HIP. Further heat treatment is used to strengthen and harden parts. Surfaces that require precise dimensions and flatness are usually CNC machined, which is an expense that also needs to be considered. Parts may undergo abrasive tumbling, electro polishing, or one of a number of other methods of surface treatment. One of the final steps is inspection.

Design

One of the most important considerations when purchasing a metal AM system is the need to design for Additive Manufacturing (DfAM). Good DfAM can result in a reduction of support structures, material, part weight, inventory, maintenance, and assembly labour, leading to considerable cost savings and a product that performs better and is more competitive. Quality hands-on DfAM training can cost $3,000 or more per person for a three-day course. Consider also the time that it takes for a designer or engineer to practise what they have learned and to become productive.

While applying DfAM, it is important to consider build orientation. Building a part on its side, upside down, or at an angle can reduce the need for support material and its removal, which can take days of time, effort and skill. Clever DfAM techniques can also reduce the need for support structures. Proper packing of parts in the build chamber is important to benefit as much as possible from the economy of scale that comes with PBF processes.

Additional considerations

Due to the cost of producing metal parts by AM, most systems are purchased with the goal of using them for production applications. It is not uncommon to build parts multiple times before getting them right. This can be expensive because a single build can take days, even a week or longer, to complete. Heat distortion is a major cause of problems in production; software tools from 3DSIM (now owned by Ansys), MSC Software, Autodesk Netfabb and others help to predict distortion and optimise the number and location of support structures.

Metal PBF systems come with a number of safety considerations. One of them is the use of reactive powders, such as titanium and aluminium. Both can ignite, burn, and even explode under the right conditions. In fact, fine aluminium powder is used for explosives and pyrotechnic displays. It is important, therefore, to take special safety precautions when using these types of powders. At minimum, a D-class fire extinguisher is required. Storage of powders, especially in large quantities, also comes with special considerations and can be expensive.

Many types of metal AM systems are available worldwide, with Powder Bed Fusion being the most popular, by far. The list of costs and considerations can be overwhelming, and even shocking, when purchasing a system without prior knowledge of them. It is important to research the metal AM systems available and to understand the differences between them, and to learn about and fully understand the need for ancillary equipment, tools and skills, as well as the many process steps required to produce quality metal AM parts.

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Beyond particle size: Exploring the influence of particle shape on metal powder performance

In recent years much effort has been put into developing powders that are optimised for AM processes. As a result, a far greater understanding of the complex requirements for powders now exists. Particle size is widely recognised as a key property, but there is also an appreciation that particle shape has an important role to play. As Malvern Panalytical's Debbie Huck-Jones and Cathryn Langley explain, finer particles are advantageous from the perspective of packing behaviour, but are typically associated with poor flowability, compromising processing efficiency. Controlling particle shape can help to alleviate this problem.

Additive Manufacturing has evolved over the last decade into a commercially viable manufacturing process with particular utility for the creation of novel and complex parts with intricate geometries and for the production of low-to-medium volumes of small components at competitive cost. Exploiting the full potential of AM relies on the availability of a consistent supply of suitably specified metal powders, particularly for applications in highly regulated industries such as the aerospace and biomedical sectors. As a result, much effort has been invested in the identification of robust correlations between powder properties and their performance in AM processes, and in learning how to manufacture powders that meet these demanding specifications.

Particle characterisation technology is essential for optimising AM powders and ensuring consistent, high quality production. Particle size is a key property, but there is widespread recognition that particle shape also has an important role to play; finer particles are advantageous from the perspective of packing behaviour, but are typically associated with poor flowability, which can compromise processing efficiency. Controlling particle shape can help to alleviate this problem. In this article, the impact of particle size and shape on metal powder performance is considered, highlighting the value of automated imaging in quantifying particle shape. Case study data illustrates what can be measured and the insight gained.

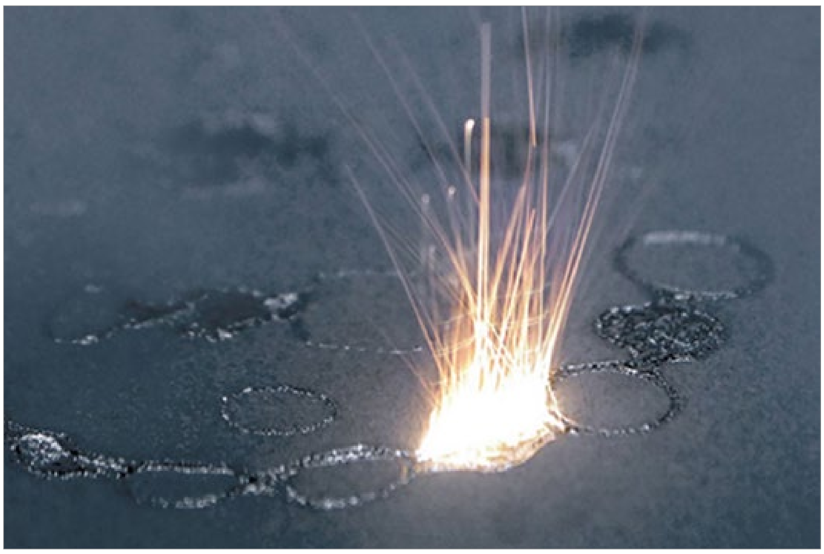

Fig. 1 AM relies on the availability of a consistent supply of suitably specified metal powders, particularly for applications in highly regulated industries such as the aerospace and biomedical sectors (Photo courtesy EOS GmbH)

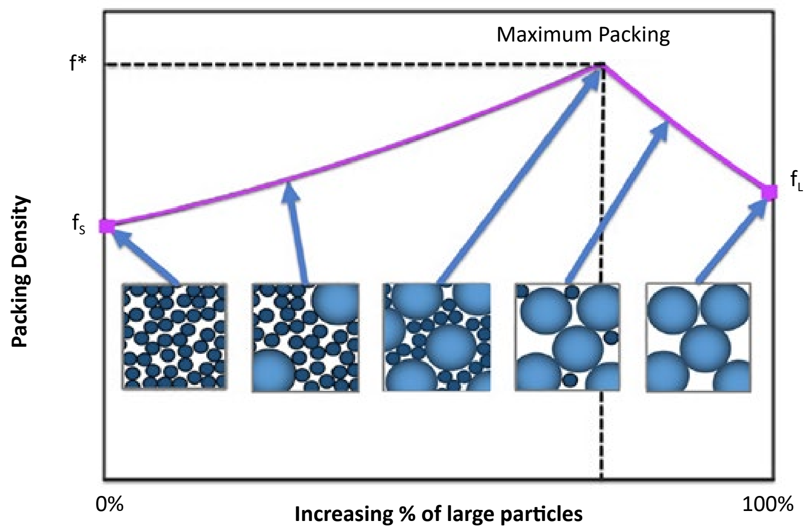

Fig. 2 A high packing density is associated with the production of high quality, minimally flawed components and can be achieved using a powder with a relatively broad particle size distribution

Optimising the physical characteristics of AM powders

Two of the major AM processes can broadly be classified as powder bed or blown powder. In powder bed processes, successive powder layers are spread across a build platform and then fused or bound in specific areas to progressively construct the component. With a blown powder process, powder flows through a nozzle in a carrier gas stream at relatively high pressures into a melt pool on the surface of the component. In both cases, the flow properties of the metal powder strongly influence process efficiency and also, potentially, the quality of the finished component. Powders that flow freely and spread evenly to give a uniform layer, free of air voids, are essential for powder bed processes, while consistent aerated flowability underpins the efficiency of blown powder processes.

Most feedstocks used in AM consist of fine powders with median particle sizes, typically in the range of 20-60 µm. This is essential to meet the requirement to form, for example, a powder bed just tens of microns thick. Fine particles can also be advantageous in terms of packing behaviour, especially in a powder with a relatively broad particle size distribution (Fig. 2). Such powders deliver the high bulk density associated with consistently high quality, minimally flawed finished components. On the other hand, because the forces of attraction between particles increase with decreasing particle size, finer particles tend to have relatively poor flowability.

Fortunately, particle size is not the only property that influences powder flowability. Other parameters that have an effect include porosity, surface texture, density, electrostatic charge and particle shape. Particles that are smooth and/or regularly shaped generally flow more easily than those of analogous size that are rougher and/or more irregular. This can be attributed to reduced interparticle friction (surface roughness) and a lower tendency towards mechanical interlocking (particle irregularity). By manipulating particle shape, it is therefore possible to offset the low flowability associated with fine powders to enhance AM process efficiency. Furthermore, smooth spherical particles also tend to pack efficiently and so can be additionally advantageous from the perspective of achieving high bulk densities.

While smooth, spherical powders may be preferable for many AM applications, they can be difficult to manufacture. The majority of metal powders for AM are produced using gas atomisation processes and the resulting product tends to be relatively spherical. However, particle shape can be influenced by

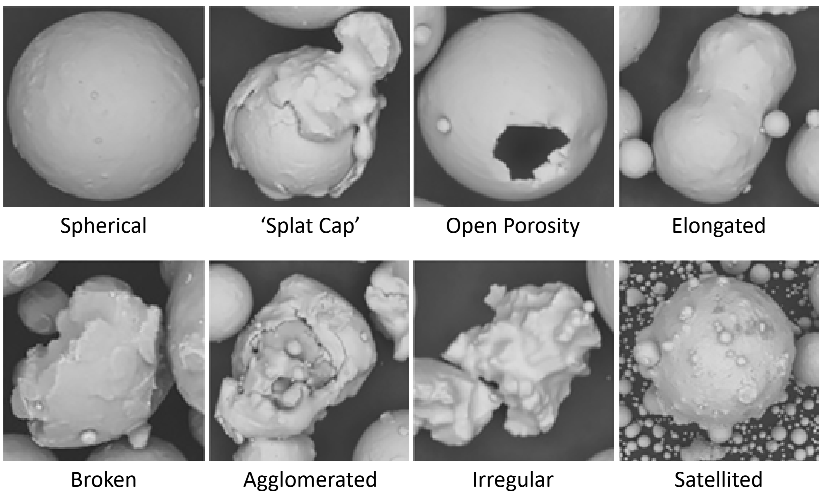

Fig. 3 Case study data from the National Centre for Additive Manufacturing, part of the UK's Manufacturing Technology Centre, details images of individual metal particles produced using gas atomisation, illustrating the many different particle shapes which may result from the process

	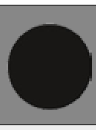		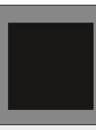			
Circularity is a measure of the closeness to a perfect circle. Circularity is sensitive to both changes in overall form and edge roughness.	Circularity = 1	Circularity = 0.64	Circularity = 0.89	Circularity = 0.67	Circularity =0.50	Circularity = 0.35
Convexity is a measure of the edge roughness of a particle. Convexity is sensitive to changes in edge roughness but not overall form.	Convexity = 1	Convexity = 0.96	Convexity = 1	Convexity = 1	Convexity = 0.59	Convexity = 0.69
Elongation is a measure of the length-width relationship. Elongation is unaffected by edge roughness – a smooth ellipse has a similar elongation to a spiky ellipse of similar aspect ratio.	Elongation = 0	Elongation = 0.82	Elongation = 0	Elongation = 0.79	Elongation = 0.24	Elongation = 0.83

Table 1 Defining the three most commonly used descriptors of particle shape

the thermal conductivity of the molten metal, which affects the speed of cooling during particle formation and the associated solidification process. In addition, collisions and subsequent fusion between molten/semi-molten particles can form irregularly-shaped particles.

In reality, gas atomised metal powders may contain particles exhibiting any of the features illustrated in Fig. 3, with satellited particles a particular problem. These not only compromise flowability and packing behaviour, but may also present an airborne health and safety risk because of the very fine nature of the easily-detached satellite particles. Alternative metal powder manufacturing processes include plasma atomisation or the plasma rotating electrode process (PREP), both of which produce more spherical particles but at a higher price.

In summary, when it comes to selecting a powder for an AM application, particle shape may well be critical, as well as particle size, but a specification for highly regular, spherical particles will typically be associated with a premium price tag, compared to a more forgiving shape specification. For AM processors, understanding the impact of particle shape is therefore crucial to enabling selection of the most cost-effective feedstock. For metal powder manufacturers on the other hand, learning how to control shape is the key to higher value products. In both cases, robust particle shape data is a critical requirement.

Automated imaging for robust, statistically significant particle shape measurement

Metal powders are typically sized by sieving, or more rapidly and accurately by laser diffraction technology. Fast, non-destructive and highly automated, laser diffraction analysis delivers a complete particle size distribution for a sample in less than a minute and can also be implemented online for the continuous monitoring of metal powder manufacturing processes. Automated imaging is highly complementary to laser diffraction and augments size data with greater insight into particle morphology by providing detailed information about particle shape.

Automated imaging systems capture images of tens of thousands of particles in just a few minutes. Parameters calculated from these images are used to generate number-based particle size and shape distributions, which can be used to characterise morphology in a more precise, objective and robust way compared with traditional microscopy techniques. Furthermore, because of the large number of particles imaged, the results are more statistically relevant than Scanning Electron Microscopy (SEM) for example.

The size parameter reported by automated imaging is circular equivalent diameter (CED) – the circle with a diameter of equivalent area to the 2D image of the particle. The three most commonly used descriptors of shape are elongation, circularity and convexity, as defined in Table 1.

Elongation and circularity both describe overall particle form. Elongation is the ratio of particle width to length and differentiates long, needle-like particles (elongation close to 1) from those with more regular symmetry that resemble cubes or spheres (lower elongation closer to 0). Circularity, as its name suggests, can indicate the sphericity of a particle with values approaching 1 associated with greater roundness. Convexity is associated with the outline of the particle shape and is defined as the ratio of the convex hull perimeter – the shape that would be outlined

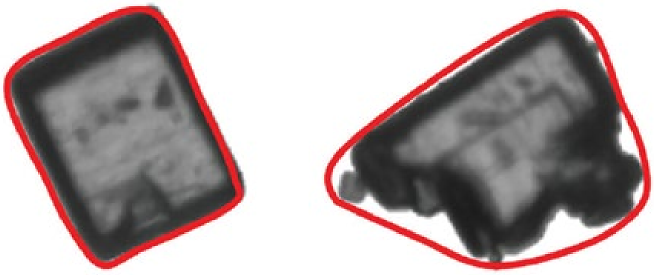

Fig. 4 Particles with a smooth, regular outline have high convexity while those that are rougher or more irregular are differentiated by lower convexity values

	Batch A: Time (s)	Batch B: Time (s)
Result 1	80.8	WNF
Result 2	79.3	WNF
Result 3	79.9	WNF
Average	80.0	WNF
Equipment: Hall Flow Meter		

Table 2 Flow testing (Hall Flow Meter) shows that Batch A has superior flow properties to Batch B (WNF = will not flow)

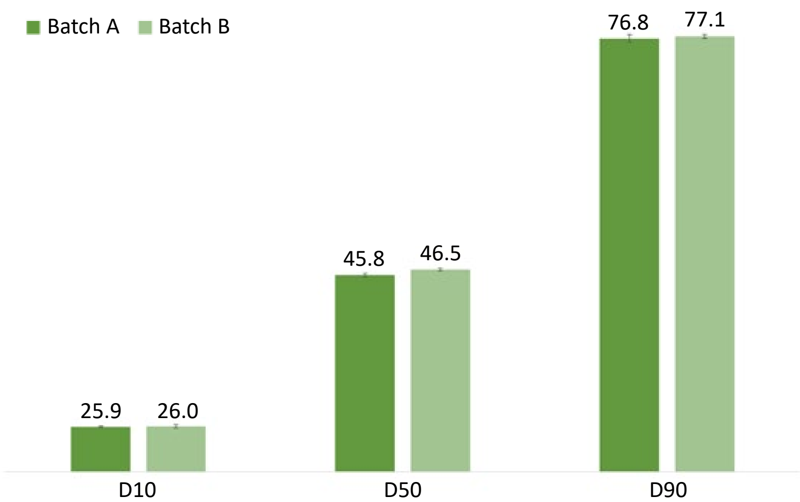

Fig. 5 Particle size data for Batch A and B indicates that in this respect the two products are closely similar

by an elastic band placed around the particle – to the actual perimeter (Fig. 4). This means that smooth particles have a convexity close to 1, while those that are less regularly shaped – with a rougher surface, for example, or agglomerates – have lower values.

Using these parameters, metal powder samples can be classified as rough or smooth, highly spherical or irregular and/or some combination properties such as smooth but non-spherical. Such data enable detailed exploration of the correlation between particle shape and process performance and the knowledge-led selection of an optimal feedstock, as illustrated by the following case study.

Comparing the properties of Aluminium-Silicon-Magnesium powders

Aluminium-Silicon-Magnesium (AlSiMg) powders, for which there are a number of different alloys commercially available, are valued for their ability to produce components with a good strength-to-weight ratio. The results reported here are from a study carried out by LPW Technology (Runcorn, UK) to compare the properties of two commercially available products and assess their suitability for AM processes.

Table 2 shows flow data for samples of the two products, Batch A and Batch B. Flow testing was carried out using a Hall Flow Meter, which determines flowability from measurements of the time taken for 50 g of powder to flow through an opening of specific dimensions. The results indicate that Batch A flows under standard test conditions while Batch B does not. This is significant, indicating that Batch B is poorly suited to AM processing relative to Batch A. The two batches were known to have been produced using different gas atomisation processes, so particle characterisation was carried out to determine whether associated differences in particle morphology could provide a rationale for flow performance.

Particle size distributions for the two batches were measured using a laser diffraction particle size analyser (Mastersizer 3000, Malvern Panalytical, Malvern, UK). The resulting data are summarised in Fig. 5, where D10, D50 and D90 are the diameter below which 10%, 50% and 90% of the sample lie respectively, on the basis of volume. These highly reproducible results indicate that the samples are strikingly similar in terms of particle size and that differences in flowability cannot be correlated with particle size distribution.

Particle shape distributions for the two batches were collected using an automated image analyser (Morphologi G3, Malvern Panalytical, Malvern, UK). These are summarised in Table 3, where D[n,0.1], D[n,0.5] and D[n,0.9] are the values of the given parameters below which 10%, 50% and 90% of the sample lie respectively, on the basis of number of particles.

Here, then, the particle shape data generated by automated imaging is able to differentiate the powders and provide a rationale for the observed difference in flowability. It is interesting to note that though the differences in particle shape are relatively subtle, they result in the difference between a 'pass or fail' for AM application, as assessed by the flow testing. This observation highlights the importance of precise, reproducible, statistically significant particle shape data.

Elongation	Batch A	Batch B
Min	0	0
Max	0.5	0.5
Mean	0.122	0.154
D[n, 0.1]	0	0.014
D[n, 0.5]	0.09	0.113
D[n, 0.9]	0.288	0.361
HS Circularity	**Batch A**	**Batch B**
Min	0.189	0.162
Max	1	1
Mean	0.943	0.933
D[n, 0.1]	0.84	0.818
D[n, 0.5]	0.962	0.962
D[n, 0.9]	0.992	0.992
Convexity	**Batch A**	**Batch B**
Min	0.755	0.694
Max	1	1
Mean	0.996	0.996
D[n, 0.1]	0.964	0.973
D[n, 0.5]	0.992	0.994
D[n, 0.9]	0.997	0.998

Table 3 Shape metrics indicate that Batch A is smoother (higher convexity) and more circular than Batch B, providing a rationalisation for the observed difference in flowability

Looking ahead

Early work in the field of AM focused on the development of the associated hardware, but there is now wide-spread recognition that the powders used in the resulting machines merit equal consideration if the full potential of this transformational technology is to be realised. Those working at the forefront of metal powder supply are already exploiting correlations between particle shape and flowability to deliver powders that are consistently free-flowing and, at the same time, pack to a high bulk density. Automated imaging efficiently provides the reliable particle shape data needed to progress in this area and is therefore of considerable value to both metal powder suppliers and AM processors as they work towards new levels of performance.

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POWDERMET2017: Developments in powder production methods for AM

In addition to the parallel Metal Powder Industries Federation's AMPM2017 conference, the programme for the POWDERMET2017 International Conference on Powder Metallurgy & Particulate Materials, Las Vegas, June 13-16, 2017, included technical sessions on AM. Two of these sessions were devoted to powder production methods for AM feedstocks and this report from Dr David Whittaker reviews three selected papers in this subject category.

Titanium alloy development for AM utilising gas atomisation

The first of the reviewed papers was authored by Chris Schade, Tom Murphy and George Bernhard (Hoeganaes Specialty Metal Powders LLC, USA) and Alan Lawley and Roger Doherty (Drexel University, USA) and focused on the gas atomisation of titanium alloys for Additive Manufacturing [1].

The use of titanium in the automotive market has been the topic of numerous articles. The advantages of using titanium are its high strength to weight ratio and enhanced corrosion resistance. However, the cost of titanium, in comparison with other metal systems such as steel and aluminium, has normally precluded its use in conventional cars. Recently, due to tighter fuel usage requirements, some automotive applications such as valve guides and connecting rods have been realised, though mostly in high end automobiles where cost is not the deciding factor, but weight and performance are.

The major cost of titanium arises from the reduction of the metal from its oxide to the metallic state, which can be as much as twenty times the cost of steel. To use titanium powder in conventional automotive applications, particularly with AM as a manufacturing route, a cost-effective method for powder production is necessary.

The reported study compared two methods to produce titanium powders. The first is a commercially accepted production route, the Elec-

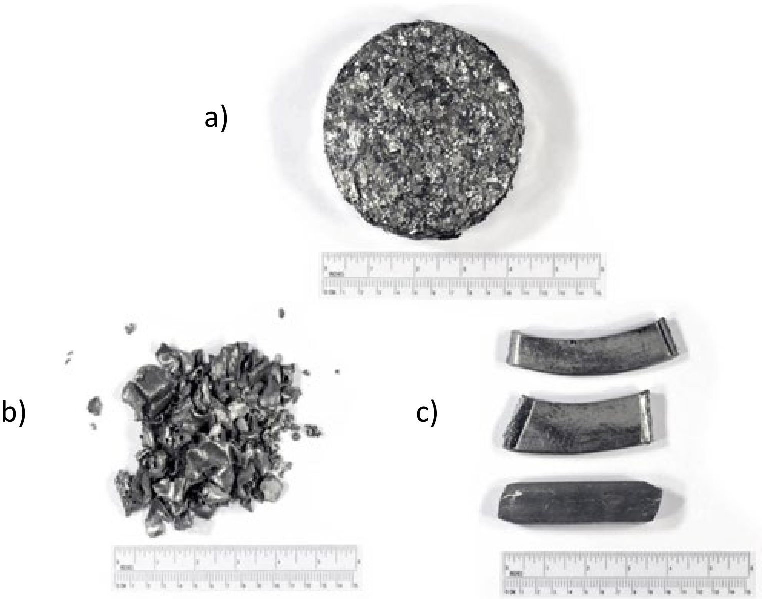

Fig. 1 Variations in titanium scrap feedstock for ISM: (a) turnings compacted into 'briquettes', (b) cobbles and (c) solids [1]

	Turnings		Cobbles		Solids		ASTM B348	
	Avg.	Std.	Avg.	Std.	Avg.	Std.	Grade 5	Grade 23
C	0.03	0.004	0.03	0.023	0.02	0.008	0.08 max.	0.08 max
O	0.25	0.031	0.17	0.006	0.20	0.004	0.20 max.	0.13 max.
N	0.013	0.002	0.011	0.001	0.009	0.003	0.05 max.	0.03 max.
H	0.002	0.001	0.006	0.004	0.002	0.001	0.015 max.	0.0125 max.
Fe	0.18	0.048	0.20	0.018	0.13	0.007	0.40 max.	0.25 max.
V	3.85	0.196	4.21	0.057	4.03	0.027	3.5 to 4.5	3.5 to 4.5
Al	6.04	0.093	5.69	0.057	6.05	0.060	5.5 to 6.75	5.5 to 6.5

Table 1 Summary of chemistry of scrap types measured in melted ingot [1]

	Turnings		Cobbles		Solids	
	Melt	Atomised	Melt	Atomised	Melt	Atomised
C	0.03	0.04	0.03	0.04	0.02	0.04
O	0.25	0.26	0.17	0.190	0.20	0.21
N	0.013	0.012	0.01	0.012	0.009	0.012
H	0.002	0.002	0.006	0.009	0.002	0.002
Fe	0.18	0.18	0.20	0.20	0.13	0.13
V	3.85	3.84	4.21	4.17	4.03	4.00
Al	6.04	6.10	5.69	5.63	6.05	6.01

Table 2 Melt and powder chemistries (wt.%) [1]

trode Induction-melting Gas Atomisation (EIGA) process. EIGA requires bar stock, typically 50-60 mm in diameter, as the precursor material. The second method utilises Induction Skull Melting (ISM) or cold crucible melting, linked to a gas atomiser, to produce powders directly from raw materials, both virgin and scrap. The primary objective of the study was to utilise various forms of titanium scrap as a basis for alloy development. This was pursued on the basis of cost and the desire to measure the impurity levels and changes in chemistry that might result in the powder.

The steps in preparing any form of titanium scrap can be categorised as sorting, sizing, cleaning, sampling and inspection. The most important of these steps from a metallurgical point of view is cleaning, which includes processes such as washing (for oils and cutting fluids) and blasting/grinding (for surface contamination). Oils and cutting fluids, if not removed, can be a source of carbon, sulphur, oxygen, nitrogen and hydrogen in the final powder. If surface contamination is not removed from the scrap, non-metallic inclusions can be present in the powder, which will have a negative impact on mechanical properties.

There are essentially three scrap types that are used in titanium re-melting: turnings, cobbles (shredded titanium sheet) and solids, as shown in Fig. 1. The most obvious difference between these material forms is the level of surface area and, therefore, the amount of surface oxidation and contamination that can take place (i.e. the turnings have the highest surface area whereas the solids have the least).

There is also a difference in apparent density for the three types of scrap. In this study, one of the first tests was to determine the consistency of the quality and chemistry of the scrap being supplied. It was also desired to understand the recovery of alloying elements and the increase in oxygen, nitrogen and hydrogen levels during the atomising process. So, 100% of the three different types of scraps, as shown in Fig. 1, were melted and the chemistry prior to atomising was analysed. This was accomplished by melting 5 kg of scrap in the ISM and then analysing the chemistry. Five different melts of Ti6Al4V were produced for each scrap type in order to ascertain the consistency of the material. A summary of the chemical results of these five melts is shown in Table 1.

The chemical compositions of the five ingots from the different scrap types had consistent chemical analyses. The highest standard deviation was found in the turnings which, as expected, had the higher oxygen content. This was probably the cause of the higher standard deviations and the lower absolute levels of aluminium and vanadium in the ingots produced from turnings, as these two elements tend to combine with the oxygen in the melt and form oxides. However, the losses of these two elements were consistent, so additions of aluminium and vanadium could be made to compensate. Another key outcome from these results was that each of the scrap types picked up very little oxygen, hydrogen or nitrogen during the melting process. The ingots produced from cobbles and solids had oxygen contents and overall chemistry that met the ASTM Grade 5 requirements for chemical composition. However, the oxygen content for the ingots made from turnings was above the maximum allowable values.

The next step was to atomise the same scraps into powder and determine the resultant chemistry and purity of the powders. The melt stream diameter was 2 mm and the atomising gas was argon. The atomising chamber was evacuated and then back filled with argon. Table 2 shows the compositions of the atomised powders relative to the starting melt compositions in Table 1 (the average of five heats). The only significant changes in composition were in the oxygen and carbon values. There was a slight increase in oxygen content (due to the surface area). The carbon content increase was attributed to the graphite pouring nozzle.

To carry out inclusion analysis, samples of the powders were sintered in an argon atmosphere to create preforms. These preforms were then re-heated (in argon) and forged into fully dense slugs, on which image analysis could be used to detect any type of inclusions. This mode of analysis is a standard quality assurance method at Hoeganaes, used to evaluate iron and steel powders used in the production of connecting rods for automobiles and other powder forged products.

The experimental atomiser used a graphite nozzle and, as a result, hard alpha inclusions can form. This precludes allowing for inclusions

	Frequency of Inclusions per 100 mm²				
Processing/ (Material)	> 25 microns	> 75 microns	> 100 microns	> 150 microns	> 200 microns
EIGA (Solids)	0	0	0	0	0
EIGA (Turnings)	0	0	0	0	0
ISM/Gas (Turnings)	2	1.49	0.75	0	0

Table 3 Results of inclusion testing (ASTM B796) [1]

coming directly from re-melting of the scrap. Therefore, a trial was run with scrap using an EIGA atomiser, which does not use a nozzle but melts a solid bar in a non-contact induction coil. The same scrap previously described (Ti6Al4V solids and turnings) was melted into ingots using an induction skull melter. Bars were then used as feedstock to produce powder. The composition of the final powder was measured and found to be similar to the results shown in Table 2; there was no significant change from scrap to powder. One of the advantages of EIGA is that no refractory is used in the process. Therefore, these trials were utilised to evaluate the level of inclusions in the final powder.

Measurement of the non-metallic inclusion content was made by evaluating consolidated, pore-free metallographic specimens using an automated image analysis system. When viewed using an optical microscope, the presence of the darker non-metallic inclusions is determined by comparing the digital representation of the microstructure with a predetermined grey-scale range. Features falling within this gray to black range were detected and separated from the remainder of the image and those located within a specified distance of other detected feature(s) were joined, thus defining inclusions as the combination of the joined individual features. These features were measured and sorted into predefined size classes.

The results of inclusion testing on various powders, produced by both the gas atomising method and the EIGA process, are shown in Table 3. The powders from the EIGA process, in which there is no contact with refractories, had no inclusions greater than 25 µm. The powders produced by the ISM/gas atomising method had several inclusions between 25 µm to 100 µm in diameter. An example of the inclusions found in the ISM/gas atomising process utilising turnings is shown in Fig. 2. SEM results indicate that this inclusion was approximately 100 µm in length and was comprised almost entirely of carbon. In addition, there was a trace amount of yttria.

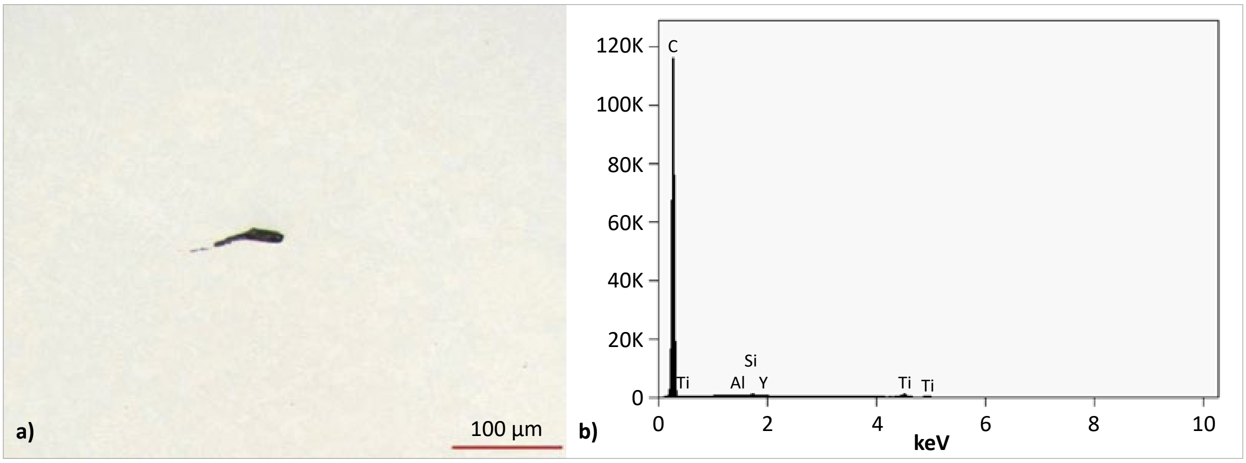

Fig. 2 (a) SEM photomicrograph of inclusion found in gas atomised powder (b) corresponding EDS spectra showing that the inclusion was carbon (graphite from nozzle) [1]

Sample	Mean Circularity	Area % Porosity	% Particles Containing Pores
EIGA- Ti-6-4	0.82	0.20	6.73
EIGA- Ti-6-4	0.85	0.28	5.03
ISM/Gas- Ti 6-6-2	0.79	0.43	15.35
ISM/Gas-Ti 5-5-5-3	0.79	0.48	14.06
ISM/Gas-Ti Beta 21s	0.81	0.19	13.76

Table 4 Comparison of shape (circularity) and porosity of titanium powders [1]

The atomising nozzle used for this material was graphite and it was coated with yttria. All the inclusions found in this sample were of this type, indicating that, in both processes, there were no inclusions coarser than 25 µm coming from the scrap.

An experimental method for evaluating powder shape and porosity was also described. Powders for both AM and MIM are required to be as spherical as possible. In the case of AM, spherical powders provide a uniform flow of the powder from the feeder and/or pack more predictably in the powder bed. To estimate powder particle shapes, metallographic (epoxy) mounts of loose powder particles were made and analysed using an automated image analysis system.

The automated image analysis system created a digital representation of individual fields and was able to separate the metallic particle cross-sections from the mounting material by the amount of light reflected by the polished surface. The highly reflective metallic cross-sections of the particles were considerably brighter and lighter in grey, compared with the mounting material. Consequently, a grey level was established, which corresponded to the particles, and these could be separated from the mounting material for further image processing and eventual testing. Test parameters included measurement of the length, perimeter and area of each detected particle. Two of these values, the perimeter and area, were used in the following expression to estimate shape:

$$SF = \frac{4\pi A}{P}$$

where *A* is the particle cross-sectional area and *P* the perimeter. This shape factor is based on the shape of a circle, where SF=1. Any particle shape more irregular than a circle or having a perimeter longer than that of a circle with the same area will have a shape SF <1. The powders, intended for use in AM, routinely have a shape factor >0.75.

The results of the measurements on the powders produced in this study are shown in Table 4. The powders produced with the EIGA process appear to have a higher circularity than the ISM/gas atomised powders. This can be partially explained by the fact that the gas atomising jet is still in the development stage, but it also appears that the ISM/gas atomised powders have significantly more satellites.

The amount of porosity in the particles can be measured during the same analysis used to estimate particle shape. This is accomplished by using the detected metallic portion of the cross-section and having the system software fill any darker, undetected areas surrounded completely by metal. These filled regions are the pores within the particles. Both the volume percent porosity in the particles and the percentage of particles containing pores can be estimated.

The area of the porosity as a function of the total area of powder and the percent of particles containing porosity is lower for the EIGA produced powders. More work will be needed to draw definite conclusions as the alloys are different and there may be other factors involved. The method developed will be useful, not only as a quality control tool, but also as a means of investigating and improving the gas atomisation process.

Finally, due to recent developments in AM, there is an interest in titanium powders other than commercially pure (CP) Ti and Ti6Al4V. When using a process which requires precursor material, this can be costly and time consuming due to the need to first melt the bar stock. With the ISM/gas atomising process, new alloys can be made quickly and in small amounts from scrap. AM processing of alloys, made from currently available scrap, may allow for cost savings, permitting their use in conventional applications, such as automotive. Therefore, a

	Optical Emission Spectroscopy				LECO			
	Al	Mo	Nb	Si	C	O	N	H
Beta 21S	%	%	%	%	%	%	%	%
Specification	2.5-3.5	14-16	2.4-3.0	0.15-0.25	0-0.05	0-0.2	0-0.04	0.015 Max.
Scrap	2.98	15.09	2.61	0.24	0.02	0.15	0.011	0.003
Powder	3.02	14.81	2.68	0.19	0.02	0.16	0.027	0.003

Table 5 Chemistry of Beta 21S - starting scrap versus final powder (wt.%) [1]

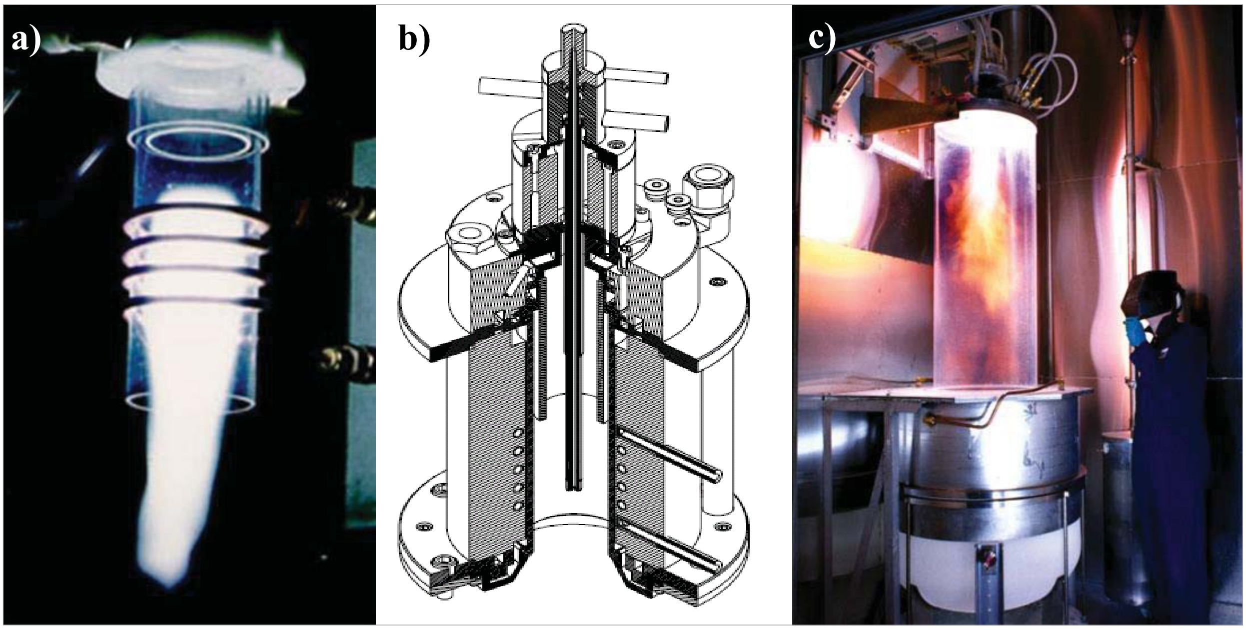

Fig. 3 (a) Picture of an open RF discharge in a quartz tube; (b) Tekna's proprietary plasma torch design; (c) Plasma processing of an oxide powder in a custom-made quartz reactor [2]

series of alloys was made utilising commercially available scrap and the ISM/gas atomising process. Alloys of interest were:

Beta 21S Alloy (UNS No. R58210)
Beta 21S, which was originally developed as the matrix for titanium metal matrix composites, has been developed as an alternative to Ti-15V-3Cr and is a high strength alloy with improved oxidation and creep resistance and which can be age hardened to develop high strength. Beta 21S scrap, available in sheet form, was sheared and compacted into small pieces (1 cm and below). The scrap was then charged and melted via ISM and atomised. The chemical analysis results of the starting scrap versus the atomised powder are shown in Table 5. The increase in oxygen and nitrogen content from scrap to final powder was very low and met the final product specification typically associated with Beta 21S. In addition, the losses of volatile elements such as aluminium and silicon appeared to be minimal. There were small amount of satellites and there were grains clearly evident in the microstructure due to a slight partitioning of some of the alloying elements.

Ti-6Al-6V-2Sn (UNS No. R56620)
Titanium 6-6-2 is a heat treatable, high strength titanium alloy with higher strength and hardenability than that of Ti-6Al-4V, but with lower toughness and ductility. Segregation of beta-forming elements, such as iron and copper, is a concern in ingots, but should pose few problems in atomised powders. Metallographic assessments showed a slight increase in the number of satellites compared with the Beta 21S and a similar decoration of grain boundaries with precipitates. However, the particles also contained precipitates within the grains.

Ti-5Al-5Mo-5V-3Cr
The aerospace industry uses Ti-5Al-5Mo-5V-3Cr in the production of parts for landing gears. The ultimate tensile and yield strengths are approximately 15-20% higher than those of Ti-6Al-4V. For this alloy, a mixture of scrap and virgin raw materials was used. Metallographic examination showed a spherical shape of the particles with an indication of a possible agglomeration of the finest particles into clusters. The etched microstructure showed a grain structure somewhat different to those for the other two alloys, with the boundaries appearing more typical. The structure also appeared to show a faint dendritic texture, which was not observed with the other alloys.

Production of spherical metallic powders for AM

A paper from Jerome Pollak, Ophelie Bailly and Richard Dolbec (Tekna Plasma Systems, Canada) concentrated on the characteristics of the spherical powders produced by the company's radio frequency (RF) plasma atomisation and RF plasma spheroidisation processes [2].

RF-PA uses metal wire or rod as feedstock, fed coaxially inside the induction plasma discharge where the material exposed to the plasma is preheated until the forward end of the wire melts. At this stage, the hot plasma gases atomise the metal in the supersonic nozzle, installed at the torch exit. RF-PS, on the other hand, can use a low-end powder (recycled or obtained from a given manufacturing process) as feedstock. As the particles passes through the plasma, they experience heating until the melting point of the material is reached and surface tension in the

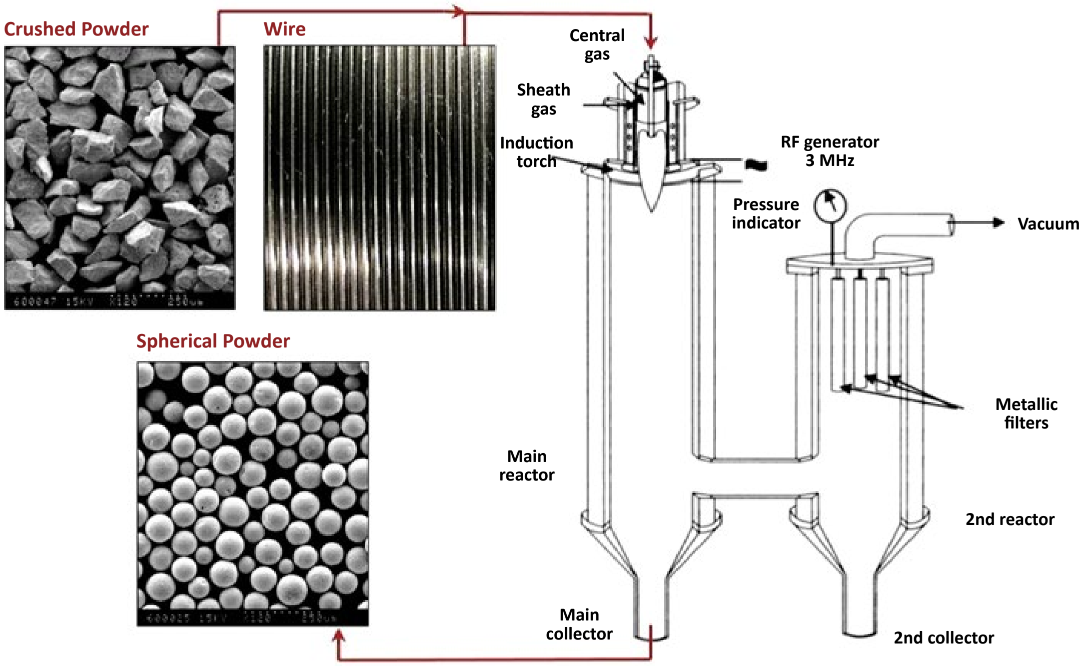

Fig. 4 Comparison of the RF-PA and RF-PS techniques used to produce spherical metallic powders for AM applications. Schematic representation of the experimental setup [2]

liquid phase enables each particle to adopt a perfectly spherical shape.

In the AM market, the requirement in terms of particle size distribution (PSD) is for powder below 150 µm and the main AM technologies have their own specifications:

- -25/+5 µm up to -63/+20 µm for Selective Laser Melting (SLM)
- -105/+45 µm for Electron Beam Melting (EBM)
- -150/+45 µm for Directed Energy Deposition (DED).

Among the different powder manufacturing processes, RF-PS offers the highest yield (>90% routinely achieved), since the PSD of the produced powder is pre-determined by properly sieving the feedstock.

The authors began by reviewing the main characteristics of RF plasmas. The first demonstration of the continuous operation of an inductively coupled RF plasma discharge can be traced back to 1961. Since then, the basic concept used for the energy coupling has remained essentially unchanged, but major improvements in torch design were made in order to adapt it to specific needs of industrial scale operations.

The core of the RF plasma technology is the plasma torch, capable of withstanding temperatures above 10,000°C. A typical RF plasma discharge is shown in Fig. 3a. This picture is representative of the plasma generated inside the plasma torches, commercialised by Tekna (Fig. 3b), while Fig. 3c presents an RF induction plasma system, manufactured by Tekna, in operation. Industrial RF plasmas are now confined in fully enclosed water-cooled vessels and processes are routinely used in 24/7 operating mode.

Being an electrode-less discharge, induction plasma torches do not contain parts subjected to erosion, thus preventing issues associated with powder contamination and enabling continuous production operations. This feature also allows for the operation with a wide range of gases, thus creating process conditions varying from inert (such as Ar or He for reactive metallic alloys such as Ti-6Al-4V) to reducing (Ar/H_2 for materials such as Fe-based and Ni-based metallic alloys) and oxidising atmosphere (Ar/O_2 for oxides) at various operating pressures.

RF plasmas represent a very interesting technological platform for developing unique powder-related processes, including the RF-PA and RF-PS processes developed by Tekna. The most obvious difference between Tekna's two production techniques stems from the fact that RF-PA uses a wire or rod as feedstock, while RF-PS uses a powder as feedstock, as illustrated in Fig. 4. Both processes benefit from the very high purity environment provided by RF plasmas.

In the case of RF-PA, the fed material is melted and atomised concurrently by the hot plasma gases. The spherical particles are formed in-flight and directed downwards in a rather concentrated jet. The reactor is engineered so that particles are allowed to cool down to a relatively low temperature before they reach the bottom of the reactor. Therefore, the hot (reactive) metal is never in contact with any solid surfaces of the system at any stage of the process, ensuring the very high purity of RF-PA powders. The powder produced has a PSD ranging typically from 0 to 200 µm. Various cut sizes are then obtained through sieving for end application requirements.

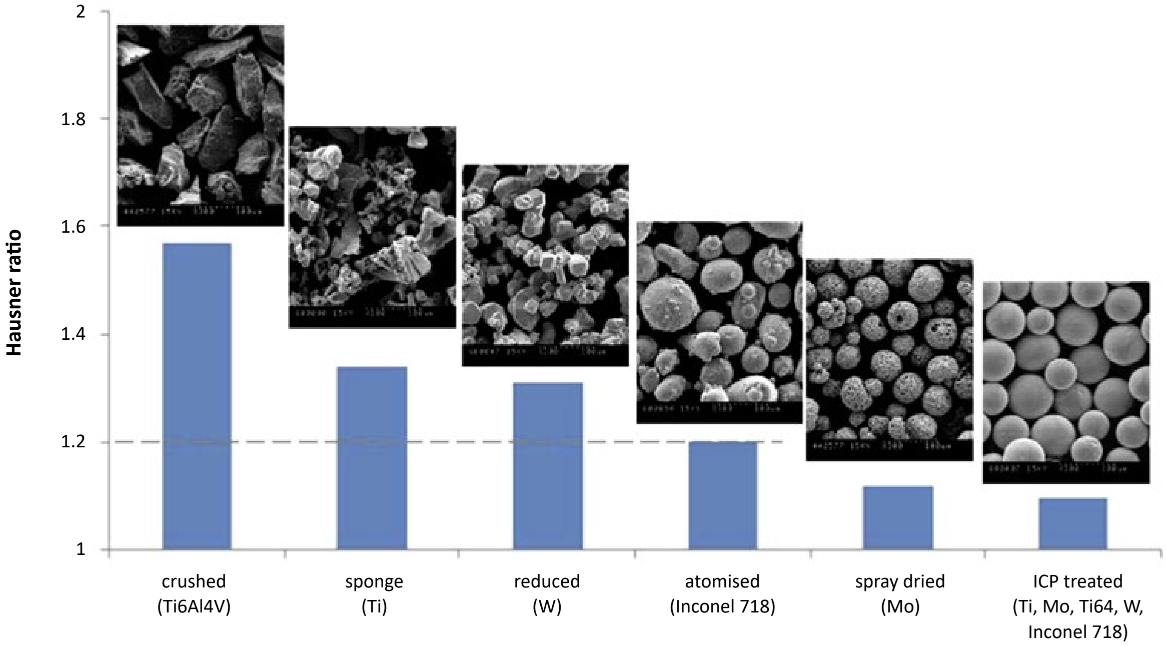

Fig. 5 Hausner ratio of various -105/+45 μm powders manufactured by various processes. Powders presenting a Hausner ratio below 1.2 are reported as high flowability powders [2]

The RF-PA technology is used for manufacturing a wide range of dense spherical powders for AM, such as stainless steel alloys, titanium alloys, aluminium alloys and nickel superalloys.

In the case of RF-PS, the PSD of the feedstock needs to match the PSD of the spherical powder to be produced, since this technology preserves material integrity and, consequently, does not modify powder PSD. It also offers the advantage of allowing the use of feedstocks from various sources.

Each of these feedstock sources present characteristics, which are inherent to the manufacturing process. The added value that these powders gain through the application of the RF-PS process is defined as follows:

Water or gas-atomised powders

The main interest for RF-PS here is to convert the morphology into perfect spheres, while eventually decreasing the oxygen content of certain materials after plasma exposure. RF-PS also offers the advantage of densifying the particles by suppressing internal pores.

Crushed (angular) powders

A typical example is Ti-6Al-4V produced by the Hydride-Dehydride (HDH) process. This process is particularly interesting for AM. The main challenge of this process consists in maintaining or reducing the oxygen content down to values specified by the AM applications, especially for finer size cuts such as -45/+15 μm.

Sponge powders

This is the cheapest source of titanium and crushed and sieved sponge powder, processed by RF-PS, has been shown to lead to spherical powders suitable for AM.

Spray-dried powder

This is a very interesting feedstock candidate for RF-PS since various elements can be added to the spray-dried material (such as mixed carbides) and in-flight melting consolidates and densifies the particles.

Out of spec AM powders

After multiple passes in an AM machine, such as in the SLM process, certain characteristics of the powders are altered to a point where they no longer meet the required specifications. Typical changes include vaporised material condensed as ultrafine particles on the powder surface, satellites consisting of small particles of a few microns sintered on the spheres and oxygen pick up. The RF-PS process is, in fact, probably the only process offering the possibility of reconditioning such materials, depending on the material to be processed and the features to be restored. This approach has been successfully demonstrated for various materials, including CP-Ti, Inconel 718 and Co-Cr powders, for instance.

Powders produced by RF-PS always consist of perfectly spherical particles, regardless of the feedstock used, and a smooth particle surface ensures excellent powder behaviour in an AM machine. This is illustrated in Fig. 5, in which the Hausner ratios (defined as the ratio between tap and apparent densities) of various -105/+45 μm powders, manufactured by different processes, are compared. After RF-PS treatment, these powders were all found to present the same Hausner ratio of about 1.1, the lowest value achievable for this selection of materials in this size range.

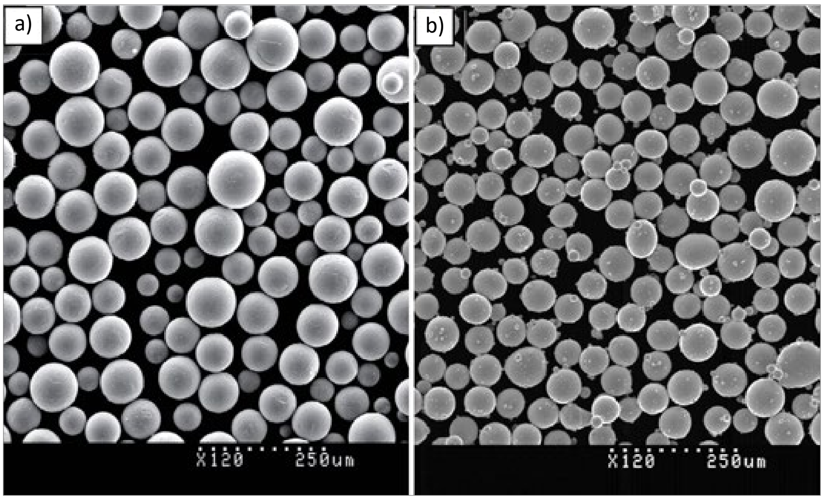

Fig. 6 Comparison of the -105/+45 μm Ti-6Al-4V powders produced by Tekna using (a) the RF-PS process and (b) the RF-PA process. Ti-6Al-4V powders commercialised by Tekna are currently produced using the RF-PA process [2]

A similar analysis was performed with the very same powders, but, this time, by comparing their relative apparent densities (defined as the ratio between the apparent density of the powder and the theoretical density of the material). Again, after the RF-PS treatment, these powders were all found to present the highest relative apparent density for this selection of materials in this size range. Both of these characteristics are highly valued by AM users and the significant improvements in powder properties can be ascribed to a combination of various material transformations, such as: morphology transformation from faceted to spheroidal, densification of porous materials, improvement of the particle surface smoothness and removal of satellites.

The choice between the RF-PA and RF-PS processes depends on various considerations, from both a technical stand point and a commercial stand point (feedstock pricing, targeted PSD, etc.). In the case of low-oxygen Ti-6Al-4V powder, low oxygen content wires are commercially available, while sourcing a suitable feedstock in powder form can be much more challenging, especially if Ti-6Al-4V spherical powder of the finest size cuts needs to be produced. Although both techniques are found to produce high quality and high purity spherical powders, Tekna chose its proprietary RF-PA process for the commercial production of Ti-6Al-4V powders.

Typical scanning electron microscope (SEM) pictures of Ti-6Al-4V powders (-105/+45 μm) produced by RF-PA and RF-PS are compared in Fig. 6. In both cases, the particles are spherical in shape, offering high tap and apparent densities as well as good flowability. The RF-PS powder (Fig. 6a) presents a very smooth surface, mainly due to the absence of shear forces applied by the plasma gas on the metal in the molten phase. Such a smooth surface is obtained after removing the ultrafine particles generated during the RF-PS process.

Two phenomena appear to contribute to the formation of these ultrafine particles. One comes from the portion of particles experiencing a temperature rise above the boiling point of the material due to their preferential exposure to the plasma, thus creating partial or complete vaporisation of these particles, which condense and form the ultrafine particles. The other phenomenon concerns preferential vaporisation of the alloying elements having the lowest boiling point. In the case of Ti-6Al-4V, the element with the lowest boiling point is aluminium and losses of up to 1.5 wt.% can occur, depending on the PSD of the powder, smaller particles being more sensitive than larger ones. One approach used to circumvent this issue involves enriching the feedstock with this element in proportion to the expected loss.

In Fig. 6b, RF-PA powder features some satellites on the surface of the particles. These are very small in size and limited in number, a consequence of process optimisation work, which has been facilitated by the flexibility that the RF-PA process provides in terms of processing conditions. The limited number of satellites is also due to the hot atomisation gas (as compared with cold gas used in more conventional gas atomisation processes), which minimises the risk of having smaller particles being solidified on the surface of the larger ones early in the process (i.e.at the nozzle exit), when particle concentration in the gas stream is at its highest level.

The authors' overall conclusion was that, although RF-PA offers a better flexibility in terms of feedstock chemistry (especially in terms of oxygen content), RF-PS is a versatile process, which can cope with a wide range of feedstocks from recycled AM powders to HDH machining chips and bulk scrap.

Fundamental progress toward increased powder yields from gas atomisation for AM

Finally, a paper presented by Iver Anderson (Ames Laboratory, Iowa State University, USA) and co-authored by his Ames colleagues Emma White, Jordan Tiarks, Trevor Riedemann, David Byrd, Ross Anderson and Timothy E Prost, and Jonathan Regele (Aerospace Engineering Department, Iowa State University) reported on recent research progress towards increased powder yields and improved powder quality from gas atomisation for Additive Manufacturing [3].

While some defects that occur during an AM part build are alloy-design or build-parameter related and can be minimised or healed by post-processing, e.g. Hot Isostatic Pressing (HIP) or annealing, many defects have their origin in the initial powder feedstock and cannot be healed. These powder-related defects include internal porosity (from trapped atomisation gas) and surface impurities (e.g. adsorbed water vapour) that can degrade AM part microstructure, properties and performance. Therefore, to deliver fully the advantages of AM for metallic parts, consistent powder feedstocks with ideal properties can provide the critical experimental control needed to develop both optimal alloy designs and build parameters.

The required improvements in powder feedstocks include:

1) the generation of smooth powder shapes, where spherical powders are highly preferred for their flowability and predictable coupling to energy input
2) the elimination of powder internal porosity, especially in coarser powders for Electron Beam Melted AM
3) improved powder surface passivation (without excessive oxide layers), particularly in fine powder size ranges for laser-based powder bed fusion.

However, in addition to the need for improved powder quality, AM process researchers and technologists have also identified the need for reduced costs in current certified feedstock powders. From the powder maker's viewpoint, the increased cost of feedstock powders is related to the tight specific powder size distributions that are optimal for each AM process and the need to size classify the powders, usually at the top and bottom of each size range. To accelerate the growth in AM applications, custom alloy powders should be designed, developed and available in both research-scale and prototype quantities for rapid development at moderate cost.

It is widely recognised that alloy melt atomisation methods are particularly suitable for producing powders that have the most favourable flowability characteristics, i.e., sphericity, for AM feedstock, especially if powder satellite accumulation can be minimised. Of the various available atomisation methods, the Plasma Rotating Electrode Process (PREP) has been found to produce smooth spherical powders with no satellite projections and with low internal porosity content. However, PREP synthesis is a low volume and high cost technique and is really not widely applicable to most common metallic systems, especially for the fine powder size range requirements of Powder Bed Fusion (PBF).

On the other hand, gas atomisation is the leading industrial process for high-volume, low-cost production of pre-alloyed metallic powders in a broad range of powder sizes. However, several process research challenges must be overcome for gas atomisation and specifically for close-coupled gas atomisation (CC-GA) with the most promise for precise atomisation control, to meet the powder needs for full-scale commercialisation of gas atomised powders for development of robust AM parts.

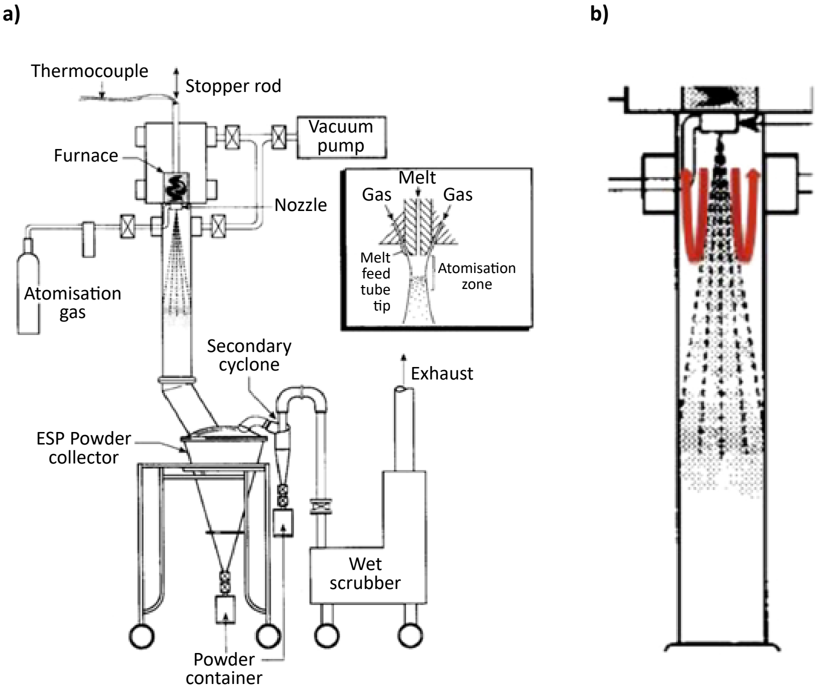

Fig. 7 Overall schematic (a) of the Ames Lab high-pressure gas atomiser that uses a CC-GA atomisation nozzle and (b) the spray chamber section of the atomiser that illustrates a cross-section of the highly confined external recirculation effect that is constrained by the small diameter [3]

In the reported study, the authors chose to study a Ni-based superalloy, well recognised for its application in harsh and extreme environments, MAR-M-247, but one that is very difficult to process by AM due to its tendency for weld cracking.

In the experimental study, the charge was a combination of pure metals and master alloys, using high purity (99.95%) elements with a total charge weight of 20 kg. The alloy composition was a low carbon (0.075%) version of MAR-M-247 (59.335%Ni-0.15C-8.25Cr-10.0Cr-0.7Mo-0.5Fe-5.5Al-0.015B-1.0Ti-3.0Ta-10W-0.05Zr-1.5Hf wt.%). The atmosphere in the melting chamber and atomisation system (Fig. 7) was evacuated with a mechanical pump to < 26.6 Pa, prior to backfilling to 111 kPa with ultra-high purity argon. The molten alloy was contained in a bottom tapped yttria-stabilized zirconia (YSZ) crucible with an alumina stopper rod (coated with yttria paint) to seal the exit of the YSZ pour tube, while heating to a pouring temperature of about 1700°C. When

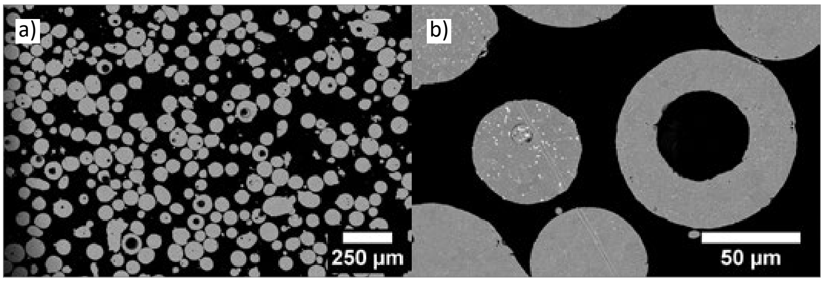

Fig. 8 SEM micrographs in backscattered imaging of inert gas atomised MAR-M-247 powder in the size range 45-106 µm from vendor B, shown in polished cross-sections at low (a) and high (b) magnification, respectively [3]

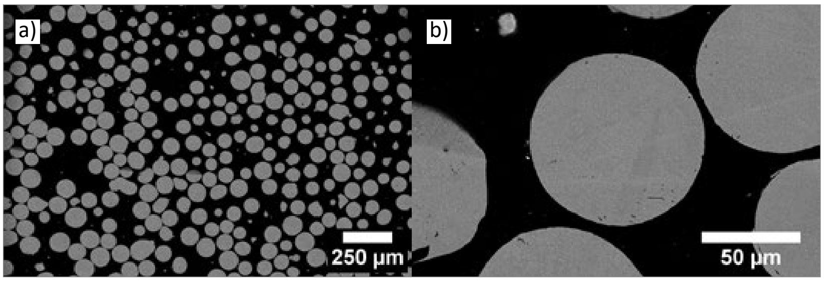

Fig. 9 SEM micrographs in backscattered imaging of Ar-atomised MAR-M-247 (of slightly modified composition) experimental powder in the size range 45-106 µm, shown in polished cross-sections at low (a) and high (b) magnification [3]

the desired superheat was reached, the stopper rod was lifted and melt flowed through the YSZ pour tube with a trumpet bell interior profile. The melt exited the pour tube orifice (3.8 mm) and was atomised with argon from a gas atomisation nozzle, having a jet apex angle of 20 degrees with 36 cylindrical gas jets, each with a diameter of 1.32 mm arrayed around the axis of a 21.34 mm central bore. The argon atomisation gas supply produced a nozzle manifold pressure of 896 kPa. Secondary gas halos of argon and helium were added to the interior of the spray chamber at various downstream locations for additional cooling of the atomised droplets and/or for surface oxidation, to passivate (and prevent coalescence of) the resulting powder.

Recent results were encouraging in terms of the suppression of large internal porosity from trapped atomisation gas and minimisation of satellite projections on as-atomised powder particles.

Suppression of the entrapment of atomising gas in the powder making process requires the use of an alternative atomisation mechanism with lower energy than the 'bag break-up and collapse' mechanism. As the authors have described in a previous publication, there are several types of ligament and direct droplet formation mechanisms that lead to instabilities and droplet pinch-off without any apparent opportunity to trap atomisation gas. However, it remains a challenge to develop the gas atomisation configuration and parameters that promote only these lower energy droplet formation mechanisms, while avoiding bag break-up and collapse.

SEM examinations of batches of commercial powders from two different suppliers showed that 28% of powder particles contained trapped internal porosity for vendor A and 21% for vendor B (Fig. 8). Results from the Ames laboratory atomisation experiment indicated that progress towards suppression of internal porosity by using gas with a reduced kinetic energy had been achieved, with only 4% of powder particles containing trapped gas (Fig. 9).

Another type of internal porosity that can persist in AM builds, in spite of post-build HIP consolidation, is derived from sphere-like powder shapes that are decorated by 'satellite' projections. This type of retained porosity in builds is especially troublesome for AM methods such as laser melting and EBM/PBF. Unlike the gas porosity trapped inside spherical powders, satellite-decorated powders will encounter problems with a lack of smooth, continuous 'flowability' when tested in gravity-induced flow out of a funnel, either Hall or Carney, when propelled by a carrier gas in the narrow tube from a powder feeder, or when spread as a fresh layer on a powder bed of a controlled height by a roller or 'doctor blade.' The latter two of these types of flowability problems can produce lean regions on the basis of a lower powder flux flowing into the molten zone of a DED system or scattered clusters of unoccupied void space in the settled layers of a powder bed fusion system.

Examination of one of the commercial samples also showed that particle shape was fairly spherical at low magnification, but there was a noticeable population of satellite projections in the higher magnification image (Fig. 10). After producing an experimental batch of a very similar alloy within the narrow spray chamber (30 cm inner diameter) of the Ames Lab pilot-scale gas atomisation system (Fig. 7), SEM analysis of the as-atomised powder (see Fig. 11) indicated that satellite decoration was greatly reduced in this experiment.

It seems possible to attribute the high degree of sphericity of the powder in Fig. 11 to the narrow spray chamber of the Ames Lab system (see Fig. 7) that limits the external recirculation flow effect, but it is still possible for classic satellite formation mechanisms to operate. Thus, more modelling on the influence of the spray chamber design and experiments to verify these results must be performed in order to perfect the satellite suppression effects that seem very promising in the initial experiment.

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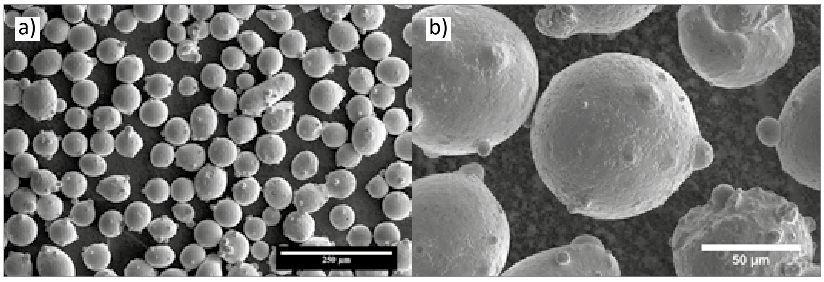


Fig. 10 SEM micrographs in secondary electron imaging of inert gas atomised MAR-M-247 powder from vendor A in the size range 45-106 µm, showing exterior powder surfaces at low (a) and high (b) magnification, respectively [3]

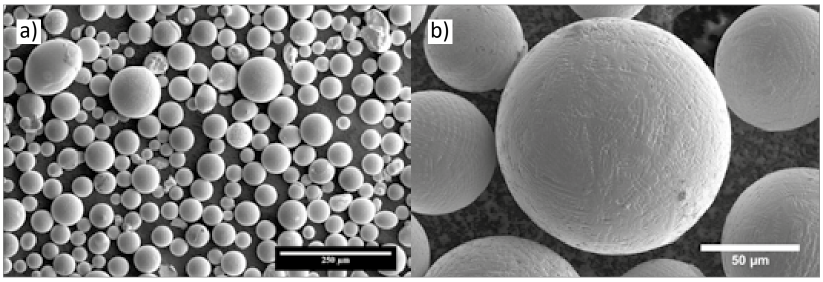


Fig. 11 SEM micrographs in secondary electron imaging of Ar-atomised MAR-M-247 (with slightly modified composition) experimental powder in the size range 45-106 µm, showing exterior powder surfaces at low (a) and high (b) magnification, respectively [3]

Proceedings

Advances in Powder Metallurgy & Particulate Materials - 2017, the proceedings of the technical sessions, poster program and special interest programs (where applicable), is published in digital format by the MPIF. These can be purchased from the MPIF's Publications Department.
www.mpif.org

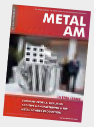
POWDERMET2018

POWDERMET2018, the International Conference on Powder Metallurgy & Particulate Materials, will take place in San Antonio, Texas, USA, from June 17–20, 2018. A Call for Papers & Posters has been issued and the abstract submission deadline is November 3, 2017.
www.powdermet2018.org

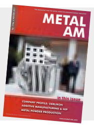
industry events

2018

MAPP First International Conference
January 30-31, Sheffield, United Kingdom
mapp.ac.uk/events/mapp-1st-international-conference



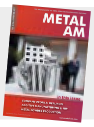
3D Printing 2018
February 14-16, Tokyo, Japan
www.3dprintingexpo.jp



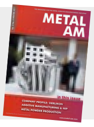
AM for Aerospace and Space
February 20-22, Krailling, Germany
https://additivemanufacturing.iqpc.co.uk/

SAE 2018 Hybrid & Electric Vehicle Tech.
February 20-22, San Diego, United States
www.sae.org/events/hybridev

METAV 2018
February 20-24, Düsseldorf, Germany
www.metav.com

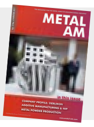


TCT Asia
February 28 - March 3, Shanghai, China
www.tctasia.com.cn

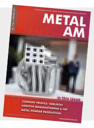


Additive Manufacturing Forum
March 5-6, Berlin, Germany
www.additivemanufacturingforum.com

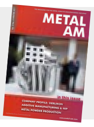
AERODEF Manufacturing
March 26-29, Long Beach, Inited States
www.aerodefevent.com



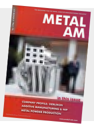
PM China 2018
March 25-27, Shanghai, China
www.cn-pmexpo.com/en/



AMUG
April 8-12, St Louis, United States
www.additivemanufacturingusersgroup.com

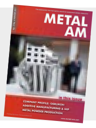


Rapid + TCT
April 23-26, Fort Worth, United States
www.rapid3devent.com

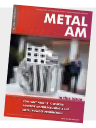


AKL'18 - Int. Laser Tech. Congress
May 2-4, Aachen, Germany
www.lasercongress.org

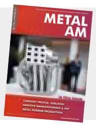
3D Print Congress & Exhibition
June 5-7, Lyon, France
www.3dprint-exhibition.com



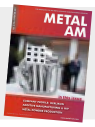
AMPM2018
June 17-19, San Antonio, United States
www.ampm2018.org



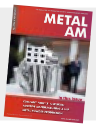
Additive Manufacturing Europe 2018
June 26-28, Amsterdam, Netherlands
www.amshow-europe.com



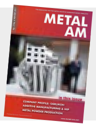
World PM2018 - World Conference on PM
September 16-20, Beiijing, China
www.worldpm2018.com



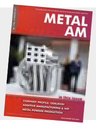
TCT 2018
September 25-27, Birmingham, UK
www.tctshow.com



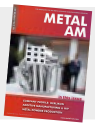
Euro PM2018 Congress & Exhibition
October 14-18, Bilbao, Spain
www.europm2018.com



IN(3D)USTRY
October 16-18, Barcelona, Spain
www.in3dustry.com



formnext 2018
November 13-16, Frankfurt, Germany
www.formnext.com



Event listings & Media Partners

If you would like to see your metal Additive Manufacturing related event listed in this magazine and on our websites, please contact Paul Whittaker: email: paul@inovar-communications.com

We welcome enquiries regarding media partnerships and are always interested to discuss opportunities to cooperate with event organisers and associations worldwide.

Pick up your free copy!

Metal AM magazine is exhibiting at and/or being distributed at events highlighted with the Metal AM cover image

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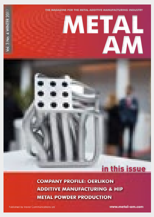

Metal AM is the business-to-business magazine that focuses on commercial and technical developments in the metal AM industry.

As well as featuring the latest business and applications news, technical developments in the industry will also be highlighted, making the magazine the essential resource for part manufacturers and end-users, along with equipment and material suppliers.

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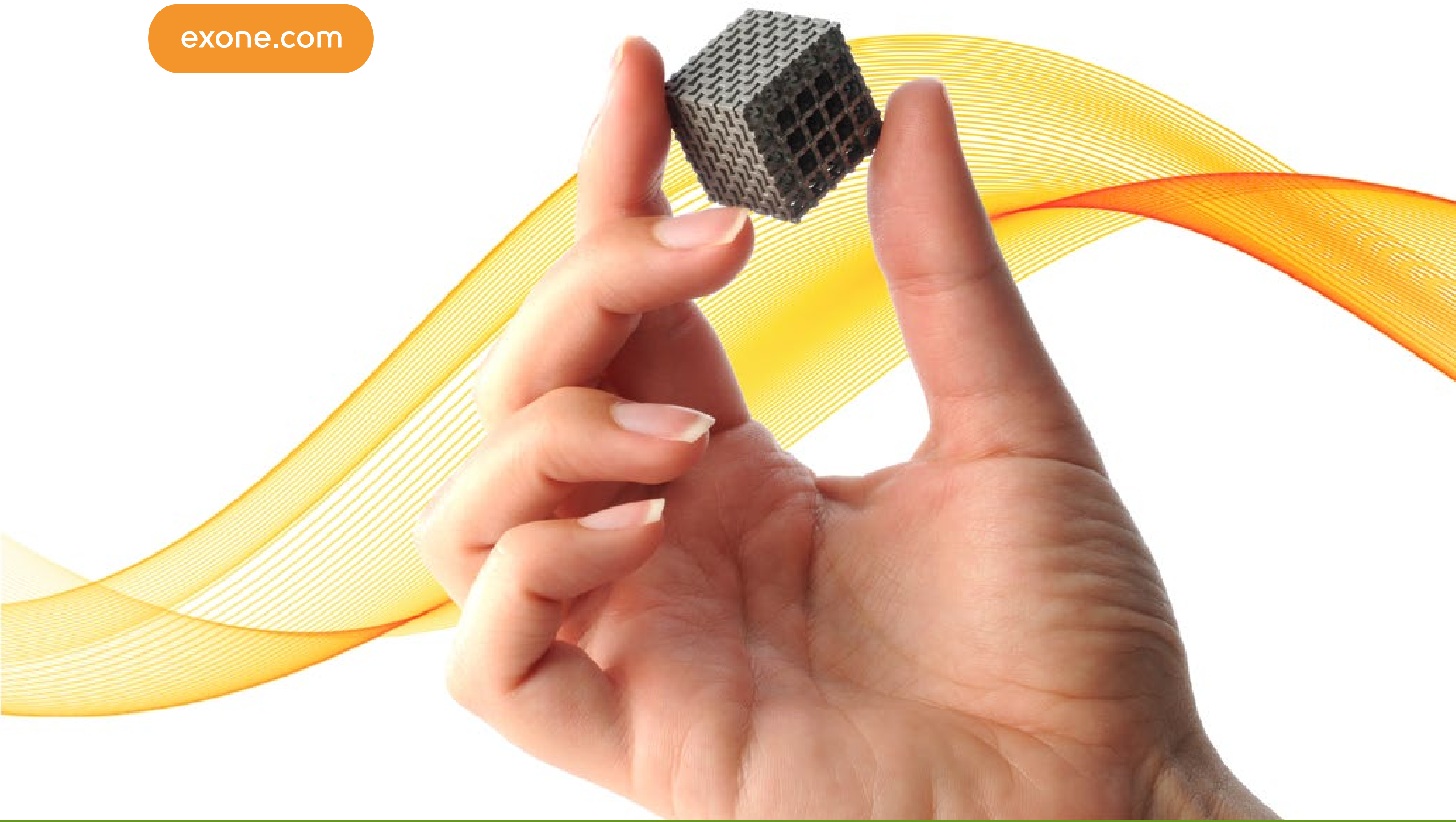

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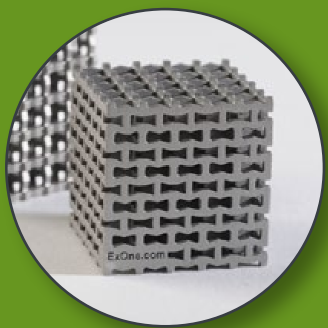

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