Vol. 3 No. 2 SUMMER 2017

THE MAGAZINE FOR THE METAL ADDITIVE MANUFACTURING INDUSTRY

METAL AM

in this issue

ON-DEMAND MANUFACTURING

AM IN THE TYRE INDUSTRY

QUALITY CONTROL WITH X-RAY CT

Published by Inovar Communications Ltd

www.metal-am.com

Publisher & Editorial Offices
Inovar Communications Ltd
11 Park Plaza
Battlefield Enterprise Park
Shrewsbury SY1 3AF, United Kingdom
Tel: +44 (0)1743 211991 Fax: +44 (0)1743 469909
Email: info@inovar-communications.com
www.metal-am.com

Managing Director, Features Editor
Nick Williams
Tel: +44 1743 211993
Email: nick@inovar-communications.com

Publishing Director, News Editor
Paul Whittaker
Tel: +44 1743 211992
Email: paul@inovar-communications.com

Assistant Editor
Emily-Jo Hopson
Tel: +44 (0)1743 211994
Email: emily-jo@inovar-communications.com

Production
Hugo Ribeiro, Production Manager
Tel: +44 (0)1743 211991
Email: hugo@inovar-communications.com

Advertising
Jon Craxford, Advertising Sales Director
Tel: +44 207 1939 749
Fax: +44 1743 469909
Email: jon@inovar-communications.com

Subscriptions
Metal Additive Manufacturing is published on a quarterly basis as either a free digital publication or via a paid print subscription. The annual print subscription charge for four issues is £95.00 including shipping. Rates in € and US$ are available on application.

Printed by
Cambrian Printers, Aberystwyth, UK

ISSN 2057-3014 (print edition)
ISSN 2055-7183 (digital edition)

Vol. 3. No. 2 Summer 2017

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

METAL ADDITIVE MANUFACTURING

Metal AM flying high at the Paris Air Show

A lot has happened in the rapidly evolving world of metal Additive Manufacturing since the previous Paris Air Show two years ago, with GE's acquisition of Concept Laser and Arcam and the launch of GE Additive being notable highlights.

It was therefore only to be expected that GE, along with a number of other aerospace leaders, were going to 'pull out all the stops' at this year's air show to send the message that Additive Manufacturing is a viable technology which is having a major impact on the twin challenges of increasing fuel efficiency and reducing manufacturing complexity.

During this year's event, GE Aviation and its joint venture companies, led by CFM International, announced more than $31 billion in orders and commitments. The bulk of these orders were for the new family of LEAP aero engines, with their widely publicised AM fuel nozzles. This brings the total orders for the LEAP engines to more than 14,000 to date, up from 12,500 before the show.

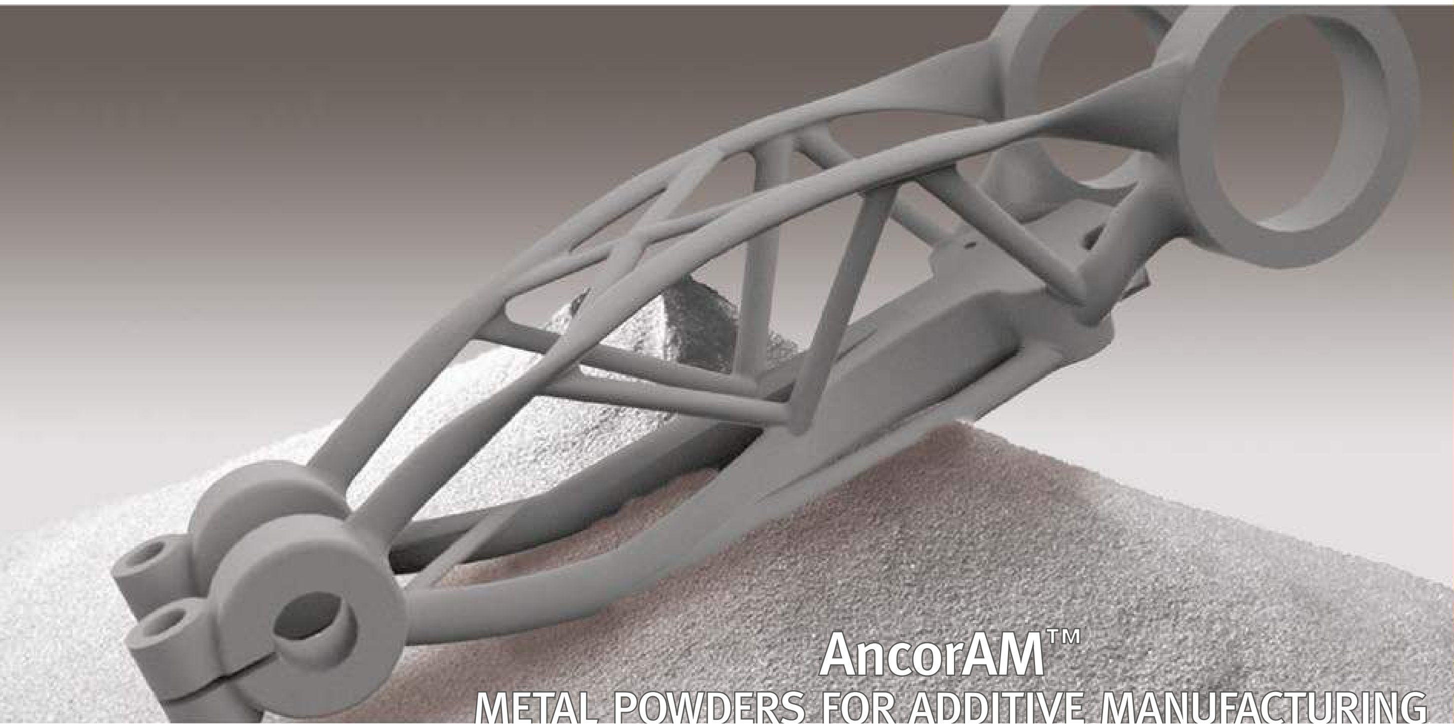
With each engine featuring up to nineteen AM fuel nozzles, production of this AM component looks increasingly likely to break through the quarter of a million barrier. This is an outstanding achievement not only by GE, but also by the many AM production machine and metal powder vendors whose expertise brought so much to the project.

Clearly, for the right applications, AM must now be recognised as a viable process for mass production.

Nick Williams
Managing Director
Metal Additive Manufacturing

Cover image
Desktop Metal's unique support structures use ceramic powder as the interface with the part surfaces (Courtesy Desktop Metal)

HOEGANAES



AncorAM™ POWDERS

Our standard range of powders are optimized for additive manufacturing and are available in particle sizes for both Selective Laser Melting (SLM) and Electron Beam Melting (EBM). Particle size and flow characteristics are specifically engineered for your AM powder feed system and melting protocol.

Titanium AM Powders

- AncorTi CP - Grades 1& 2
- AncorTi 6Al4V - Grade 5 & ELI/Grade 23
- AncorTi Beta 21S
- Additional titanium alloys are available upon request

Stainless Steel & Nickel Based AM Powders

- AncorAM 17-4 PH
- AncorAM 316L
- AncorAM 1.2709
- AncorAM IN625
- AncorAM IN718
- Additional alloys are available upon request

- ADVANCED AM POWDER TECHNOLOGY

- High Purity Titanium Melting
- Custom Alloys for AM
- Unique Property Development

- RIGOROUS SYSTEMS & PROCESS

- AS9100 Quality Management System Certified
- Intelligent Process Control & Specifications
- Complete Inspection, Testing & Certification

- COMPREHENSIVE SUPPORT

- AM Powder Application Specialists
- World Class Innovation Centers
- Metal AM Part Testing & Analysis Capabilities

- SCALABLE PRODUCTION

- State-of-the-Art USA Production Facility
- Scalable Capacity to Meet Future Growth
- Continuous Process Development & Improvement

FOLLOW US ON SOCIAL MEDIA AT:
@HoeganaesCorp
YouTube LinkedIn

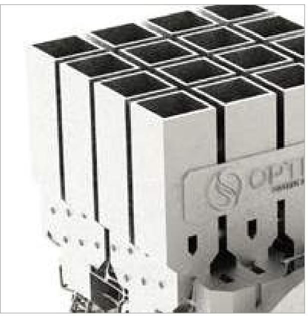
MOBILE DEVICE APPS NOW AVAILABLE FOR DOWNLOAD
App Store Google play

TECHNOLOGY... QUALITY... SUPPORT

www.gkngroup.com/hoeganaes

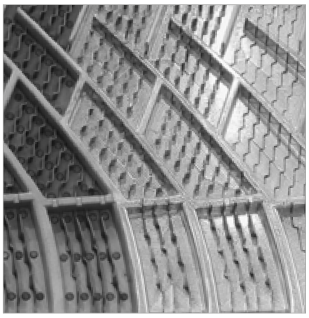
ENGINEERING > THAT MOVES THE WORLD

METAL ADDITIVE MANUFACTURING

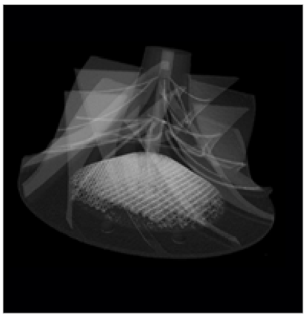


39

74



83



106

114

Contents

industry news

Safran obtains certification for a major AM auxiliary power unit part

Safran Power Units, Toulouse, France, states that it has crossed a new milestone in the field of Additive Manufacturing by obtaining the first certification from the European Aviation Safety Agency (EASA) for a major part for an auxiliary power unit (APU) made by Additive Manufacturing. This certification paves the way for its mass production.

The certified part is the turbine nozzle for the eAPU60 that is manufactured by Selective Laser Melting (SLM) using Hastelloy X, a nickel-based material. Conventionally machined by Inconel casting, the AM printed part is now 35% lighter and is now comprised of only four components, versus eight when manufactured conventionally.

It was stated that this certification is the result of intensive endurance tests at very high temperatures on a test bench at the Safran Power Units site in Toulouse. An extensive material testing campaign, conducted by the Safran companies, also contributed to preparing the certification submission.

The results demonstrate that the new design of the nozzle is suitable for the SLM process. The metallurgical properties are also perfectly in line with the mechanical and thermal requirements for high-performance APU components subjected to extreme conditions.

"Safran Power Units now has complete mastery of the Additive Manufacturing process, which includes the ability to design differently, while exploiting the optimisation potential in terms of industrial implementation. This allows us to offer our customers lighter engine components and reduced manufacturing cycles, whether for new or spare parts. All of our programmes will progressively adopt this new manufacturing process" said François Tarel, CEO of Safran Power Units.

The turbine nozzle for the eAPU60 (Courtesy Safran Power Units – Astrid Desclos)

www.safran-power-units.com

GE Additive to create the world's largest laser-powder AM machine

GE Additive has announced that it is in the process of creating the world's largest laser-powder Additive Manufacturing machine. Tailored for the aerospace industry, GE states that the machine will be able to print in a build envelope of one metre cubed (1000 mm x 1000 mm x 1000 mm). The development project, announced at the Paris Air Show, will be unveiled in November at the Formnext exhibition in Frankfurt, Germany.

"The machine will 3D print aviation parts that are one meter in diameter, suitable for making jet engine structural components and parts for single-aisle aircraft," stated Mohammad Ehteshami, Vice President and General Manager of GE Additive. "The machine will also be applicable for manufacturers in the automotive, power, and oil and gas industries."

The initial technology demonstrator machine, called ATLAS, is a laser/powder machine and will be 'meter-class' (1000 mm) in at least two directions. The GE team has been developing the machine over the past two years and several proof-of-concept machines have been built.

GE explained that in the machine's production version, the build geometry will be customisable and scalable for an individual customer's project and its feature resolution and build-rate speeds will equal or better today's additive machines. The system is also designed to be used with multiple materials, including non-reactive and reactive materials, such as aluminium and titanium.

"We have customers collaborating with us and they will receive beta versions of the machine by year's end," Ehteshami added. "The production version – yet to be named – will be available for purchase next year." GE is targeting first deliveries of the machine in late 2018.

The technology demonstrator builds upon GE technology, combined with Concept Laser's expertise in laser additive machines. Concept Laser, the German-based company in which GE Additive has controlling ownership, currently has the largest laser-powder bed additive machine on the market with a build envelope of 800 mm x 400 mm x 500 mm.

www.geadditive.com

GKN Hoeganaes begins production of titanium powder in the US

GKN Hoeganaes, a global leader in the production of high quality metal powders, has started production at its Additive Manufacturing powder facility, co-located with its Powder Innovation Center in Cinnaminson, New Jersey, USA. The new powder atomising facility is part of the joint venture with TLS Technik of Germany, announced last year, and provides customers with a North American source for titanium and other specialised powders for Additive Manufacturing.

The facility now serves as the USA production hub for AncorAM™ powder products and includes full-scale atomising and powder finishing for titanium alloys and other speciality powders for metal Additive Manufacturing. The dedicated Additive Manufacturing powder production lines are housed in a 10,000 ft^2 (930 m^2) state of the art facility that is fully climate controlled for quality and consistency. The advanced powder atomising process uses a proven refractory-free melting method to produce very high purity powders said to be suitable for aerospace and medical applications. All production is certified and completed according to the AS9100 quality management system with medical quality management system certification now underway.

AncorAM™ powders are specifically designed for Additive Manufacturing

AncorAM™ metal powders are produced on full production scale processing equipment and have been engineered with alloy chemistry and powder characteristics specifically designed for Additive Manufacturing, focusing on final product consistency. Powders for both selective laser melting and electron beam melting systems are available. Standard titanium powder grades now available include AncorTi™ CP and AncorTi™ 6Al4V as well as a host of nickel and ferrous based powders. Additionally, GKN Hoeganaes is developing a family of new powder alloys for Additive Manufacturing including advanced titanium powders to be used in applications that require high oxidation-resistance, specialised nickel-based alloys to be for high temperature applications, and nickel-titanium powders engineered for use in advanced medical devices.

Peter Oberparleiter, CEO of GKN Powder Metallurgy, commented, "The launch of titanium powder production is a key part of GKN's continued drive to offer a comprehensive set of products, services and technologies that enable the growth of metal Additive Manufacturing into a major industry and positions GKN Hoeganaes to enable its customers to launch demanding additively manufactured components for aerospace and medical applications."

www.hoeganaes.com

Uddeholms AB to produce metal powders for Additive Manufacturing

Uddeholms AB, part of the Special Steel Division of voestalpine Group, has announced the commencement of fine metal powder production at its new pilot plant at Hagfors, Sweden. The new plant is the result of ongoing investment at the site, which has seen voestalpine invest over €100 million in expanding technology and capacity at Uddeholms AB over the past decade.

Powders produced at Uddeholms' Hagfors facility will be tested and processed into complex components at voestalpine's Additive Manufacturing Centre, Düsseldorf, Germany, as well as being sold to external customers in the AM industry. According to the company, this will open up a new business segment for Uddeholms AB and support voestalpine's planned expansion into metal Additive Manufacturing in Asia and the NAFTA regions as a materials supplier.

"In order to reinforce the company's global leadership in special steels for industrial tool manufacture, over the coming years further investments totalling around €30 million are planned, for new high-tech heat treatment facilities, as well as research establishments to further refine our steel grades. A focus of our future activities in Hagfors also lies in producing metal powders designed for use in 3D metal printers," stated Franz Rotter, Member of the Management Board of voestalpine AG and head of the Group's Special Steel Division.

voestalpine, which operates globally, has around 500 group companies and locations in more than 50 countries on five continents.

Part production at voestalpine's Additive Manufacturing Centre, Düsseldorf, Germany (Courtesy voestalpine)

In the business year 2015/16, the group generated revenue of €11.1 billion, with an operating result (EBITDA) of €1.6 billion. The group employs 48,500 staff worldwide.

www.voestalpine.com

Wohlers Report 2017 shows increased AM commercialisation and development worldwide

Wohlers Associates, Inc., Fort Collins, Colorado, USA, is a consulting firm and leading authority on Additive Manufacturing and the associated industries. The company has announced the publication of its *Wohlers Report 2017*, marking the report's 22nd consecutive year.

According to the detailed report, some 97 manufacturers produced and sold Additive Manufacturing systems in 2016, compared to 62 companies in 2015 and 49 in 2014. This increase in development and commercialisation is putting pressure on established producers of AM systems, the report states.

The Additive Manufacturing industry grew by 17.4% in worldwide revenues in 2016, a decrease of 25.9% from 2015. According to the report, this decrease is the result of declines by the two largest system manufacturers in AM. Together, the two companies represent $1.31 billion (21.7%) of the $6.063 billion AM industry. If these two companies were excluded from the analysis, the industry would have grown by 24.9%.

For Wohlers Report 2017, input was collected from 100 service providers, 61 industrial system manufacturers, and 19 producers of third-party materials and low-cost desktop 3D printers.

Separately, 76 experts and organisations in 31 countries contributed information and insight to the new publication. Together, they form the basis for computing growth, analysing trends and forecasting the future of Additive Manufacturing. The 344-page report includes 28 charts and graphs, 26 tables and 232 photographs and illustrations.

wohlersassociates.com

Keppler new CEO of EOS GmbH

EOS GmbH, Krailling, Germany, has appointed Dr Adrian Keppler as CEO and Speaker of Corporate Management at EOS GmbH with immediate effect. Dr Hans J Langer, founder of EOS, is handing over leadership of EOS GmbH and, as CEO & Chairman of the EOS Group, will increasingly dedicate his efforts to strategically expanding and developing the EOS Group in its entirety.

Together with Dr Tobias Abeln (CTO) and Eric Paffrath (CFO), Keppler heads up the operational management at EOS GmbH. A new member will be appointed to his previous management position as CMO of EOS GmbH. In the interim period, however, Keppler will fulfil both duties.

www.eos.info

Major expansion in gas atomised powder production at Sandvik Osprey

Sandvik Osprey has signalled a major expansion of gas atomised powder production capacity with the commissioning of a new atomising facility in Neath, UK. According to the company, the expansion is prompted by strong demand for its premium metal powders from both the rapidly growing metal Additive Manufacturing sector and well-established Metal Injection Moulding industry. News of this latest expansion follows a considerable capacity expansion in late 2012.

Sandvik Osprey has been atomising metals for more than 40 years and has 25 years' experience producing fine gas atomised powders, typically of less than 30 microns, for the global MIM industry. Over that time, it has invested continually in new capacity and has extended its range of powders to cover many thousands of alloys, including a comprehensive selection of pre-alloyed stainless steels, master alloys, low-alloy steels, tool steels, nickel-based super alloys, cobalt alloys, copper alloys and specialist alloys, including soft magnetic alloys and controlled expansion alloys.

The company states that its extensive powder offering serves diverse market sectors including consumer, hand tools and medical devices, aerospace components and automotive turbochargers; fast growing sectors whose demand for high quantities of metal powder necessitate Sandvik's continued growth. Expansion at the company's Red Jacket Works, Neath, will include a new fine powder atomiser – providing a substantial increase in production capacity and a commensurate increase in powder processing capability – with additional sieving and air classification equipment, as well as new blending facilities offering homogeneous batch sizes of up to 6000 kg.

Sandvik Osprey's powder production equipment has been designed using the latest atomisation modelling and simulation techniques to produce powders which are optimised for metal Additive Manufacturing. Here the company is focused on key markets including maraging tool steel for conformal mould cooling, stainless and low-alloy steels for structural parts and nickel-based alloys for high temperature applications. Aluminium alloys are a new addition to Sandvik's portfolio, aimed at satisfying the specific demands of the Additive Manufacturing market.

Recent growth in dental market applications, including custom-fit crowns and bridges, has also prompted investment in a purpose-built facility for cobalt powder processing equipped with sieving, air classification, blending and automated packing facilities. New rounds of expansion are planned over the coming years to further increase capacity and capability.

www.smt.sandvik.com

Prodways Group develops Rapid Additive Forging for large ti parts

Prodways Group, Les Mureaux, France, a subsidiary of Groupe Gorgé, has announced its development of Rapid Additive Forging (RAF) technology for the Additive Manufacturing of large titanium parts. The machine that has been developed uses a robot equipped with a head depositing molten metal in an atmosphere of inert gas. Metal is deposited layer-by-layer and large parts are completed within a few hours.

This innovative technology, states the company, quickly manufactures titanium blanks with very close geometries to the final part. These blanks are then finish-machined, thus avoiding considerable losses of material which can represent up to 95% of a metal block with traditional machining processes.

The technology was developed in collaboration with Commercy Robotique, a subsidiary of Groupe Gorgé that has specialised in robotised welding for more than 40 years. A patent application has been filed by Prodways Group. The process has been tested on various metals, however there is a strong focus on titanium, a metal seeing increased use in new-generation aircraft.

The company states that the third generation of the prototype can produce parts of more than 70 cm in length, however a version is being developed that will be able to manufacture parts of up to 2 m in the main dimension.

It was stated that Rapid Additive Forging has been developed with a focus on metallurgical quality and the repeatability of the process. The first metallurgical tests conducted on parts have revealed an absence of porosity and greater mechanical resistance compared with metal AM processes using laser or electron beams.

Example of AM and partially finish-machined titanium part (Courtesy Prodways)

Prodways stated that several players in the aeronautical industry believe this technology family could be applied to nearly 50% of the titanium parts used to manufacture an aircraft and generate savings of up to 50% on the cost of parts.

www.prodways.com

Boeing passenger jet enters into service with metal AM engine components

GE has reported the first regular flight of the Boeing 737 MAX 8, an aircraft which is powered by two CFM International LEAP-1B engines. The LEAP engines are the first to be built with additively manufactured fuel nozzles. According to GE Reports, fuel nozzles made this way can be manufactured in a single, complex piece instead of requiring assembly. This makes them lighter and more durable, helping to improve the aircraft's fuel burn.

"These new aircraft offer lower operating costs with better fuel efficiency due to its new LEAP-1B engines, and aerodynamic improvements will allow us to go to farther destinations," explained Chandran Rama Muthy, the CEO of Malindo Air, a carrier that has ordered eight 737 MAX 8s so far.

LEAP engines were developed by engineers with CFM International, a joint venture between GE Aviation and France's Safran Aircraft Engines, and have been in operation since 2008. Altogether, GE states that LEAP-1B engines are providing 15% lower fuel consumption compared with the CFM56-7B engines operating on today's global 737 fleet. CFM reports that this leads to "dramatic reductions" in engine noise and emissions of CO_2 and other exhaust gases.

The LEAP is the best selling engine in GE Aviation's history. The A320neo Airbus passenger jet, powered by twin LEAP jet engines with AM fuel nozzles, completed its maiden flight in May 2015.

www.geaviation.com
www.gereports.com

Materialise broadens AM solutions and launches inspection software

Materialise, headquartered in Plymouth, Michigan, USA, has introduced a number of enhancements to its Materialise Magics 3D Print Suite software portfolio. The company's new Materialise Inspector software allows users to analyse data at all stages of the production process in order to meet predetermined quality standards. According to the company, the software optimises image processing for efficiency in post-build analysis and is capable of processing more than 4,000 images in minutes – making big data analysis easier and more efficient.

Materialise is also offering Magics Print Metal software, said to be an easy-to-use solution designed to facilitate access to metal AM. This software combines basic build preparation and job file generation, which Materialise states will streamline the AM process. Metal machine manufacturers can tailor the lay-out and bundle it to their machines.

"Demand for additively manufactured metal products and components is increasing across several industries, and manufacturers need the tools to adapt and meet this demand," explained Bryan Crutchfield, Vice President and General Manager of Materialise North America. "Magics Print Metal extends our existing metal offerings. The Magics 3D Print suite represents the full digital thread, giving metal machine manufacturers the ability to develop, implement and manage each step of the 3D printing process. Now, with the new Inspector software, users can also efficiently analyse data during each step to ensure workflows and products will fit their needs as well as the needs of their customers and partners."

Further enhancements to the Magics 3D Print Suite were announced aimed at allowing users to take full control over their AM workflows. The company's Robot 5.1 software update offers a 3D Nesting module, optimising part positioning to save time, money and materials. The companies 3-matic 12 software update includes new ways to manipulate and optimise CAD designs for AM and accepts a wider variety of FEA file formats to create improved lightweight structures.

"The components of the Materialise Magics 3D Print Suite work together to address each step in the AM process and form the software backbone of AM solutions for all businesses and industries, from design optimisation and data preparation to production management and automation," added Crutchfield.

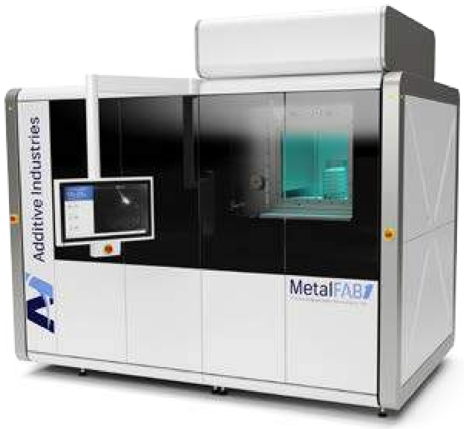
Materialise also announced its commitment to embedding simulation technology into its AM software, allowing users to simulate builds before production to avoid costly defects in designs, materials and processes.

www.materialise.com

Latest MetalFAB1 system from Additive Industries targets process development and prototyping

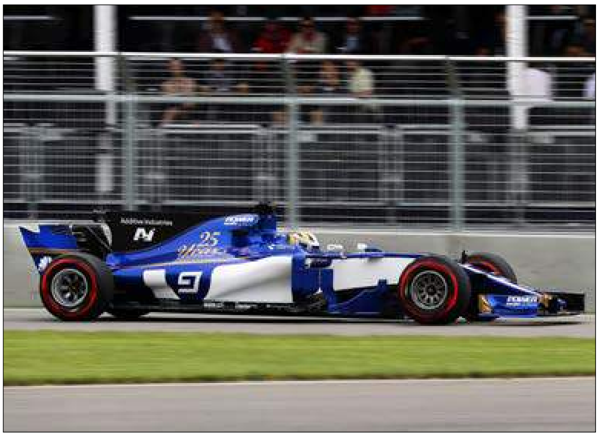
Additive Industries, Eindhoven, Netherlands, has announced a new model of its MetalFAB1 industrial metal Additive Manufacturing system. The 'MetalFAB1 Process & Applications Development Tool' is aimed at prototyping applications and designed to help first-time users gain experience with metal Additive Manufacturing before scaling for series production.

The system incorporates the modular architecture typical of the MetalFAB1 system family, and will allow users to upgrade to a full-size MetalFAB1 system at a later date. The technology and build volume (420 x 420 x 400 mm) are identical to the larger systems for series production. Additive Industries suggested that existing MetalFAB1 users might also use the new system to develop build strategies and process settings for new materials and applications, before transferring these to their larger industrial systems for series production. This will prevent disturbances to production planning and regular operations, the company added.



The MetalFAB1 Process & Application Development Tool (Courtesy Additive Industries)

"This machine is the result of a productive dialogue with our customers and prospective users and completes the range of MetalFAB1 systems for industrial metal Additive Manufacturing," stated Mark Vaes, CTO, Additive Industries. "There is no other solution offering so much flexibility to expand in combination with future-proof 3D printing capabilities," added Daan Kersten, Co-founder and CEO.



A Sauber F1 team race car (Courtesy Sauber F1)

The Sauber F1 Team, headquartered in Hinwil, Switzerland, will be the first customer of the MetalFAB1 Process & Application Development Tool. The deal is part of a three-year technology partnership between the two companies and was announced by Steffen Schrodt, Head of Wind Tunnel Operations at Sauber F1 Team, and Christoph Hansen, who is responsible for Additive Manufacturing, during a keynote speech at the Rapid.Tech conference and exhibition, Erfurt, Germany, June 20-22, 2017.

The Sauber F1 Team, which has significant experience in polymer-based Additive Manufacturing, will purchase two industrial MetalFAB1 3D metal Additive Manufacturing systems over the course of two years to expand its expertise into metal AM. The partnership with Sauber F1 Team was said to underline the ambition of Additive Industries to become a leading AM system manufacturer for demanding markets such as aerospace, automotive, medical implants and high-tech equipment.

"We are honoured to be invited to join the Sauber F1 Team as a Technology Partner. Sauber has been the launch pad for champions for decades, Michael Schumacher, Kimi Räikkönen, Felipe Massa and Sebastian Vettel all started their F1 careers at this unique private Swiss team. The professionalism of the Sauber F1 Team as well as their drive for technological innovation, they own one of the most advanced automotive wind tunnels in the world, fits beautifully with our quest for industrial excellence," stated Kersten.

"We are delighted to welcome Additive Industries on board as our new technological partner at the Sauber F1 Team. Since this innovative fabrication technology is still in the early stages of industrialisation, it is an ideal moment for us to take on this challenge with our new partner. By doing so, we will gain and develop the necessary know-how in this area. It is our mission to set new standards," stated Monisha Kaltenborn, Sauber F1 Team CEO and Team Principal at the time of the announcement.

www.additiveindustries.com
www.sauberf1team.com

Norsk Titanium to expand production capacity at New York facility

Norsk Titanium AS, headquartered in Oslo, Norway, has finalised a definitive purchase agreement for twelve of its Rapid Plasma Deposition™ (RPD™) Merke-IV™ machines with Fort Schuyler Management Corporation and Empire State Development for use in its Plattsburgh, North Country, New York, USA, production centre. This new order will begin delivery in mid-2018.

The agreement is in addition to a twenty-machine order announced last year. Machines from that order are being delivered throughout 2017. Each machine is capable of producing up to 20 tons of printed material per year, with significantly less waste and machining energy than conventional processing, allowing for a cost savings of more than 30%.

"Norsk Titanium's new production and development facilities will bolster the North Country's advanced manufacturing sector and the increasing demand for their products is great news for the local economy," stated Empire State Development President, CEO & Commissioner Howard Zemsky.

www.norsktitanium.com

solidThinking®

CONVERGE 2017

REGISTRATION IS **NOW OPEN!**

AMERICAS
Los Angeles, CA
September 13

EUROPE
Essen, Germany
October 17

ASIA
Tokyo, Japan
November 22

EXPLORING THE INTERSECTION OF **DESIGN & TECHNOLOGY**

Join a community of your creative peers and innovators to uncover strategies behind developing top products. Hear from leaders across industries, discover new technologies, and leave with new insights toward product and experience design and development.

Get amped up with invigorating keynote speakers, technology demonstrations, and direct interaction with people who have boldly shown how things can be done.

Register now at **Converge2017.com**

An Altair Company

Aeroswift developing large scale metal powder based AM machine

According to Reuters, researchers at South Africa's government and Aerosud backed Aeroswift research project are reported to be developing a large scale titanium powder-based metal Additive Manufacturing machine.

With a production chamber measuring 2 m x 0.6 m x 0.6 m, Aeroswift's newly designed AM machine is reported to have achieved production speeds of up to ten times that of currently available commercial laser melting machines. Last year, the machine was used for the first time to produce a pilot's throttle lever, fuel tank pylon bracket and condition lever grip. These parts are expected to be in test flights later in 2017.

"Our machine is unique and the only one in the world," stated Hardus Greyling, Contract Co-ordinator. "We have developed new technologies and patents which allows us to upscale the additive process to go significantly faster and significantly larger than other systems."

The Aeroswift research project was created in 2011, with the aim of boosting South Africa's economic outlook by leveraging its natural titanium reserves. According to the 2013 US Geological Survey, South Africa's natural titanium reserves rank fourth in the world behind China, Australia and India.

Airbus, who helped found the project through partnership with South Africa's Council for Scientific and Industrial Research (CSIR) and Boeing, who joined the project in 2013, are reportedly in talks with Aeroswift and the South African government to secure the project's commercial success.

"How best to commercialise the process is a discussion we are currently having with the Aeroswift partners and relevant government agencies," said Simon Ward, Airbus's Vice President for International Co-operation in Toulouse.

If successful, Aeroswift's metal Additive Manufacturing process could save the automotive, aerospace and military industries millions of dollars on fuel and production costs, as aluminium bodies are replaced by lighter titanium alloys.

www.aerosud.co.za/tech

Carpenter Technology begins production of high-strength, low-oxygen titanium powder

Carpenter Technology Corporation, Philadelphia, PA, USA, has announced the production of CARTECH® PURIS 5+™, claimed to be the market's first high-strength, low-oxygen titanium powder solution.

A custom composition of Ti-6Al-4V that meets all Grade 5 specifications, the company states that the powder signals a breakthrough in additive manufacturers' ability to better control oxygen content inherent to their processes without compromising powder strength.

"Balancing oxygen levels with desired strength properties is a challenge in Additive Manufacturing. CARTECH PURIS 5+ provides the simultaneous optimisation of powder recyclability and strength, alleviating concerns about using low oxygen powder (to maximise powder reuse) while still exceeding standard strength requirements," explained Michael Murtagh, Carpenter's Chief Technology Officer. "CARTECH PURIS 5+ makes this balance easier, more efficient and more effective from the start and throughout the titanium powder lifecycle". CARTECH PURIS 5+ is Carpenter Technology's first major powder product introduction since its acquisition of Puris, LLC earlier this year.

"The future of aerospace hinges on advancing Additive Manufacturing technology," stated Tony R Thene, Carpenter's Chief Executive Officer. "It's an exciting, yet complex process with enormous potential and it requires extensive metallurgical expertise, in addition to quality powder products. Carpenter Technology is well-positioned to provide these value-added solutions to customers."

www.cartech.com

Cooksongold and BMC collaborate to offer precious metal AM jewellery

B.M.C. srl, Gusago, Italy, has announced a collaboration with UK-based Cooksongold and its precious metal Additive Manufacturing division. B.M.C will adopt the Precious M 080 AM system developed by Cooksongold and EOS at its Italian facility, enabling the company to offer a complete precious metal AM service to its customers in the luxury jewellery sector.

"We are always looking to incorporate the latest technology and production possibilities. Direct precious metal 3D printing with the M 080 system provides us with another tool and production method which will ensure we can continue to push the boundaries of jewel and watch creation," stated Carlo Massavelli, B.M.C CEO and Chairman.

www.cooksongold-emanufacturing.com

www.bmc-srl.com

GE Additive adds Predix Platform to Concept Laser machines

GE Additive has announced that it will add Predix Platform capabilities to its Concept Laser M2 cusing additive machines, giving customers the opportunity to remotely monitor their machines, increasing their productivity and improving their operations. From September this year, all Concept Laser M2 cusing and additive machines will be delivered to customers equipped with Predix Edge technology. This move will allow customers to remotely monitor and collect data from their machines, helping them analyse trends and uncover insights to improve asset performance and operations.

"What you're witnessing is the beauty of the GE Store," stated Mohammad Ehteshami, Vice President and General Manager for GE Additive. "We've taken the best technology from GE and applied it to Concept Laser's additive machines, improving them and making our customers more efficient and more productive."

Developed by GE Digital, the Predix Platform connects machines, data and people to power digital industrial transformation. As a distributed operating system from the edge to the cloud, Predix helps companies develop, manage and monetise applications for the Industrial Internet. For GE Additive customers, Predix enables industrial-scale analytics for them to:

- Know exactly when their build has finished – regardless of their location – optimising capacity in their factory
- Know if their machine parameters are running on trend or outside of their control limits – augmenting their quality management systems
- Get early detection notifications to customer's mobile phones – reducing down-time and maximising capacity.

The M2 cusing machine from Concept laser

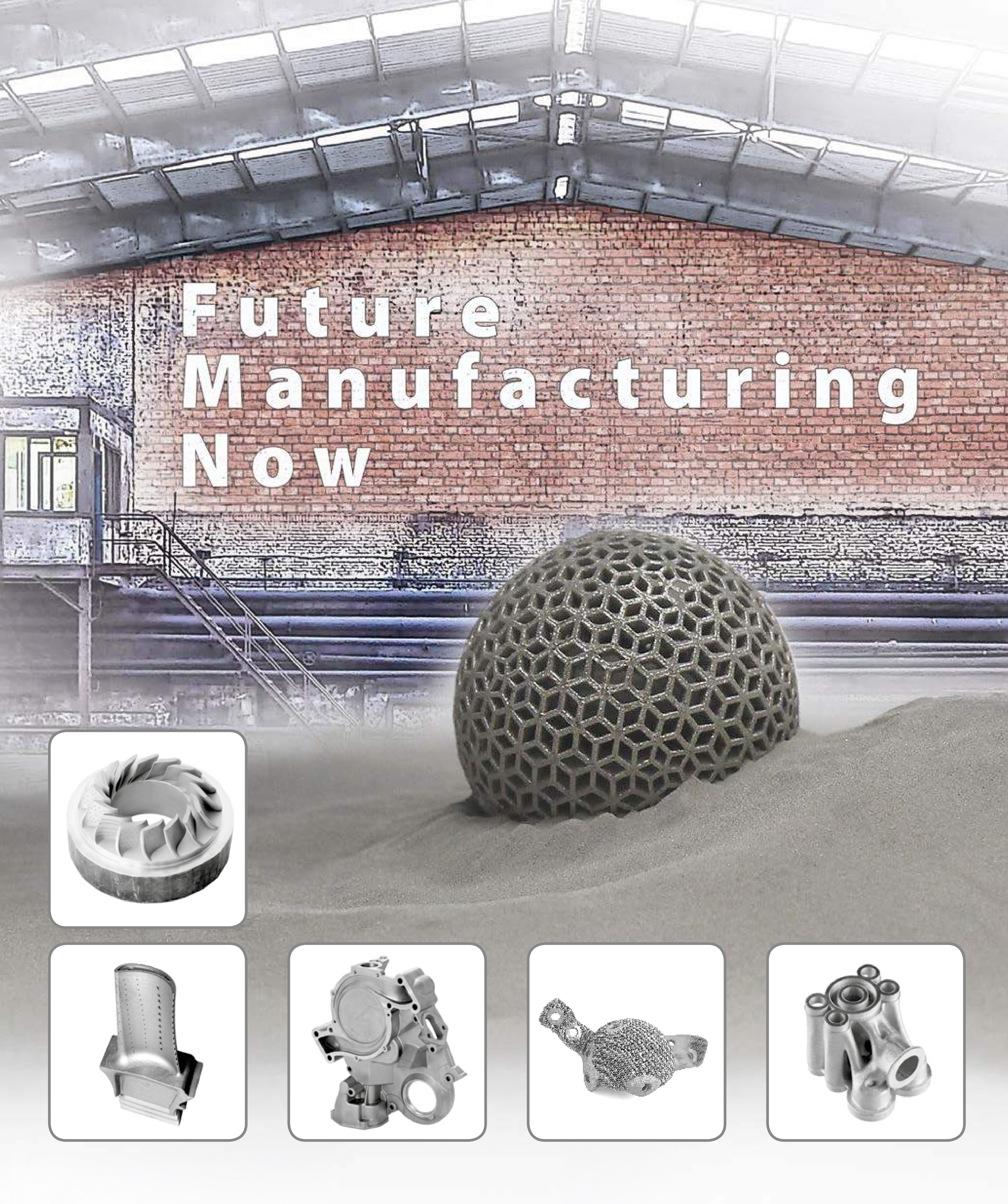
In the future, GE Additive updates, supported by Predix technology, will give customers the ability to:

- Predict when preventive maintenance is required – reducing unscheduled downtime and improving machine availability
- Create their own applications to review and analyse the data they want, where they want and when they want
- Control the ability for real-time parameter modifications – allowing for faster development cycles.

Predix Edge Manager allows industrial companies to monitor and control devices at the edge, on a device or machine, as well as make software updates as soon as they are available. The technology enables operators to make changes that can improve performance, mitigate security threats and better manage assets, even from thousands of miles away. This move is said to reinforce Predix as the only platform that provides computing capabilities from the edge to the cloud, giving customers visibility, control and analytic insights to every part of their industrial operations.

Access to this information and the ability to generate insight can save a customer time by preventing unplanned downtime on their machines. "We want customers to fully utilise their capacity and realise the full potential of their machines," stated Ehteshami. "All of this information will be available to them from the cloud, accessible from anywhere."

www.geadditive.com


Future
Manufacturing
Now

VDM Metals puts new powder plant into operation

VDM Metals GmbH has announced that it is putting a new powder atomisation plant into operation at its site in Unna, Germany. VDM presented its plans for powder production for Additive Manufacturing at the 2017 Paris Air Show in June and the company states that this investment will allow the company to extend its product portfolio. The development includes the construction of a new hall for powder production as well as procurement of the required units.

A vacuum inert gas atomisation (VIGA) plant forms the core of the powder manufacturing facility, comprising a vacuum induction melting furnace and an atomisation unit in which the extremely pure powder is produced under vacuum conditions via vacuum induction melting and subsequent inert gas atomisation. The plant is currently in the commissioning phase.

"Our aim is to consolidate our position as a world market leader in high-performance materials with this investment", stated Dr Niclas Müller, Chief Executive Officer. "This means we can rise to the challenge of utilising new technologies to thrive in tomorrow's changing market environment. The new production plant will allow us to extend our product portfolio as a reliable supplier of powder materials."

www.vdm-metals.com

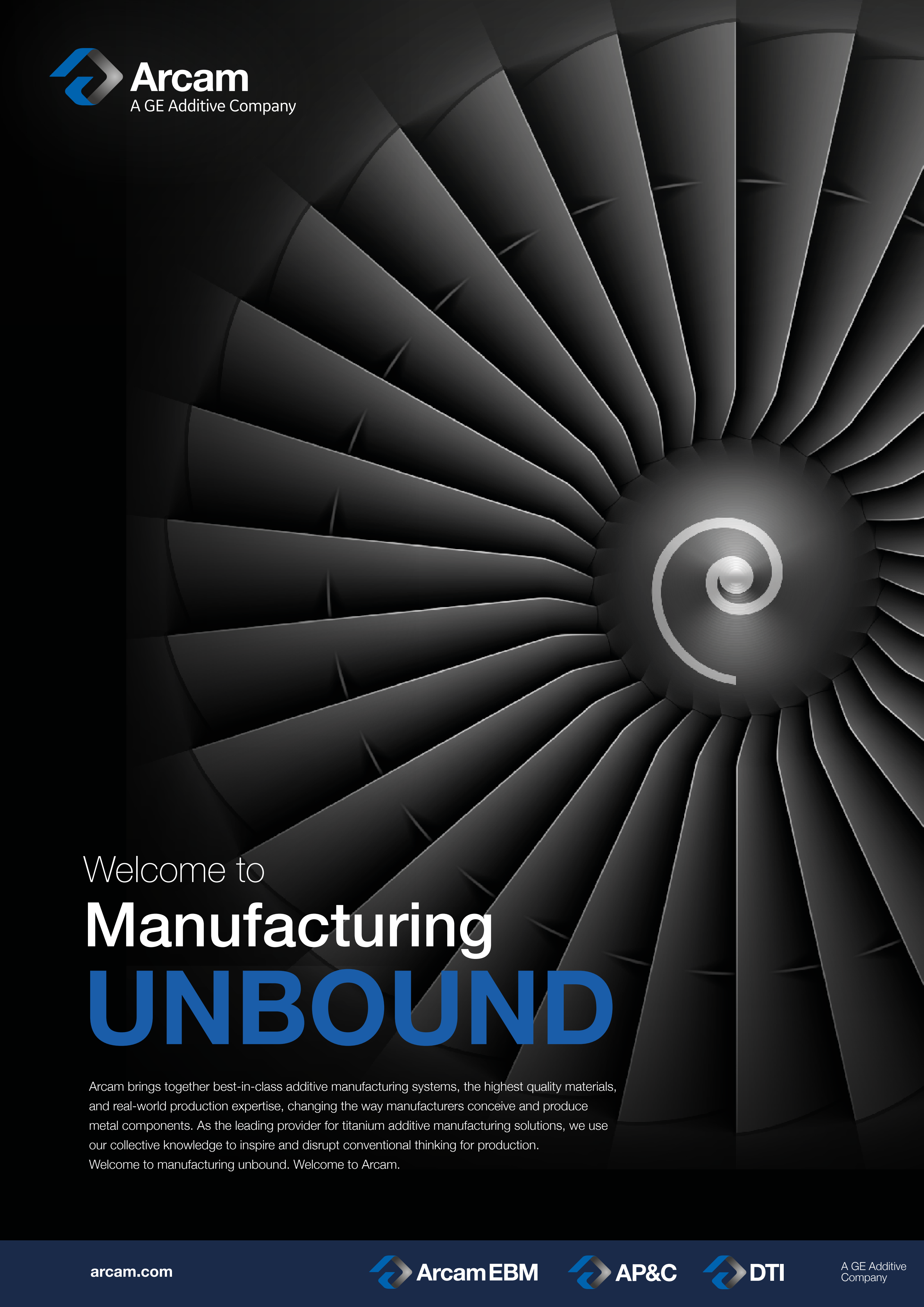
3T RPD adds finishing facility to AM services

3T RPD, Newbury, UK, has announced the addition of a complete finishing facility to complement its manufacturing capability. According to 3T RPD, this will enable the company to supply the complete AM process chain from design to delivery; improve its customer offering; have greater control over the key AM processes and reduce delivery lead times, becoming a 'one stop shop' for Additive Manufacturing services.

3T's new finishing facility augments its pre-existing AM production front-end process services, such as design for AM, R&D, training and powder management. As part of its capacity upscaling, 3T's metal finishing facility now includes a GF 5-Axis CNC milling machine, allowing the company to precision machine components in-house. The facility also includes a vibro-polisher, which can reportedly provide a better than 0.8Ra finish on metal components.

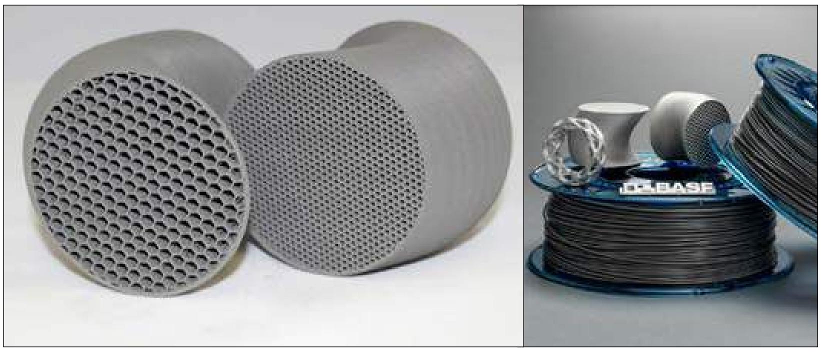
3T previously invested in an aluminium heat treatment oven and has just installed a large vacuum furnace, enabling the company to provide high-integrity heat treatment for Titanium, Inconel and other alloys.

www.3trpd.co.uk



Arcam
A GE Additive Company
Welcome to
Manufacturing
UNBOUND
Arcam brings together best-in-class additive manufacturing systems, the highest quality materials, and real-world production expertise, changing the way manufacturers conceive and produce metal components. As the leading provider for titanium additive manufacturing solutions, we use our collective knowledge to inspire and disrupt conventional thinking for production.
Welcome to manufacturing unbound. Welcome to Arcam.
arcam.com
Arcam EBM
AP&C
DTI
A GE Additive Company

BASF launches Ultrafuse 316LX for fused filament fabrication of metal parts



BASF'S Ultrafuse 316LX is suited to a broad range of applications for functional prototyping and small series production (Courtesy BASF)

BASF, Ludwigshafen, Germany, has developed its Ultrafuse 316LX for use in fused filament fabrication (FFF) systems for the production of metal parts. Ultrafuse 316LX is metal-polymer composite filament with a non-slip surface allowing its application in any bowden or direct drive extruder. Its high flexibility allows it to be funnelled through complex idler pulleys as well as guide roller filament transportation systems.

Once formed, the parts undergo a standard debinding and sintering process introduced to the Metal Injection Moulding (MIM) market by BASF in the 1980s. Catalytic debinding removes the polymer from the part and sintering in pure hydrogen or a vacuum results in the finished metal part. The whole process is said to be faster and less expensive than offered by existing SLM systems.

Ultrafuse 316LX is available in 1.75 and 2.85 mm diameter filament. According to BASF, no changes to the FFF hardware are required to process the material. Currently only a 316L stainless steel option exists, but BASF states that other metal options will be developed.

The filament is said to be suited to a broad range of applications for functional prototyping and small series production. BASF lists various applications including watches, decorative parts, medical equipment and parts for the food and chemical industry.

www.basf.com

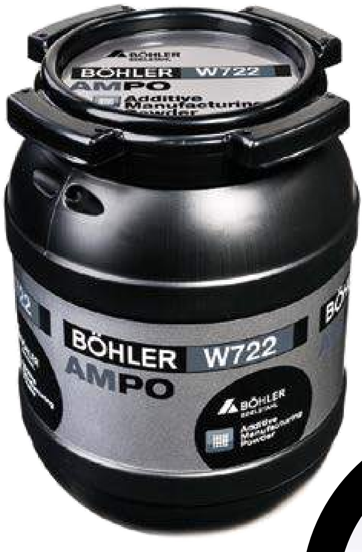
BÖHLER
EDELSTAHL

AMPO

Additive
Manufacturing
Powder

THE NEXT GENERATION OF COMPONENT MANUFACTURING

SCIENCE!
NO FICTION



Additive manufacturing is the revolution in manufacturing technology! Especially in this promising segment, we as **BÖHLER Edelstahl** can build on our extensive materials experience and expertise in the field of powder metallurgy. **We are expanding our portfolio to include powder for additive manufacturing with the brand BÖHLER AMPO: High quality powder and printing know how from the material expert.**

Quantity ordered	**At least 10 kg**
Grain size/ fraction	**15 to 150 µm**

BÖHLER W722 AMPO	DIN 1.2709 / MS1 / ~ Marage 300
BÖHLER N700 AMPO	DIN 1.4542 / 17-4PH (capable to meet chemistry of AMS)
BÖHLER L718 AMPO	DIN 2.4668 (capable to meet the chemistry of API and AMS)

Why to buy at BÖHLER:

- Launch with 3 brands - **BÖHLER W722 AMPO, BÖHLER N700 AMPO, BÖHLER L718 AMPO** - but great flexibility to expand the brand portfolio in the future.
- **Atomization of BÖHLER standard brands** (theoretical selection from 250 steel brands). **Customization of alloys** with small scale production plant and metallurgical expertise.
- **BÖHLER Edelstahl leverages the metallurgical knowledge** and manufacturing options of a special steel producer **for this new technology**.
- **Powder is produced on latest atomization techniques** and tested in-house.
- **Vacuum induction melting** and atomization under inert gas **ensure the highest product quality.**
- **Depending on the steel grade and customer requirements, raw-materials molten under vacuum or remolten can be used. This ensures the highest quality standards and minimizes undesired impurities.**
- Depending on the requirements of the AM process used, **we can provide the appropriate particle fraction in a range from 15-150µm.**
- **Properties such as flowability, particle size distribution and bulk density are ascertained upon request and included in delivery.**

BÖHLER

AMPO - POWDER FOR THE WORLD'S TOP PERFORMERS

www.bohler-edelstahl.com

Leading industrial bakery equipment supplier orders second MetalFAB1 system

Kaak Group, a leading supplier of production equipment and technology to the bread and baked products markets, has placed an order for a second MetalFAB1 metal Additive Manufacturing system from Additive Industries. The MetalFAB1, which will be used for series production of industrial bakery equipment parts, is a five-module four-laser production series system. The order comes within nine months of the installation of the Kaak Group's first MetalFAB1 system.

In May 2017, Additive Industries upgraded their first MetalFAB1 system to the new four-laser version to increase speed and capacity, but Kaak reports that it expects this will not yet be sufficient to keep up with the demand for internal parts for its baking systems. "Our engineers have embraced metal Additive Manufacturing and the number of parts with a positive business case over other fabrication technologies is growing rapidly," stated Lodewijk van der Borg, Kaak Group CEO.

Jaap Bulsink, Senior R&D Engineer at Kaak, added, "the MetalFAB1 has been used successfully to print a broad range of components for our systems, offering improved performance, lighter weight parts and a substantial reduction of development lead-time."

According to Additive Industries, this follow-on order is a clear signal to the market that the MetalFAB1 system has matured and that the production series system – the first having been installed at BMW in December 2016 – is gaining traction. "We are proud and grateful for this follow-on order from Kaak, one of our most valuable Beta customers. They have truly stress-tested our MetalFAB1 system and helped us to improve its performance and mature the machine for series production. This order underlines their commitment and confidence in our technology," stated Daan Kersten, CEO, Additive Industries.

www.additiveindustries.com

The build chamber on a MetalFAB1 machine (Courtesy Additive Industries)

GKN Sinter Metals reports development of new metal powder for AM

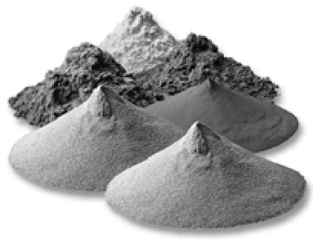
GKN's Sinter Metals has reported the development of a new case-hardened low carbon alloy steel, 20MnCr5. In the company's blog, edited by Dr Simon Hoeges, Manager of Additive Manufacturing at GKN, it is stated that GKN Sinter Metals, working with GKN Driveline, produced the powder for use in additively manufactured gear prototypes.

As well as the ability to be case hardened, 20MnCr5 also features the following desired characteristics, which GKN states are key in parts for a host of industries. According to GKN, the material offers:

- High strength while remaining ductile
- High fatigue strength
- Excellent wear resistance through case hardening
- And is inherently tough, but still machinable

Manufacturing prototype parts in the new material uses a very similar process to the old, but the parameters and process have been optimised for the case-hardened alloy by carburising each component's surface before quenching and tempering the part. Carburised components include gears of all kind, camshafts, universal joints, driving pinions, link components, axles and arbours.

Hoeges states that GKN can now manufacture parts made completely of 20MnCr5 and offer hybrid production; meaning that the company is able to combine different manufacturing techniques with metal AM. 20MnCr5 can also be combined with all weldable materials, which Hoeges states could create widespread potential for AM in the aftermarket sector, particularly regarding the production of low-volume spare parts.



GKN Sinter Metals has produced a new case-hardened low carbon alloy steel for use in AM gear prototypes (Courtesy GKN Sinter Metals)

Since completing its first small batch of 32 gear wheels in 20MnCr5 for a leading gearbox supplier, GKN Sinter Metals states that it has received numerous enquiries regarding its AM capabilities, and that it will continue working with GKN Driveline on applications for aftermarket sales.

www.gknsintermetals.com

Norsk titanium completes testing of Rapid Plasma Deposition component with Thales Alenia Space

Norsk Titanium AS, Oslo, Norway, has completed testing of its Rapid Plasma Deposition™ (RPD™) material with Thales Alenia Space, the Franco-Italian joint venture between Thales Group and Leonardo SpA, to develop, produce and test components for use in spaceflight. Under a contract signed in 2016, Norsk Titanium collaborated with Thales Alenia Space to develop, produce and test an initial qualification component. Under the terms of the test plan, Norsk Titanium evaluated the suitability of their RPD material to replace near-net shape forgings for spaceflight applications. Norsk Titanium confirmed that mechanical testing had been completed and the RPD material performed in accordance with the mutually developed requirements.

"Norsk Titanium is delighted to mature our relationship with Thales Alenia Space," stated Norsk Titanium CEO Warren M Boley Jr. "Along with our recent commercial aerospace successes, this provides further evidence that Norsk Titanium's Rapid Plasma Deposition material is ready to support the stringent requirements of the in-space market, revolutionising how the industry incorporates titanium into their critical designs."

Successful completion of this testing is said to have positioned Norsk Titanium to be a leading supplier of structural AM components to Thales Alenia Space. Adoption of RPD material allows Thales Alenia Space to cut current part buy-to-fly ratios in half and reduce lead-times by six months.

"Thales Alenia Space is very pleased to confirm that the Rapid Plasma Deposition solution from Norsk Titanium was successfully tested from a mechanical point of view. Thales Alenia Space builds larger and larger material parts using additive manufacturing, which represents an important advance during the fabrication phase", explained Florence Montredon, Additive Manufacturing Technology Development manager at Thales Alenia Space.

Norsk Titanium's Rapid Plasma Deposition process uses titanium wire to produce complex components suitable for structural and safety-critical applications. The company is a tier-1 supplier to Boeing and states that RPD is the world's first FAA-approved, AM structural titanium, delivering substantial lead-time and cost savings for aerospace, defence and commercial customers.

www.thalesaleniaspace.com
www.norsktitanium.com

Carpenter enters supply relationship with Desktop Metal

Carpenter Technology Corporation, Philadelphia, PA, USA, has entered into a supply relationship with Desktop Metal, Inc., Burlington, MA, USA. More than twenty CarTech® alloy grades will be available to be used in Desktop Metal's end-to-end metal Additive Manufacturing systems.

"As we develop technology for next generation manufacturing solutions, it is essential to collaborate with innovative partners," stated Tony R Thene, Carpenter Technology's Chief Executive Officer. "Leveraging the combined capabilities of Desktop Metals and Carpenter Technology, we will undoubtedly bring enhanced value to this rapidly growing market."

Ric Fulop, CEO and Co-Founder of Desktop Metal, stated, "We are excited to include Carpenter Technology in our materials catalogue. When you a have a supplier whose stellar reputation for material quality, technical expertise and market diversity is known throughout the industry, it will only help our customers succeed in the metal 3D printing market."

www.cartech.com
www.desktopmetal.com


TRUMPF
Visit us at
EMO: hall 27 - D46
TCT Birmingham: hall 3 - B24
formnext: hall 3 - E50
Industrial Additive Technologies
TRUMPF offers both key technologies for metal additive manufacturing: Laser Metal Fusion (LMF) and Laser Metal Deposition (LMD). Both processes meet the characteristics and quality required in various applications. Industrial solutions for the entire process by TRUMPF, based on the following keys to success: robust machines, intelligent digitalization and clever services.
www.trumpf.com/s/3dprintingsystems

EOS releases EOSTATE Exposure OT: Optical Tomography for real-time monitoring of metal AM

EOS, headquartered in Krailling, Germany, is expanding its EOSTATE monitoring suite to include an additional tool, EOSTATE Exposure OT. This is said to be the first commercial system for Optical Tomography (OT) and provides real-time, camera-based monitoring of the build process in the EOS M 290 system. The solution fully maps each part throughout the build process, layer-by-layer, regardless of its geometry and size.

Dr Tobias Abeln, Chief Technical Officer at EOS, stated, "With EOSTATE Exposure, we are offering companies an even more comprehensive process monitoring and quality assurance. As such, we are helping customers meet the stringent inspection requirements for each component, particularly in sectors such as aerospace."

The system was developed in close collaboration with MTU Aero Engines. The EOSTATE Exposure OT enables MTU to significantly reduce costs for downstream, non-destructive examination in technical Computer Tomography (CT), as potentially defective parts can be rejected at an earlier stage. At MTU the system was primarily developed for series manufacturing purposes, where it has been in use for several months and proven its efficiency.

"At MTU Aero Engines we recognised the potential of Additive Manufacturing early on. However, until now we didn't have the experience and the volume of data needed to sufficiently evaluate the quality of the parts and transfer the technology to large-scale manufacturing. We are confident that we will be able to do so with EOSTATE Exposure OT," stated Dr Jürgen Kraus, Senior Consultant Additive Manufacturing at MTU.

Two other pilot customers, Liebherr and IPC, will also continue to use the system after the pilot phase and integrate it in their manufacturing processes. Alexander Altmann, Lead Engineer Additive Manufacturing/TRPI Research & Technology at Liebherr, commented, "We are now using EOSTATE Exposure OT and EOSTATE MeltPool from EOS and expect both technologies to give us a profound understanding of the phenomena relevant for quality when additively producing titanium parts."

Optical Tomography: How the process works

With Optical Tomography, the system deploys a high-resolution camera to monitor the exposure process. The camera records the complete building platform at high frequency in the near-infrared range throughout the entire AM process, thereby providing detailed data on the melting behaviour of the material across the entire build space.

Based on the data captured, the melting behaviour of steel, aluminium, titanium and a variety of alloys involved in the additive build process can be analysed and monitored in great detail using special software. If certain results deviate from a 'normal range', which can be individually defined by means of parameters, these areas are marked.The growing volume of data makes it possible to determine the impact of these so-called indicators on the quality of the manufactured parts with ever greater precision.

EOSTATE Exposure OT is a self-learning system that becomes increasingly intelligent the more data it is fed. The ultimate aim is to recognise possible sources of defects during the building process and reject any defective parts.

www.eos.info

Concept Laser and Lauak sign Letter of Intent for Additive Manufacturing collaboration

Concept Laser, a GE Additive company based in Lichtenfels, Germany, and Lauak Group, an aeronautical company based in Ayherre, France, have signed a Letter of Intent (LOI) to launch an alliance that they state will advance Additive Manufacturing in the aerospace industry. The agreement was signed at the 2017 Paris Air Show. Lauak will invest in Concept Laser additive machines as a reference customer for Concept Laser technology. Also, Concept Laser will work closely with Lauak to implement additive processes and design new products.

"Lauak sees the potential of Additive Manufacturing and I'm delighted they've chosen Concept Laser equipment to help the company on its journey," stated Frank Herzog, CEO of Concept Laser. "We will support them with equipment, processes and people to allow them to meet their objectives."

Concept Laser will support Lauak during the implementation phase of the equipment into its manufacturing process. Lauak will also present the Concept Laser machine to reference customers in its showroom, including the presentation of test objects for demonstration purposes. Concept Laser and Lauak will collaborate to redesign components from the Lauak portfolio.

Mikel Charritton, CEO of Lauak stated, "We see the huge potential in Additive Manufacturing and we want to use this technology to complete and improve our current manufacturing processes, as well as the manufacture of new components for the aviation industry."

www.geadditive.com
www.groupe-lauak.com

EURO PM2017 conference programme published

The European Powder Metallurgy Association (EPMA) has announced the publication of the conference programme for its Euro PM2017 International Conference and Exhibition. Taking place in Milan, Italy, October 1–5, 2017, the event will cover all aspects of Powder Metallurgy including dedicated sessions on metal Additive Manufacturing.

The Euro PM2017 exhibition will take place in parallel to the technical sessions and will provide a showcase for the global Powder Metallurgy and Additive Manufacturing industries. Euro PM2017 will also include a number of special interest seminars, workshops and social events.

www.europm2017.com

Sintavia unveils plans for new advanced manufacturing facility

Sintavia, LLC, has announced plans to construct a 55,000 ft² factory in Hollywood, Florida, USA, close to the company's current Davie, Florida facility. The new plant, which will also serve as Sintavia's new headquarters, is expected to launch in mid-2018 and to quadruple the company's current production capacity.

"With this new facility, we are excited to continue our leadership in the development of the metal AM supply chain for OEMs in precision industries," stated Brian Neff, Sintavia's Chairman and CEO. "We will use this additional space not only to grow our existing competencies in laser and electron beam melting, but also to industrialise new technologies such as metal binder jet manufacturing."

In addition to the company's current manufacturing equipment and materials laboratory, Sintavia reports that the new facility will house over $20 million of new machinery, including larger AM equipment, an automated powder handling system, an uninterruptable power supply, an inert gas farm and an enhanced post-processing footprint.

"The key to Sintavia's success over the past few years has been our vertically integrated approach to metal AM," explained Doug Hedges, Sintavia's President and COO. "Our ability to rapidly qualify machines and processes through the use of our on-site laboratories, scanning, and post-processing equipment demonstrates meaningful value to our customers. This same approach will continue on a larger scale with our new production facility."

Sintavia anticipates that the expansion will create more than 135 jobs for skilled employees and support staff in the South Florida region.

www.sintavia.com

Former Boeing CTO joins 3D Systems' Board of Directors

3D Systems, Rock Hill, South Carolina, USA, has announced the addition of Dr John Tracy to the company's Board of Directors. In line with 3D Systems' strategy and focus on key vertical applications, the company states, Tracy brings with him deep experience in engineering, technology and leadership within the aerospace industry.

Tracy has more than 37 years of experience in the aerospace industry, most recently as CTO and Senior VP of Engineering, Operations and Technology at Boeing from 2006-2016. Prior to working for Boeing, he was with Hercules Aerospace Company and McDonnell Douglas Corp.

www.3dsystems.com

De-powdering enclosure with argon gas management

Inert, Amesbury, Massachusetts, USA, exhibited its latest de-powdering enclosure at Rapid + TCT, May 8-11, 2017, in Pittsburgh, Pennsylvania, USA. The company's latest enclosure features an argon gas management system, designed to protect operators from unhealthy exposure and metal powders from atmospheric contamination.

Inert's de-powdering enclosure is designed to benefit the post-build Additive Manufacturing process by safely collecting excess metal powders from printed parts for reuse, thereby reducing both cost and waste. This de-powdering procedure is conducted within an argon atmosphere controlled by Inert's Argon-2 Gas Management System to avoid contamination from oxygen, moisture, dust, organic matter or plastic— any of which could render metal powders useless or require costly tracing and removal. Keeping airborne powder particulate within Inert's controlled atmosphere also eliminates user health risks, damage to area electronics and fire hazards related to the combustibility of titanium powders.

Following news of Inert's recent partnering with Sievgen, the company also displayed a Sievgen 04 automated sieving station during the exhibition. According to Inert, the station allows users to work safely with, weigh and measure, reclaim, and transfer metal and other powders.

www.inert-am.com

Desktop Metal announces two new metal AM systems for prototyping and mass production

Desktop Metal's new Studio System incorporates easily changeable print cartridges in its Bound Metal Deposition process

Desktop Metal, based in Burlington, Massachusetts, USA, has announced two new metal Additive Manufacturing systems aimed at prototyping and mass production. According to the company, the new systems, DM Studio and DM Production, mark a 'fundamental shift' in how products will be developed and brought to market, reducing production costs and increasing speed, safety and net quality.

The DM Studio System has been designed as an 'office-friendly' metal AM system for rapid prototyping and claims to be ten times less expensive than existing technologies. The system is sold as a complete platform, including a printer, debinding unit and microwave-enhanced sintering furnace. It is stated that DM Studio will help to eliminate the need to house Additive Manufacturing systems in large industrial facilities through the use of Bound Metal Deposition, a proprietary process which uses no hazardous technologies and is similar in method to Fused Deposition Modelling, used in plastic AM. In addition, by using cloud-based software to link stages of the workflow, the system is expected to help eliminate the need for dedicated operators, making it possible to input designs direct from CAD software.

The DM Studio will also feature Desktop Metal's proprietary Separate Supports, a type of support structure which can be removed safely by hand, along with swappable print cartridges for rapid material changes. It is reportedly compatible with a large variety of metal alloys, making it possible to prototype parts in the material that will be used in mass production.

The DM Production System is designed for the mass Additive Manufacturing of metal parts. Using the company's proprietary Single Pass Jetting technology, it is claimed that the DM Production system will operate at speeds one hundred times faster than most laser-based AM systems, having the potential to dramatically reduce cost-per-part and allow metal AM to compete with mass production techniques such as casting.

"Until now, metal 3D printing has failed to meet today's manufacturing needs due to high costs, slow processes and hazardous materials," stated Ric Fulop, CEO and Co-founder of Desktop Metal. "With a team of some of the world's leading experts in materials science, engineering and innovation, Desktop Metal has eliminated these barriers by developing metal 3D printing systems that can safely produce complex, strong metal parts at scale."

www.desktopmetal.com

Oerlikon and GE Additive sign MoU for Additive Manufacturing collaboration

Oerlikon, Pfäffikon, Schwyz, Switzerland, has announced that it has signed a Memorandum of Understanding (MoU) with GE Additive to collaborate on accelerating the industrialisation of Additive Manufacturing. The five-year agreement specifies the provision of additive machines and services by GE to Oerlikon, and Oerlikon becoming a preferred AM component manufacturer and materials supplier to GE Additive and its affiliated companies. Further, GE and Oerlikon will collaborate on R&D in additive machines and materials over the period of the agreement. The MoU includes GE Additive affiliated companies Concept Laser and Arcam AB.

Dr Roland Fischer, CEO of the Oerlikon Group, stated, "Developing innovative technology is key to our growth strategy and a distinct advantage Oerlikon brings to customers. Partnering with GE Additive, Concept Laser and Arcam AB on innovative AM materials and machines will strengthen both companies' positions in Additive Manufacturing, and allows us to meet the growing demand for additive components, materials and services in many industries."

Vice President and General Manager of GE Additive, Mohammad Ehteshami, added, "GE Additive and Oerlikon both understand the transformative power of Additive Manufacturing. As the adoption rate of AM grows rapidly, it is through strategic partnerships that we can push forward the uptake of AM in industries, and we're proud to partner with Oerlikon."

Oerlikon has extensive expertise in advanced materials, AM production, post-processing and surface solutions. In 2016, the company acquired citim GmbH to complement its additive production capabilities in Europe and the USA. Oerlikon is also building a state-of-the-art AM powder production facility in Plymouth, Michigan, USA, an R&D and production facility in Charlotte, North Carolina, USA, and an R&D and innovation centre in Munich, Germany.

www.geadditive.com
www.oerlikon.com/am

Sumitomo Heavy Industries acquires spray-form metal AM start-up in $33 million deal

Sumitomo Heavy Industries, Tokyo, Japan, recently announced its acquisition of Persimmon Technologies, Wakefield, Massachusetts, USA for $33 million. With the acquisition, Sumitomo will gain access to Persimmon's hybrid-field technology, which uses spray-form metal Additive Manufacturing to produce winding cores for electric motors.

Persimmon's spray-forming AM process produces each winding core from consecutive layers of soft magnetic composite material, sprayed as metallic droplets to create three-dimensional magnetic flux paths. It says its motors provide considerably higher power output (40% higher power density) and improved energy efficiency (up to 15% lower losses) compared to the state of the art.

"Our technology offers a new approach to making electric motors using an Additive Manufacturing process that significantly increases power density, eliminates multiple production steps and reduces costs," explained Dr Martin Hosek, Vice President and CTO of Persimmon. "Being part of SHI will allow us to step up the pace of technical development and further expand our portfolio of world-class products."

Michael Pippins, President and CEO of Persimmon Technologies, added, "We are thrilled to become part of a $7 billion organisation with such a strong global presence and balance sheet. SHI [Sumitomo] is positioned to invest heavily in our Hybrid-Field electric motor technology. The merger will also enable us to take advantage of the massive market potential for hybrid-field electric motors in rapidly growing electric vehicle and industrial robotics markets."

"SHI has been impressed by Persimmon's team and its research and development activities in vacuum robotics and hybrid-field motor technology," stated Shunsuke Betsukawa, President and CEO of Sumitomo. "The acquisition will expand our product line and accelerate the growth of our company in semiconductor-related fields and new markets."

www.persimmontech.com
www.shi.co.jp/english/

Premium AEROTEC, EOS and Daimler to develop next generation of metal AM technology

Premium AEROTEC, EOS and Daimler have announced a joint project to develop the next generation of Additive Manufacturing technology. According to AEROTEC, the new project, entitled NextGenAM, seeks to accelerate the implementation of metal Additive Manufacturing in large-scale serial production.

The primary objective will be to progress the automation of the entire industrial AM process. To do this, the NextGenAM project team will review the entire AM process to examine which parts of it can be automated, from the delivery of metal powder to post-processing. Using its findings, the team is expected to invest several million Euros into the planning of and construction of an automated production facility for AM serial production. A development and test environment for the project will also be established in Varel, Germany.

By automating more of the AM process, the partners hope to gain significant cost advantages and lay the foundations to use this technology for large-scale serial manufacturing in the future. In metal AM, the process stages before and after the actual manufacturing process constitute around 70% of the manufacturing costs. In addition to advanced system technology, the project aims to achieve a qualification of aluminium for use in industrial AM.

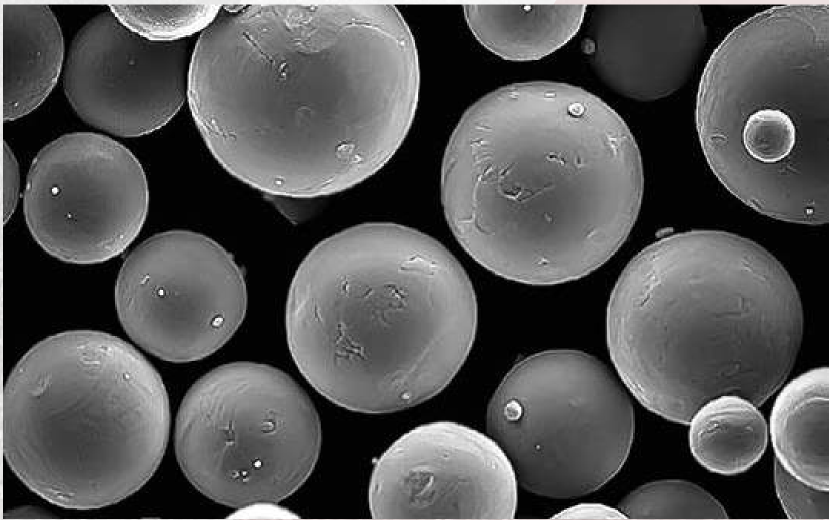
According to AEROTEC, EOS's Quad-Laser System EOS M 400-4 metal AM machine will be at the core of the new production process as the partners seek to design an economically efficient aluminium-based system, which is suitable for the automotive and aerospace industries.

"We are currently the leader for metal 3D printing in the aerospace industry," stated Dr Thomas Ehm, CEO, Premium AEROTEC. "Now, we need to continue developing this technology extensively in order to expand its application spectrum significantly. Together with our partners, we can thus ensure state-of-the-art technology for our industry."

"We are proud to be part of such a forward-looking project alongside Premium AEROTEC and Daimler," commented Dr Hans J Langer, Founder of EOS. "This underlines the growing footprint of industrial 3D printing in serial production. As a technology pioneer in powder-based AM, we contribute full engagement and long-lasting expertise. With EOS platforms, we push ahead the setup of this future production solution."

Dr Stefan Kienzle, Head of Advanced Development at Daimler, added, "We invented the car and we are actively shaping the future of mobility. The elements that we bring to this collaboration are our extensive experience in automotive materials and the qualification of those materials, as well as our know-how on efficient and large-scale capacity manufacturing processes, in conjunction with component design that is topologically optimised and uses the latest calculation methods."

www.premium-aerotec.com
www.eos.info
www.daimler.com



Additive Manufacturing transforms RF antenna design

Optisys LLC, Grapevine, Texas, USA, is a provider of sophisticated, metal additively manufactured micro-antenna products for high performance aerospace and defence applications. The company has recently completed a project that documents the significant advantages of employing metal Additive Manufacturing to produce such systems.

Antennas are widely employed in commercial and military aircraft, spacecraft, satellite communications, unmanned aerial vehicles and by ground terminals and land-based troops. Yet the complex radio frequency (RF) components that make up an antenna system can be large and heavy, characteristics that can impact mobility and performance.

"Companies in the commercial and military space are pressured for shorter lead-times, lighter weight and smaller antennas," explained Clinton Cathey, Optisys CEO. "By combining RF design simulation, mechanical engineering and system optimisation focused on AM, we provide metal 3D-printed antenna products at greatly reduced size, weight, lead-times, part count and cost – with as-good or better RF performance than conventionally manufactured systems. We're creating structures that were simply not possible to produce in the past."

The test-piece demonstrator project involved a complete redesign of a high-bandwidth, directional tracking antenna array for aircraft, known as a Ka-band 4×4 Monopulse Array. Optisys performed every aspect of the design work in-house and printed the component in a single piece on their Concept Laser machine.

Manufacturing antenna systems via conventional methods such as brazing and plunge EDM is said to be a complex, multistage process that can take an average of eight months of development time and three to six more of build time. "Our unique offering is that we redesign everything from an AM perspective. We take into account the entire system functionality, combine many parts into one, and reduce both development and manufacturing lead times to just a few weeks. The result is radically improved size and weight at lower costs," stated Optisys COO Robert Smith.

Optisys conducted a profitability analysis on how their redesigned microwave antennae test piece compared to a legacy design that is conventionally manufactured. By optimising the design for AM, Optisys achieved the following benefits:

- Part count reduction from a hundred discrete pieces to a one piece integrated assembly
- Weight savings of over 95%
- Lead time reduced from eleven months to two months
- Production costs down by 20-25%
- Non-recurring costs down by 75%

Other advantages of Additive Manufacturing

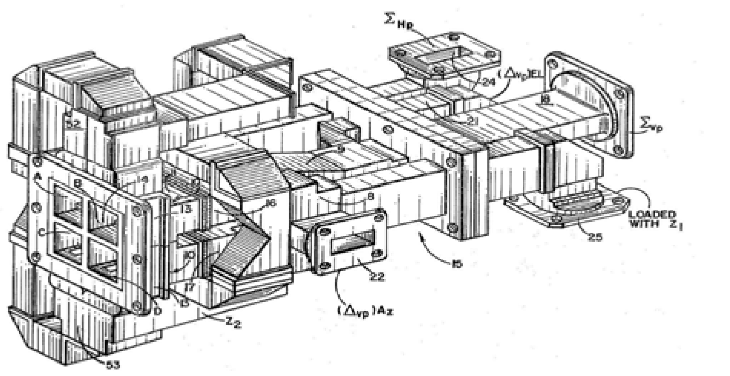
"When we design multiple antenna components into a single part, we reduce the overall insertion loss of the combined parts. And because our antennas are so much smaller this also lowers insertion loss dramatically despite the higher surface roughness of AM build, for similar or even better RF performance than conventional assemblies," stated Smith.

The palm-sized, lightweight, one-piece, AM antenna component

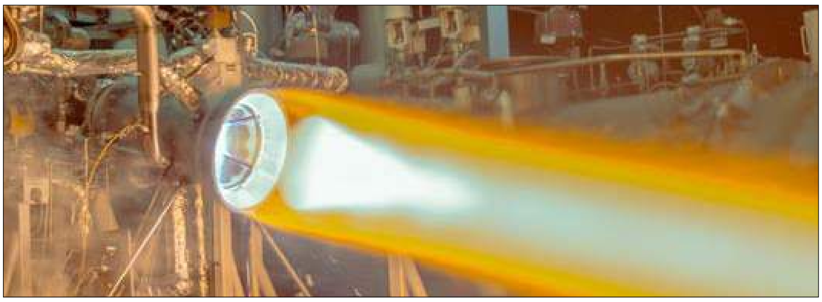
Optisys can manufacture in a variety of metals with its Concept Laser machine, though for antenna products aluminium is preferred because of its surface conductivity, light weight, corrosion resistance and strength under shock and vibration. "Structurally the products have been tested in rigorous vibration environments and they also have the same coefficient of thermal expansion (CTE) as wrought metals. This also gives them better stability over temperature than plastic RF components," explained Smith.

Part consolidation through AM provides a number of downstream benefits as well. "Reducing part count also reduces assembly and rework. It's easy to add features to an existing AM design, easier to assemble the finished components and, long-term, you have less testing, maintenance and service when you have fewer parts," Smith concluded.

www.optisys.tech
www.conceptlaserinc.com


The original multi-part antenna assembly

Aerojet Rocketdyne successfully tests full-scale metal AM thrust chamber



Aerojet Rocketdyne's full-scale, Additively Manufactured thrust chamber assembly in testing in West Palm Beach, Florida (Courtesy Aerojet Rocketdyne)

Aerojet Rocketdyne, Sacremento, California, USA, has successfully hot-fire tested a full-scale additively manufactured thrust chamber assembly for the RL10 rocket engine. The thrust chamber was built from a copper alloy using Selective Laser Melting (SLM) technology.

The successful test follows a decade of metal AM development by Aerojet Rocketdyne, which has sought to develop Additive Manufacturing methods for the RL10 and other propulsion systems to make them more affordable while taking advantage of the design and performance capabilities that AM makes possible.

The additively manufactured RL10 thrust chamber will replace the current RL10C-1 model design, the company stated. The RL10C-1 uses a complex array of drawn, hydroformed stainless steel tubes that are brazed together to form a thrust chamber. The new chamber design is made up of only two primary copper parts and reportedly takes just under a month to print using SLM technology, reducing overall lead time by several months. The part count reduction is also significant as it reduces complexity and cost when compared with traditionally manufactured RL10 thrust chambers.

"Aerojet Rocketdyne has made several major upgrades to the RL10 to enhance the engine's performance and affordability since it first entered service in the early 1960s," stated Eileen Drake, Aerojet Rocketdyne CEO and President. "Incorporating AM into the RL10 is the next logical step as we look to make the engine even more affordable for our customers."

"We believe this is the largest copper-alloy thrust chamber ever built with 3D printing and successfully tested," added Jeff Haynes, Aerojet Rocketdyne's Additive Manufacturing Program Manager. "Producing aerospace-quality components with Additive Manufacturing is challenging. Producing them with a high-thermal-conductivity copper alloy using SLM technology is even more difficult. Infusing this technology into full-scale rocket engines is truly transformative as it opens up new design possibilities for our engineers and paves the way for a new generation of low-cost rocket engines."

Another key benefit provided by Additive Manufacturing, the company has stated, is the ability to design and build advanced features that allow for improved heat transfer. For many rocket engine applications, this enhanced heat transfer capability enables a more compact and lighter engine, which is highly desirable in space launch applications.

"This full-scale RL10 thrust chamber test series further proves that Additive Manufacturing technology will enable us to continue to deliver high performance and reliability while substantially reducing component production costs," explained RL10 Program Director Christine Cooley. "Now that we have validated our approach with full-scale testing of a 3D printed injector and copper thrust chamber, we are positioned to qualify a new generation of RL10 engines."

Aerojet Rocketdyne is applying AM technology to many of its other products, including the RS-25 engines intended for deep space exploration and the company's new AR1 booster engine.

www.rocket.com

VBN Components to showcase metal AM wear resistant materials for commercial vehicle transmissions

VBN Components, Uppsala, Sweden, will present its latest technology for Additive Manufacturing of high-strength wear resistant materials at the 'Transmissions in Commercial Vehicles' conference organised by VDI Wissensforum in Bonn, Germany, July 5-6, 2017. The presentation by Ulrik Beste, Chief Technical Officer, Materials Science and Additive Manufacturing, VBN Components AB, will discuss wear resistant and high strength materials and look at cutting tools and functional prototypes.

As part of VDI's larger 'Drivetrains for Vehicles' congress, the event will focus on the growing trends of CO_2 reduction, networking and automation and their potential impact on the commercial vehicle sector. Experts will present their forecasts on how the current market developments will affect engineering and what new technologies are emerging to tackle these changes.

Visitors to the conference will also have the opportunity to attend the parallel events "Powertrains in Vehicles" and "Control Solutions for Transmissions" free of charge.

www.vdi-wissensforum.de
www.vbncomponents.se

SLM Solutions and BeamIT agree multi machine deal

SLM Solutions Group AG, headquartered in Lübeck, Germany, has signed a long-term cooperation agreement with BeamIT S.p.a., Fornovo di Taro, Italy, which includes the sale of fifteen SLM Solutions multi-laser machines to the Italian company.

BeamIT is one of the leading contract manufacturers for the automotive, biomedical, aeronautic and aerospace industries in Italy and already has SLM Solutions machines in use. The deal, which runs through to December 31, 2019, will see the company purchase ten SLM 280 2.0 machines as well as five quad laser SLM 500 machines.

"We have been working very closely with BeamIT for some years now. Italy is a market with huge potential and we are greatly looking forward to stepping up this cooperation," stated Uwe Bögershausen, CFO of SLM Solutions Group AG. The cooperation between SLM Solutions and BeamIT concerns the joint development and testing of various parameters for setting the machines when using various metal powders.

"We have been using the machines of the SLM Solutions Group for some time now and find the quality and the advantages of the multi-laser technology compelling, especially regarding productivity, build-part-costs and the high quality of parts. SLM Solutions systems play a very important role for us in further optimising our productivity and the build-part-costs," added Mauro Antolotti, founder and President of BeamIT S.p.a.

The signing of the cooperation agreement is said to represent an important step for SLM Solutions toward leveraging the opportunities that arise from the growing use of Additive Manufacturing technology in the automotive as well as biomedical, aeronautic and aerospace sectors.

www.slm-solutions.com

www.beam-it.eu

BeamIT have agreed to purchase ten SLM 280 2.0 machines as well as five SLM 500 machines equipped with a quad laser system (above)

Datasheet on quantitative shape analysis of metal powder

LPW Technology Ltd, Runcorn, UK, has released a new laboratory services datasheet examining the role of morphology in metal powder characterisation. The datasheet, titled 'Quantitative shape analysis of metal powder samples by morphology', is available via the company's website.

"This datasheet explains the methodology of quantitative shape analysis and discusses the benefits of understanding powder morphology in the metal AM process," stated Lisa Holman, LPW's Quality Engineer. "The testing we undertake delivers a comprehensive set of results, giving an effective overview of the powder's characteristics that adds assurance about condition and consistency."

www.lpwtechnology.com

World PM2018: Powder Metallurgy industry to meet in China

The 2018 World Conference on Powder Metallurgy, World PM2018, organised by China Powder Metallurgy Alliance (CPMA), will take place September 16 - 20, 2018, in Beijing, China. The event marks the first time that the World PM series has been held in China and will give those from outside the country an insight into PM, MIM and AM developments in one of the fastest growing economies in the world.

The conference will cover the full range of Powder Metallurgy topics, ranging from metal powder production and technology, powder compaction, sintering and post-processing to Metal Injection Moulding, cemented carbides, porous materials, Additive Manufacturing and the design and simulation of PM parts. The conference is expected to include over 500 presentations, giving a detailed overview of the latest developments in PM.

In addition to the conference there will be an exhibition held over four days. In excess of 200 international exhibitors are expected to participate, providing the ideal opportunity to network with material and equipment suppliers, part producers and end-users.

The World PM2018 exhibition is being managed on behalf of the organising committee by IRIS Exhibitions Service Co.,Ltd, organiser of the annual PM China exhibition series held in Shanghai each Spring. Exhibition sales enquiries should be addressed to Maggie Song, exhibition@worldpm2018.com. Those wishing to submit abstracts should note the submission deadline of October 15, 2017.

www.worldpm2018.com

Carnegie Mellon University develops machine vision for metal Additive Manufacturing

Researchers from Carnegie Mellon University's Department of Materials Science and Engineering (MSE), Pittsburgh, Pennsylvania, USA, have developed a process known as 'machine vision technology' that is said to autonomously identify and sort metal AM powder types better than humans. The system, reports the university, will enable machine users to accurately test and qualify printed metal parts for any number of applications including aerospace and medical devices.

"In traditional manufacturing, parts are often qualified through destructive testing. A company might produce multiple parts and physically test them to see how they hold up to stress and fatigue. However, that costs a lot of time and money, so it should be avoided in AM in order to preserve the on-demand nature of 3D printing," stated Elizabeth Holm, Professor of Materials Science and Engineering, and primary investigator of this research.

By training a computer to autonomously identify and sort powders, Holm and her team can recognise whether or not a metal powder has the microstructural qualities associated with the production of a part with desired properties, such as strength, fatigue life and toughness. Importantly, the machine vision approach is autonomous, objective and repeatable.

Machine vision for metal AM can autonomously identify and sort metal AM powder types

Holm and her team applied computer vision and machine learning methods to eight different commercial feedstock powders. They found that the machine vision system captures more about metal AM powder than is possible with normal manual measurement. It can measure important information such as how big particles are, how particles group together, the surface roughness of particles and the shape of particles. The team also found that the technology can tell metal powder types apart even where humans cannot.

www.cmu.edu

Methods 3D and Markforged partner to offer range of AM solutions

Methods 3D, Inc., Sudbury, Massachusetts, USA, recently announced the formation of a partnership with Markforged, Cambridge, Massachusetts. Methods 3D will provide sales, service and support for Markforged's line of Additive Manufacturing systems. The partnership is said to expand North American manufacturers' access to both companies' advanced AM solutions.

"Markforged printers are an ideal complement to our extensive suite of Additive Manufacturing solutions," stated Jamie Hanson, COO, Methods 3D. "With Markforged, we will significantly enhance our customers' production efficiencies by enabling them to quickly create tools, jigs and fixtures for myriad industrial applications. Our deep experience in metalworking manufacturing combined with Markforged's expertise in high-strength parts is a perfect match for meeting today's demanding manufacturing challenges."

The Markforged partnership will also enable Methods Machine Tools' Automation Group to design, integrate and provide unlimited solutions for its CNC machining automation systems with the ability to print unique end of arm tooling components for robots, jigs, fixtures and more.

www.markforged.com
www.methodsmachine.com

Opportunities for Additive Manufacturing in submarines

Norsk Titanium AS, Oslo, Norway, has announced it is exploring industrial cooperation opportunities with the Germany's Thyssenkrupp Marine Systems following the signing of a Memorandum of Understanding for industrial cooperation supporting Thyssenkrupp's effort to replace four Ula class submarines currently in service with the Norwegian Navy by modern submarines based on the HDW class 212A design.

As titanium is an important material for this new submarine generation, Norsk Titanium's Rapid Plasma Deposition™ technology is said to offer the potential to provide significant cost and schedule advantages. "The collaboration with Thyssenkrupp constitutes a significant opportunity for Norsk Titanium and complements our achievements in the aerospace sector," stated Norsk Titanium President & Chief Executive Officer Warren M Boley, Jr. "We look forward to working closely with Thyssenkrupp to identify and further develop joint business opportunities that benefit both our customers and Norway."

www.norsktitanium.com
www.thyssenkrupp-marinesystems.com

Sciaky to provide multiple Electron Beam AM systems

Sciaky, Inc., Chicago, Illinois, USA, has reached an agreement to provide multiple Electron Beam Additive Manufacturing (EBAM®) systems to an American-based metal AM parts supplier. The supplier will serve as a turnkey parts bureau for many industries, including aerospace, defence, automotive and oil & gas.

"Sciaky is excited to further expand our one-of-a-kind, large-scale metal AM technology with the marketplace," stated Bob Phillips, Vice President of Marketing for Sciaky, Inc. "We are also proud that two American companies are working together in the Additive Manufacturing market to provide jobs for American families, without burdening the American taxpayer."

Delivery of the first round of Sciaky EBAM systems is scheduled for the fourth quarter of 2017. The systems claim to be the most widely scalable metal AM solution in the industry in terms of work envelope and can produce parts ranging from 203 mm (8 in) to 5.79 meters (19 ft) in length. EBAM is reportedly the fastest deposition process in the metal Additive Manufacturing market, with gross deposition rates ranging from 3.18-9.07 kg (7-20 lbs) of metal per hour.

www.sciaky.com

Toolcraft announces plans for new AM centre

Toolcraft, Georgensgmünd, Germany, has announced further equipment investment and plans to construct a dedicated Metal Laser Centre with a production area of 800 m^2. The company has also purchased a new TRUMPF TruPrint 3000 Additive Manufacturing machine to complement its range of systems from Concept Laser and EOS.

The TruPrint 3000 is used for the series production of complex, metal components. It is said to offer considerable flexibility in terms of the size, number of parts and geometry of the components it is used to produce. An interchangeable cylinder principle reduces set-up times, increases productivity and machine utilisation rate, and ensures a clean, powder-free production run.

"We decided to purchase the TruPrint machine in order to spur on developments in the area of Additive Manufacturing," explained Christoph Hauck, Managing Director of Toolcraft.

Daniel Lichtenstein, Head of Sales and Market Development at TRUMPF's Additive Manufacturing division added, "We are delighted at Toolcraft's forward-looking decision to implement and help drive forward the use of Additive Manufacturing in industry by purchasing the TruPrint 3000 with its industrial part and powder management features."

www.toolcraft.de

MPIF seeks to form trade association for the metal AM industry

The Metal Powder Industries Federation (MPIF), Princeton, New Jersey, USA, has announced its intention to form a trade association for the metal Additive Manufacturing industry. An organisational meeting was held at the AMPM2017 conference on June 16 at the Bellagio Hotel, Las Vegas. Manufacturers of metal AM products, precursor materials and equipment manufacturers that support the metal AM industry were invited to attend.

As with existing MPIF affiliated associations, the tentatively named Association for Metal Additive Manufacturing's (AMAM) main mission would be to increase the visibility and stature of metal AM within the industrial community and, in the process, enhance the metal AM industry's opportunities for continued growth. The MPIF stated that this approach was being proposed because:

- Metal AM represents a natural relationship to Powder Metallurgy (PM) technology;
- MPIF is already well established as the organisation representing the worldwide interests of virtually all facets of PM technology;
- MPIF has in place associations with combined parts manufacturing and supplier-base organisations;
- Overseas members recognise and endorse MPIF as a highly respected international trade organisation.

Of all organisational options, the trade association is said to have the greatest credibility and acceptance as being representative of an industry and its technology. By becoming a trade division of MPIF, AMAM will benefit from the well-established reputation and high regard with which this organisation is held by the US government and the engineering public.

www.mpif.org ■■■

Senvol labelled 'Cool Vendor'

Senvol, New York, USA, reports that it has been selected as a 'Cool Vendor' in Additive Manufacturing by Gartner Inc. To be selected for such distinction, the company stated, the vendor must be considered innovative or transformative for products, services or initiatives.

"Senvol is cool because its embedded knowledge of Additive Manufacturing gives designers and engineers unprecedented choices to design parts that can deliver much more value to customers at lower cost," stated Marc Halpern, Research VP of Engineering and Design Technologies at Gartner. "Senvol may revolutionise engineering design practices as the knowledge of 3D printable materials in its software and databases accelerates manufacturers' confidence in industrial 3D printing."

www.senvol.com ■■■


Advanced CAD
for advanced manufacturing.
nTopology Element
nT
www.ntopology.com

FIT and Caterpillar join to focus on aluminium and titanium AM

FIT AG, Lupburg, Germany, and Caterpillar Inc, Peoria, Illinois, USA, have announced a strategic alliance agreement that focuses on the design and Additive Manufacturing of aluminium and titanium parts. By joining Caterpillar's product-specific knowledge and FIT's additive design expertise, the new alliance aims to take advantage of the benefits of Additive Manufacturing in the heavy equipment manufacturing sector.

It was stated that the that the new alliance will complement ongoing work in Caterpillar's Additive Manufacturing Factory and strengthen FIT's commitment to the industrial equipment market.

"We are thrilled to enter into a strategic alliance with Caterpillar. Caterpillar is a world leader in many markets, which will benefit greatly from Additive Manufacturing. However, this requires innovative technologies and new thinking combined with experience and deep know-how. Our companies complement each other with their respective strengths," stated Carl Fruth, CEO of FIT AG.

"Caterpillar has a long history of creating innovative products designed to fit the needs of our customers and entering into a strategic alliance with a leader in Additive Manufacturing will help further that tradition," added Stacey DelVecchio, Caterpillar Additive Manufacturing Project Manager. "Not only will Caterpillar now have access to FIT AG's cutting-edge technologies in Additive Manufacturing but this alliance will also help accelerate our adoption of 3D printing."

It was stated that the strategic alliance between FIT AG and Caterpillar will have an initial three-year term and will evolve to the next step based on the success of the alliance.

FIT AG and Caterpillar will focus on aluminium and titanium AM parts

Albert Klein, CFO FIT AG (left) and Ken Gray, Chairman FIT America Inc. (right)

FIT expands US activities with new Boston facility

FIT also announced it will expand its US activities with a move to a new facility in Boston. The company's US activities were first established in 2014, with the launch of FIT West Inc. in Santa Clara, California, USA. The fully owned subsidiary, renamed FIT America Corp., will now move to Southborough in Boston, Massachusetts, USA.

To coincide with the move, former Caterpillar Inc. Director of Innovation Kenneth D Gray will take over as the new Chairman of FIT America Corp. Gray's 30-year career at Caterpillar encompassed a diverse range of global leadership positions in product, operations, marketing, dealer development and engineering, reported FIT. His products and teams were featured in Forbes, Inc. Magazine, Fast Company Magazine, and Crane's Business. He is an Edison and Platts Global Energy Award winner and holds Bachelor's and Master's Degrees in Mechanical Engineering from Bradley University, Peoria, Illinois, USA. John Baliotti, Vice President of US Sales since 2016, will support Gray's transition to Chairman.

"FIT's additive design and manufacturing capabilities are second to none, but the business model is even more intriguing. Partnerships to accelerate industrial clients toward their own additive independence are what I am most excited about. Our aim is for additive to be a mainstream tool for US industrial manufacturers - and soon," stated Gray.

"We are delighted to welcome Ken to the FIT Management Team and, with the establishment of our first factory in the United States, we are expecting a major market in the USA for FIT's Additive Manufacturing capabilities and have now established a management team and structure to develop more partnerships with US clients and make further investments," Fruth added.

www.caterpillar.com
www.fit-america.com
www.fit.technology

Sievgen partners with Inert on metal powder handling solutions for AM

Sievgen, Mapledurwell, Hampshire, UK, and Inert, Amesbury, Massachusetts, USA, have announced a new partnership for the supply of metal powder handling equipment to the US Additive Manufacturing market. The two companies will work together to promote the Sievgen 04 automated sieving station to companies working with powders used in the metal Additive Manufacturing process.

"It was a win-win situation," stated Daniel Clay, Inert President. "We met with Farleygreene [Sievgen's parent company] at last year's TCT show in Birmingham and that initial meeting led to discussions about how our two companies can benefit from what the other has to offer. We've been providing inert gas enclosures to additive manufacturers, now we can offer them more ways to improve their AM processes with the Sievgen in our portfolio."

"For us the US is one of the key markets where AM is taking off," added David Buckley, Sievgen's Product Manager. "As a company we are investing heavily in the AM sector and, as an established partner, Inert are well placed to unlock both sales and market knowledge to help feed back into future development, something that we see as vitally important in any partner that we work with in this sector."

According to Clay, the high cost and corrosive properties of metal powders are some of the biggest hurdles additive manufacturers face. "The Sievgen is hermetically sealed like our glove boxes, and allows users to safely work with, weigh and measure, reclaim and transfer metal powders to and from AM machines. That saves time and money," he explained.

The Sievgen 04 automated sieving station (Courtesy Sievgen)

www.inert-am.com
www.sievgen.com

SpaceX schedules first flights with AM rocket engine parts

SuperDraco thrusters in testing (Courtesy SpaceX)

SpaceX has announced plans to fly two private citizens on a trip around the moon on its Crew Dragon (Dragon Version 2) spacecraft late in 2018, following an automatic non-crewed flight to the International Space Station in late 2017. This follows the completion of development testing of SpaceX's SuperDraco rocket engines in 2015.

Elon Musk's space-tourism venture designed the engines using metal Additive Manufacturing technology in order to cut down on cost and waste and increase the overall flexibility of the production process. Each engine's combustion chamber is fabricated from Inconel super alloy on an EOS metal AM machine.

Playing a key role in the Dragon spacecraft's Launch Abort System (LAS), the SuperDraco's engine design is vital to the mission's success. In the event of a launch failure, the LAS is designed to safely abort astronauts from the capsule. The engine, containing metal AM parts, can be throttled from 20–100% of thrust and restarted multiple times, ensuring the safe landing or splashdown of capsule crew. In recent tests, the SuperDraco's thrusters were successfully fired 27 times through various thrust cycles.

SpaceX is currently under agreement with NASA to develop refinements to the Dragon spacecraft to ensure maximum safety for crew members. The complex design and successful testing of the SuperDraco thrusters helps to ensure that these stringent criteria will be met.

www.spacex.com/dragon

RP Platform releases email system integration for AM workflow management

RP Platform, London, UK, has launched a feature to fully integrate its Additive Manufacturing software with the most widely-used email systems, including Gmail, Microsoft Office 365 and Exchange. The feature was rolled out as part of the company's most recent software update, following a long period of development, testing and consultation with the platform's longstanding users. According to RP Platform, the goal of the update is to empower Additive Manufacturing companies to better manage customer requests and communications and make more effective use of their time and resources.

The update is the latest stage of RP Platform's ongoing work to bring together all the project states and communication channels involved in Additive Manufacturing operations. Using the new feature, the company stated, users will be able to better integrate their email systems with their wider workflow management processes, with no additional admin required of their teams. When any customer requests are received via email, a file will be created automatically within the user's system to capture all future project communications, with no manual effort required. This is expected to help maintain a higher degree of efficiency, transparency and consistency throughout the entire project lifecycle, from the initial quote to delivery of the printed part.

"This new feature has been a long time in development," commented Keyvan Karimi, Company Founder & CEO. "Ever since we launched RP Platform, we've seen over and over again that email integration is a huge gap in most AM companies' workflow management processes, with no solution available that offered the functionality or versatility that AM workflows demand. Given the percentage of customer communication that now takes place via email, this will prove a stumbling block for many AM companies, particularly during this period of rapid growth and innovation the sector is enjoying.

"The new feature has gone live and is already available to all our clients, as is the case with all updates we roll out," he continued. "Going forward, it will be offered as a standard part of our product for all new users. We're confident this type of strategic automation will benefit all areas of AM operations, leaving companies perfectly positioned to deliver a better customer journey and uncover innovative new solutions to the sector's evolving challenges."

www.rpplatform.com

Metalysis opens Materials Discovery Centre to focus on high performance metal powders for AM

Metalysis, UK, has announced the opening of a new facility, the Materials Discovery Centre, at the Advanced Manufacturing Park in Rotherham, South Yorkshire. Metalysis will carry out bespoke, commercial R&D projects to produce exotic metal powders for high-performance alloys for AM applications at the new centre.

Metalysis has reportedly invested around £10 million in opening the Materials Discovery Centre and increasing production capacity at its Materials Manufacture Centre, also in Yorkshire, where the company says it is completing its 'Generation 4' technological expansion, taking production capability to new levels. Completion of 'Generation 4' expansion will enable 'Generation 5', which Metalysis anticipates commencing this calendar year and which it expects will offer manufacturing options for thousands of tonnes per annum of high-value metal alloy powders.

Company executives, researchers, scientists, politicians and financiers visited the Materials Discovery Centre's opening (Courtesy Metalysis)

"We are very proud to be part of the UK's fourth industrial revolution," stated Douglas Caster, Metalysis Chairman, "and we do so with responsibility and optimism. We have a truly unique, patented technology that can produce highly desired metals and novel alloys which have historically been considered too difficult, or too exotic and costly. The UK stands to benefit from our world-leading, transformational process and I am very excited to seeing what the coming decade will bring for Metalysis."

Following its expansion, Metalysis will employ at least one hundred people across its South Yorkshire sites and is now recruiting for staff, with talks ongoing to create local apprenticeships adding to its operations, R&D, analytical services and administration business functions. Metalysis will also continue to create work placement opportunities and support school career activities for science, technology, engineering and maths students from local secondary schools, having last year created four positions.

In March, rare earth miner Mkango Resources announced the formation of a partnership with Metalysis for a commercial R&D programme to develop metal Additively Manufactured rare earth magnets for electric vehicles.

www.metalysis.com

New metal Additive Manufacturing dust collection system

Ruwac, based in Holyoke, MA, USA, is a worldwide provider of industrial vacuum solutions. The company states that its new NA35 Series is the only immersion separator available on the market featuring a complete self-contained vacuum system.
AM environments using explosive or impact sensitive materials that may contain an ignition source, such as aluminium or titanium, will not only benefit from eliminating the risk of an explosion, but keeping workspaces clean in the process.

The system collects explosive materials entering the vacuum and immediately mixes them in a turbulent liquid bath. From there, moving air and liquid are rapidly forced onto the materials, submerging and neutralising them in the process in the vacuum's hydrophobic and oleophobic water filter system. This process stops contained materials from finding any ignition source that may be introduced into the vacuum, guaranteeing a safe, explosion-proof work environment.

Rewac reports that newly designed as part of the NA35 Series is the NA35 HD-110. This immersion separation vacuum features a stainless steel liquid discharge valve located beneath the main housing that acts as the primary source in releasing filtered contents, eliminating any heavy lifting required for emptying out of the equation. Counterbalanced heavy duty casters and its two-stack design provide a maximum portability while the system's external sight glass remains in place. For the collection of smaller amounts of metal AM dust, the CV-NA7 immersion separation vacuum is also available.

www.ruwac.com

Concurrent invests in metal AM

Concurrent Technologies Corporation (CTC) has announced the investment of $1.2 million in Additive Manufacturing equipment at its facility in Johnstown, Pennsylvania, USA. According to the company, the new equipment includes a VRC Metal Systems Gen III Max Cold Spray system and an AMBIT™ Hybrid AM multi-task system (installed in a HAAS VF 11 multi-axis machine tool).

With these additions, CTC states it can offer clients three metal processes: cold spray, hybrid AM, and powder bed fusion-laser. These processes can also be merged to provide customised solutions.

"We are applying our 30 year history in metals and metal processing to be an all-encompassing service provider for AM solutions," stated Edward J Sheehan, Jr, CTC's President and Chief Executive Officer.

www.ctc.com

University of Waterloo receives funding boost for Multi-Scale AM Lab

The University's Multi-Scale AM Lab (Courtesy UoW)

The University of Waterloo, Canada, reports that it has received cash and in-kind funding of nearly CAD $27 million for its Multi-Scale Additive Manufacturing Lab, including $8.9 million from the Federal Economic Development Agency for Southern Ontario (FedDev Ontario). Combined with $6.2 million from the Government of Ontario, this is reportedly the largest-ever government investment in AM at a Canadian university. The lab aims to help Canadian companies tap into the potential of AM, while also advancing the technology itself through funded research programmes.

"Additive Manufacturing is poised to fundamentally change the way things are made," explained Feridun Hamdullahpur, President and Vice-Chancellor at Waterloo. "Fuelled by a culture of innovation and backed by broad expertise in the advanced manufacturing sector, we look forward to playing a key role with our partners in unlocking the potential of this exciting technology."

Bardish Chagger, MP for Waterloo and Minister of Small Business and Tourism, visited the university campus to announce FedDev Ontario's contribution. "We are proud to support the University of Waterloo in continuing its role as a leader in Additive Manufacturing, innovation and strategic partnerships with the private sector," he stated. "Today's announcement demonstrates our commitment to supporting innovation, which translates into creating jobs and opportunities for middle-class Canadians."

"The Government of Canada is committed to supporting innovation and competitiveness on a global scale," added Navdeep Bains, Minister of Innovation, Science and Economic Development, and Minister responsible for FedDev Ontario. "This means investing in research and development to place Canada at the leading edge of disruptive manufacturing technologies. It also means supporting skills training for manufacturing jobs now and in the future."

"The Multi-Scale Additive Manufacturing Lab at the University of Waterloo is an innovative initiative that aligns perfectly with our province's innovation strategy," stated

Reza Moridi, Ontario's Minister of Research, Innovation and Science. "It is key to ensuring Ontario's competitiveness when it comes to the manufacturing sector, which is an integral part of our province's economy."

The Waterloo lab is focused on the development of next-generation AM to process metals through the use of new sensors, quality-assurance software and machine intelligence. A major patented innovation is the fabrication of smart components by the Additive Manufacturing of sensors and their embedment into metal parts. Experts at the lab will work directly with companies to develop high-value products using AM processes, equipping them to either do their own production or outsource it. Building on expertise and patented technology developed at Waterloo in the last 17 years, research will involve at least 14 professors and dozens of engineers, post-doctoral fellows, graduate students and co-op students.

When fully equipped, the Waterloo lab will reportedly be one of the ten largest university-based AM facilities in the world. Researchers will also collaborate with peer institutions with top AM labs, including those in Germany, the United States, England and Singapore.

msam-uwaterloo.ca

GE Additive to open German Customer Experience Centre

GE Additive, based in Boston, USA, is establishing a new Customer Experience Centre in Munich, Germany. Launched with an investment of some $15 million, the new centre will adjoin GE's Global Research Centre (GRC) in Munich and is expected to be operational by year's end.

According to GE, the centre will allow current and potential customers to experience AM component design and production first-hand. Up to 50 GE Additive employees will be based at the centre, including technicians and engineers specialising in additive design and production. Around ten additive machines from Concept Laser, Germany and Arcam EBM, Sweden (in both of which GE has majority ownership) will be installed, operating on GE's cloud-based Predix platform and GE Edge devices.

GE's Munich centre will augment the customer training and support centres within both Arcam and Concept Laser facilities. As with the Arcam and Concept Laser sites, the Munich centre will also operate as a distribution centre for critical spare parts.

"The concept of customer experience centres is an integral part of GE Additive's strategy to expose and engrain the additive technology to manufacturers worldwide," explained Robert Griggs, General Manager of Customer Experience Centres for GE Additive. "We expect to announce the second GE Customer Experience Centre later this year, with others to follow."

www.geadditive.com

Fathom adds Desktop Metal to expand machine portfolio

DM Studio System (Courtesy Desktop Metal)

Additive Manufacturing solutions and service provider Fathom, based in Oakland, California, USA, has announced the signing of a partner agreement with Desktop Metal. Fathom states that it will adopt Desktop Metal's technologies as part of its in-house manufacturing solutions and managed services to further develop its focus on changing the way products are designed and manufactured.

"Fathom is very excited to partner with Desktop Metal to help bring a lower barrier-of-entry solution for metal additive technologies to a broader engineering and manufacturing market," stated Rich Stump, Co-Founder and Principal at Fathom. "With current metal 3D printing equipment, it is cost prohibitive to 3D print metal prototype parts. Desktop Metal has introduced a solution, the Studio System, which will allow designers and engineers to cost effectively produce metal prototypes."

"We are excited to be partnering with Fathom both as a manufacturing service centre and a sales partner as we look to broaden the adoption of our metal 3D printing systems," added Ric Fulop, CEO and Co-Founder of Desktop Metal. "Rich Stump and Michelle Mihevc have built an incredible team who will be integral in expanding market opportunities and driving the growth of our customer base across diverse industries."

"Fathom and Desktop Metal share a passion for additive technologies, as well as a similar vision for finding unique processes that change the way products are designed and manufactured today— so when we heard about what was in development at Desktop Metal, we knew we had to be involved as one of their first customers and now as a go-to-market partner," stated Michelle Mihevc, Co-Founder and Principal at Fathom. "We feel very strongly that by providing this solution, one that is both office-friendly and accessible at a lower cost, there will be immediate growth in the adoption of metal 3D printing. Our team already has plans for R&D exploration into furthering application innovations for this technology. For example, we aim to leverage our expertise in 3D printed tooling to develop a process that achieves more robust tools even faster and more economically."

"We help companies focus on how a product should function rather than how it's made, designing from the outside-in, to drive greater innovation and push the limits of manufacturing," added Stump.

www.studioFathom.com

www.desktopmetal.com ■■■

European Space Agency develops new research centre for Additive Manufacturing

The European Space Agency reports that it is establishing a new 'one-stop shop', the ESA Additive Manufacturing Benchmarking Centre (AMBC), for research and development concerning Additive Manufacturing for space. The new centre is being developed in partnership with the Manufacturing Technology Centre (MTC), Coventry, UK, home to the UK National Centre for Additive Manufacturing. The MTC's research organisation will manage the new centre, which the ESA states will provide a simple and easy way for ESA projects and high-tech companies to investigate the potential of Additive Manufacturing for their work.

According to the ESA, the MTC offers access to the latest state-of-the-art AM capabilities, allowing prototype parts to be produced and then assessed in terms of their suitability for specific applications. Dr Dave Brackett, Technology Manager for Additive Manufacturing at the MTC, believes ESA's exploration of the use of AM will be beneficial for the technology: "This is a brilliant opportunity to further the technology in one of the most testing and dynamic application areas," he stated. "As the UK National Centre for Additive Manufacturing, we are in a unique position to work with ESA as their Additive Manufacturing Benchmarking Centre and provide the space sector with access to state-of-the-art capability and understanding to support industrial exploitation."

"The ESA's Directorate of Technology, Engineering and Quality has called for the creation of a detailed roadmap for the harnessing of 3D printing to the space sector," explained Torben Henriksen, Head of ESA's Mechanical Department. "We've been guided to set up this centre, with customers and industrial partners questioning us about the best way to try out 3D printing for the first time and test out the maturity of the results for their specific needs and applications."

Tommaso Ghidini, head of Structures, Mechanisms and Materials Division, added: "To be very clear: with this centre, we don't want to compete with industry; on the contrary, the idea is that ESA missions and interested companies can investigate this new engineering world to the point where they can take a decision whether to adopt this technology or not. If the decision is positive, then they can mature the technology further and even in non-space markets and applications, counting on the support and expertise of this centre of excellence."

Europe's Vega small launcher will be the first project to make use of the Centre. "By evolving Vega over time, we aim to hone its competitiveness, increase its flexibility and reduce recurring costs," stated Giorgio Tumino, overseeing Vega's development programme for ESA. "We're cooperating with AMBC to investigate the use of 3D printing for rocket engine thrust chambers for Vega's upper stage, potentially allowing for a significant simplification in production and reduced costs."

The new facility maintains a broad portfolio of materials, machines and post-processing options, which will enable AMBC to print a variety of test hardware, using polymers, metal and ceramic 3D printers. Follow-up testing, including detailed failure investigations, will supply customers with a fuller understanding of the strengths and weaknesses of their chosen AM method, along with advice on future improvements.

www.esa.in
www.the-mtc.org

Superior 3D Solutions signs seller agreement with Markforged for Metal X

Superior 3D Solutions, Rancho Cucamonga, California, USA, has signed an agreement with Markforged, Cambridge, Massachusetts, to sell the company's new Metal X Additive Manufacturing system. Superior 3D Solutions currently sells and provides service for the entire Markforged line of Additive Manufacturing systems, including the Onyx series, Mark Two and Mark X. The Metal X is designed to print 17-4 stainless steel and several other materials including aluminium, tool steels, titanium and Inconel are in beta testing.

"The level of strength the Markforged system is able to produce is amazing," stated Shayne Denston, President of Superior 3D Solutions. "Adding metals to the line-up puts Markforged at the front of the pack in the 3D printing industry. We are very fortunate to team up with Markforged and excited to demonstrate the game-changing capabilities this technology has to help advance design, engineering and manufacturing."

Superior 3D Solutions tested 20 different printers before deciding to sell Markforged's line of printers exclusively. The company provides a range of services highlighting the Markforged line, including weekly 'lunch and learns'. It also provides on-site demonstrations.

"Superior 3D Solutions has a deep knowledge of the 3D printing industry, enabling them to provide critical insights to their customers," commented Matt Katzman, Director of Worldwide Sales, Markforged. "They have a strong track record of helping companies in many different industries receive the maximum value from their Markforged printers."

www.superior3Dsolutions.com
www.markforged.com

Renishaw displays additively manufactured implants for craniomaxillofacial applications

Renishaw recently attended the International 3D Printing in Medicine Conference in Mainz, Germany, May 19-20, where the company highlighted some of the opportunities that Additive Manufacturing is creating in the field of craniomaxillofacial surgery. Renishaw, headquartered in Gloucester, UK, exhibited its bespoke AM implants and provided demonstrations of its new implant design software, Additive-manufacture for Design-led Efficient Patient Treatment (ADEPT).

During the conference, Renishaw demonstrated its knowledge of patient-specific implants for craniomaxillofacial applications and explained the benefits that a digital workflow can bring to the field. On the company's stand, visitors were introduced to successful examples of instances in which Renshaw's implant technology was used to improve patient outcomes, including a recent case where neurosurgeon Bartolomé Oliver performed a craniotomy using parts manufactured on a Renishaw AM250 metal AM machine.

Renishaw also offered demonstrations of its new ADEPT software package, aimed at enabling the widespread use of AM to produce bespoke maxillofacial implants by mitigating cost and efficiency barriers. According to Renishaw, the collaborative project also draws on the academic and industrial expertise of several UK partners; LPW Technology Ltd, Abertawe Bro Morgannwg University Health Board and PDR, located within Cardiff Metropolitan University.

"3D printing is a rapidly growing technology in many areas of medicine, as it has the potential to improve efficiency, accuracy and ease of customisation," explained Ed Littlewood, Marketing Manager of Renishaw's Medical and Dental Products Division. "Since we presented at the first annual conference last year, we have seen a growing interest and awareness of AM bespoke implants," added Littlewood.

"AM patient-specific implant technology offers benefits to the surgeon, hospital and most importantly the patient," explained Amy Davey, Reconstructive Scientist at Southmead Hospital and Renishaw's Medical and Dental Products Division. "The implants can have a positive impact on hospitals, by improving patient outcomes and speeding up surgery. Demonstrating successful cases of additively manufactured patient-specific implants will help open the industry's eyes to the potential of AM technology, increasing uptake and improving clinical outcomes."

www.renishaw.com

Left to right: model of defect, cutting guide, model of defect removed, cranial plate (Courtesy Renishaw)

AM systems to be installed in more than 400 schools under GE Additive Education Program

More than 400 schools will receive Additive Manufacturing systems as a part of the GE Additive Education Program, reaching more than 180,000 students around the globe. Of these, eight colleges and universities will receive metal Additive Manufacturing systems. GE has previously stated that it plans to invest $10 million over the next five years in two educational programmes, with the aim of developing pipelines of future talent in Additive Manufacturing.

GE will provide the following eight schools with a Concept Laser MLAB cusing 100R metal printing machine, with a market value of about $250,000 each, in the first year of their Additive Education Program:

- Auburn University, USA
- Boston University, USA
- Iowa State University, USA
- North Carolina State University, USA
- Ohio State University, USA
- University of Cincinnati, USA
- University of New South Wales, Australia
- U.S. Naval Academy, USA

GE will provide eight schools with a Concept Laser MLAB cusing 100R

GE believes that enabling educational institutions to provide access to AM systems will help accelerate the adoption of Additive Manufacturing worldwide. "Additive manufacturing and 3D printing is revolutionising the way we think about designing and manufacturing products," stated Mohammad Ehteshami, Vice President of GE Additive. "We want a pipeline of engineering talent that have additive in their DNA. This education program is our way of supporting that goal."

The Additive Education Program reportedly generated more than 250 applications from colleges and universities and more than 500 applications from primary and secondary schools around the world. A hand-picked team of GE specialists evaluated each school and made the final selections.

GE will deliver the systems later this year and plans to provide machines to more schools each year over the next four years. The next application window will open during the first quarter of 2018.

www.geadditive.com

Arconic Foundation awards $600,000 across six schools to expand advanced manufacturing education worldwide

Arconic Foundation, the independently endowed philanthropic arm of Arconic Inc., New York City, New York, USA, reports that it has awarded six US$100,000 grants as part of its Advanced Manufacturing Education Grant Programme. Launched to fund education programmes focusing on emerging transformative technologies for the manufacturing industry, Additive Manufacturing is seen as one such technology. In the next two years, academic and training institutions in the United States, Germany, Hungary and the United Kingdom aim to educate 375 students through these grant programs.

According to Arconic, the Advanced Manufacturing Education Grant Program addresses the rapid shift taking place in manufacturing – in cutting-edge technologies like automation, robotics, Additive Manufacturing and the digitalisation of information – to help solve the skills shortage faced by manufacturers globally. In the United States alone, over 365,000 manufacturing jobs are currently open, according to the National Association of Manufacturers (NAM), and over two million of the 3.5 million job openings over the next decade will go unfilled due to the skills gap. The need is particularly acute for skilled and highly skilled positions, which can be exacerbated by the pace of technological change, states the Association.

"A healthy manufacturing sector is a top priority," explains Todd Boppell, NAM's Chief Operating Officer. "Manufacturing is the backbone of the U.S. economy, and it's public-private collaborations like this Arconic Foundation grant programme that help equip today's students to forge successful manufacturing careers."

The six grant recipients are:

- Ivy Tech Community College, Lafayette, Indiana, United States
- Muskegon Community College, Muskegon, Michigan, United States
- Pellissippi State Community College, Knoxville, Tennessee, United States
- University of Sheffield, Sheffield, United Kingdom
- Cologne Institute for Economic Research in cooperation with the students' network D.E.M.I.N.G. at the University of Applied Science Fresenius Dusseldorf, Germany
- Obuda University, Szekesfehervar, Hungary.

www.arconic.com

P&G and AMM partner with Canada Makes on customised AM parts

An example of an additively manufactured fluid delivery system produced by Canada Makes (Courtesy Canada Makes)

Procter & Gamble Belleville Plant (P&G) and Additive Metal Manufacturing Inc. (AMM), both based in Ontario, Canada, have partnered with Canada Makes to explore the building of new customised parts using Additive Manufacturing. The project was funded through Canada Makes' Metal Additive Demonstration Program.

"Metal Additive Manufacturing offers an exciting alternative to commercial off-the-shelf parts that cannot achieve complicated design requirements or internal cavity geometry. Even in cases where commercial customisation is available and able, it usually comes with significant additional costs or an unbearably long lead-time," stated Haixia Jin, P&G Engineering Technical Manager.

"AMM is delighted to be partnering with P&G and Canada Makes in helping P&G introduce metal Additive Manufacturing into their supply chain," added Norman Holesh, AMM President. "P&G embarked on this journey with the full understanding that to be successful, the technology must be embraced as early as possible in the design stage. This technology is neither an alternative to subtractive manufacturing nor a replacement for it but an addition to the entire manufacturing process and allows for previously unthinkable designs and a dramatic reduction in lead times."

Canada Makes' Metal Additive Manufacturing Demonstration Program is funded by the National Research Council Canada's Industrial Research Assistance Program and is designed to help Canadian industries increase awareness and understanding of the advantages of the metal AM technology. Canada Makes works with a group of AM experts who offer participating companies guidance on the cost savings and efficiencies of Additive Manufacturing.

www.canadamakes.ca
www.pg.ca
www.additivemet.com

Autonomous Cluster Fund and Metalysis announce metal AM partnership

Kazakhstan's Autonomous Cluster Fund (Almaty Tech Garden) has signed an agreement with UK-based Metalysis to develop high-value metals and alloys for Additive Manufacturing. Under the agreement, the partners will reportedly conduct a development programme using Metalysis' electrochemical process at its South Yorkshire Materials Discovery Centre, and support Kazakhstan's developing metal Additive Manufacturing industry through additional efforts at Kazakhstan's Park of Innovative Technologies – a science and technology complex aimed at diversifying national, economic and industrial development.

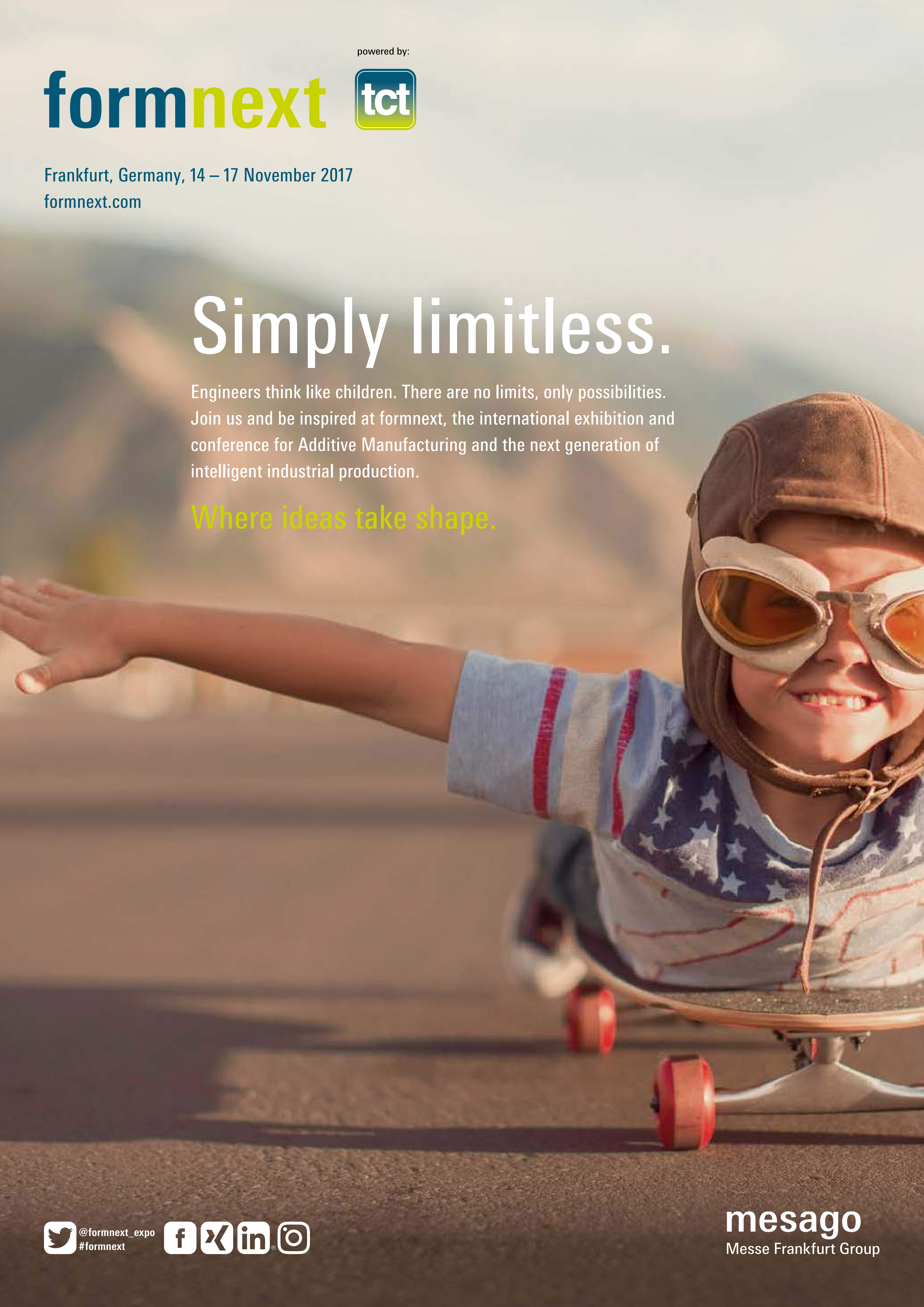
Company representatives and UK and Kazakh Government officials attended the signing ceremony, where Sanzhar Kettebekov, CEO of Kazakhstan's Autonomous Cluster Fund, commented, "For the purposes of adhering to the priorities outlined in the President's Address, we are working to grow new industries with the use of digital technologies. Our cooperation with Metalysis is aimed to develop Kazakhstan's industry sector in the field of metal additive production. We are delighted to have established such a partnership, which will contribute to the diversification of the economy of Kazakhstan."

Dr Malek Deifallah, Director of Business Development at Metalysis, added, "This is an exciting time for Metalysis. We are very pleased to partner with the Autonomous Cluster Fund and together pursue the clear opportunities Kazakhstan presents for metal alloy powder production and Additive Manufacturing. We look forward to providing future updates as we go about applying our unique know-how and technology."

The partners will reportedly use Metalysis' electrochemical process to develop metals and bespoke alloy powders suitable for Additive Manufacturing, in an attempt to diversify the Republic of Kazakhstan's economy. Initially, an R&D programme will be conducted at Metalysis' new Materials Discovery Centre. Subject to its findings, the partners will then seek to develop Kazakhstan's metal Additive Manufacturing industry, basing their efforts within the Autonomous Cluster Fund's Park of Innovative Technologies; weighing opportunities for in-country production of metal alloy powders and printing commercial products using Additive Manufacturing techniques.

According to the Fund, Kazakhstan is well placed to prosper from the development of in-country metal AM. Representatives state that the sector is a natural fit within a sustained development programme of economic and industrial frameworks, which can build on the country's geological endowment and know-how in natural resource extraction.

www.metalysis.com


powered by:
formnext
tct
Frankfurt, Germany, 14 – 17 November 2017
formnext.com
Simply limitless.
Engineers think like children. There are no limits, only possibilities. Join us and be inspired at formnext, the international exhibition and conference for Additive Manufacturing and the next generation of intelligent industrial production.
Where ideas take shape.
@formnext_expo
#formnext
mesago
Messe Frankfurt Group

Linear AMS: How an AM service provider is embracing the new infrastructure of on-demand manufacturing

In 2016 SAP and UPS announced their collaboration to develop a supply chain management solution that spans the complete AM process chain, from component evaluation and design to delivery of the final product. Leading US-based AM service provider Linear AMS, a Moog company, is one of several manufacturers involved in the venture. Linear AMS's Bruce Colter and Moog's George Small review the drivers behind on-demand manufacturing and present recent developments in materials, applications and component verification.

Much is made in the contemporary business world of 'creative disruption' – reinventing and replacing outdated assets and cultures in favour of improved processes, increased efficiencies and more engaged employees. Manufacturing is certainly not immune to this need, but, as opposed to flexible working or pet-friendly workspaces, manufacturing, particularly in critical industries such as aerospace, defence, transportation and energy, demands more. Disruptive concepts must be followed immediately by a superior infrastructure wherein parts with tight tolerances come to market faster, with orders-of-magnitude improvements in quality and deliverability, all from the hands of a digitally savvy 21st Century workforce.

Some of the world's leading businesses are currently establishing the pillars of this new infrastructure around the core of metal Additive Manufacturing. Interestingly, these giants are not manufacturing companies *per se*, but visionaries in software and logistics, reaching out to metal AM process leaders with new thinking, while metal AM itself continues to evolve in response.

At the 2016 Sapphire Now meeting in Orlando, Florida, USA, enterprise resource planning giant SAP SE named Moog Inc. and Linear AMS, a Moog company based in Livonia, Michigan, USA, as co-innovators in its agreement with UPS to, in SAP's words, "transform the ad-hoc world of industrial 3D printing into a seamless, on-demand manufacturing process

Fig. 1 An example of the design and functionality that can be achieved with metal Additive Manufacturing (Courtesy Linear AMS)

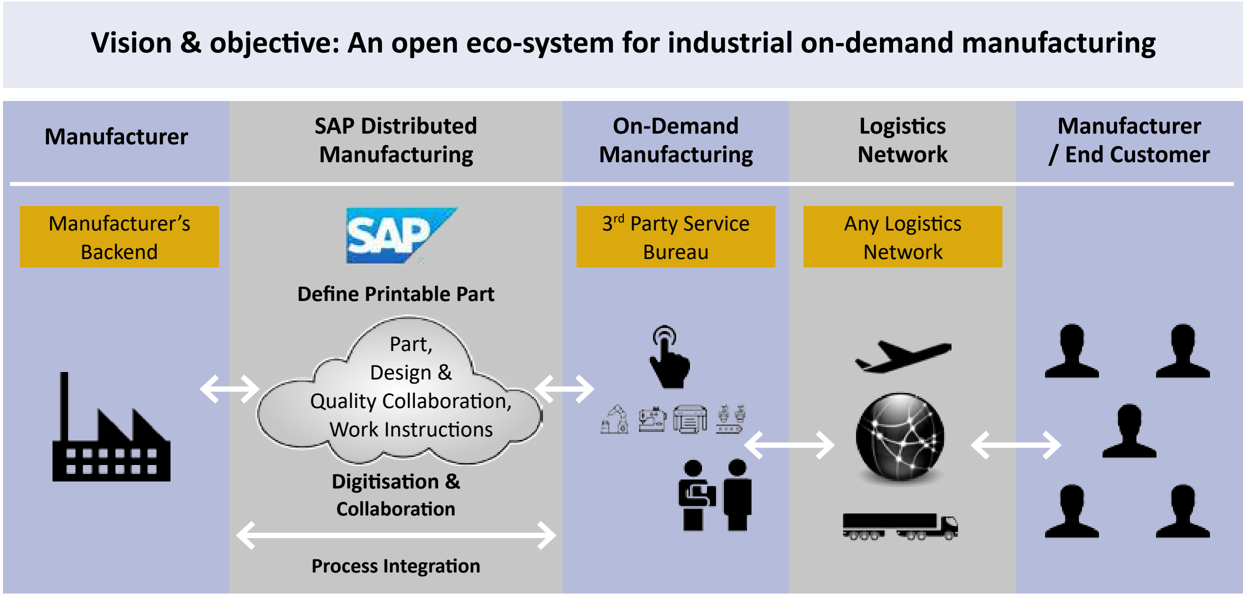


Fig. 2 SAP and UPS announced the era of an on-demand infrastructure with metal AM at the core

from order through manufacturing and delivery." Stan Deans, President, UPS Global Distribution & Logistics, stated at the event, "Markets are changing rapidly and no company can solve all customer problems on its own. This agreement with SAP adds an important UPS capability to help customers right-size inventories and lower short-run production costs, and help entrepreneurs bring their ideas to life faster than ever."

Additive Manufacturing ties it all together. With networks becoming tighter in response to unrelenting competition and delivery schedules, one unplanned production halt can bring down an entire supply chain. With this agreement, SAP customers can digitise and streamline production part approval processes and orders can be seamlessly routed to UPS stores equipped with Additive Manufacturing systems or experienced service bureaus such as Linear AMS.

Currently, UPS stores will have systems for additively manufacturing in resins and plastics; Linear AMS has a fleet of twenty metal Additive Manufacturing machines and more than twelve years of processing and troubleshooting experience manufacturing parts from a wide range of materials. "Technology innovations such as 3D printing are revolutionising traditional manufacturing and redefining our notion of the industrial supply chain," explained Bernd Leukert, member of the Executive Board, Products & Innovations, SAP SE, at the time of the announcement. "By bringing together the on-demand manufacturing and logistics expertise of UPS and the extended supply chain leadership of SAP, we can enable direct digital manufacturing and an on-demand industrial manufacturing network that connects from the manufacturing floor to the customer door."

In his keynote at the Sapphire Now event, Leukert continued to state that all businesses have a common desire to succeed in the so-called digital age and part of the solution is to deliver a 'live' customer experience. "For many years, we, as well as many other companies, have talked about the 360° customer view. Today, we are moving more to a contextual view, a real-time view of each individual customer. That view can get you virtually inside your customers' heads; you can understand the hopes, the dreams, the mental pictures, which then lets you provide the right product at the right time at the right place," he said.

In a recent white paper, 'The Rise of Smart Operations: Reaching New Levels of Operational Excellence', UPS describes how it conducted research to gauge the pace at which manufacturers are evolving. The results indicate a widening gap between companies that are aggressively embracing smart operations principles and those that are falling further behind. Those companies taking the lead are much better positioned to achieve the level of operational excellence necessary to be competitively effective in today's demanding markets, says UPS.

Not surprisingly, the research also revealed another prominent success factor — the increasingly important role of external service providers. Manufacturing companies must recognise the need to focus on their key internal competencies while leveraging the scale, technology and skills of those providers that can deliver crucial support processes. This includes enterprise-wide software partners like SAP, logistics experts like UPS and metal AM pioneers like Moog and Linear.

Reinventing the industrial supply chain

"3D printing has been around since the 1980s, but today there's really an explosion going on," states Alan Amling, Vice President of Marketing at UPS Global Logistics & Distribution. "Every week you see something new about it in the press." Speaking at a 2016 SAP event focusing on the aerospace and defence industries, Amling made the point that manufacturing, and manufacturing's customers, have followed the same rules of mass production for decades. "But there are numerous advantages that make Additive Manufacturing especially attractive," Amling says, "like no minimum quantities, no upfront tooling costs, faster production times and more cost-effective customisations."

"The 3D market is expected to triple over the next three years," he continued. "If you can imagine that just 5% of manufacturing moves to 3D printing, that would represent $640 billion."

In fact, Amling envisions Additive Manufacturing as part of a larger, more connected digital economy, taking the previously announced SAP/UPS infrastructure and building even further. In a recent TED talk, he describes a global network where thousands of intelligently connected AM machines are located in key areas all around the world, creating an elastic, on-demand manufacturing cloud.

But why do Amling and UPS, in particular, have such a keen interest in Additive Manufacturing? Well, remember – in addition to delivering millions of packages per day to businesses and consumers worldwide, UPS is also a global supply chain solution provider. "We maintain more than 1,000 global field stocking stations," notes Amling, "and these warehouses store critical spare parts for companies around the world." So what happens to this significant segment of the business when inventory is stored virtually and can be created using Additive Manufacturing?

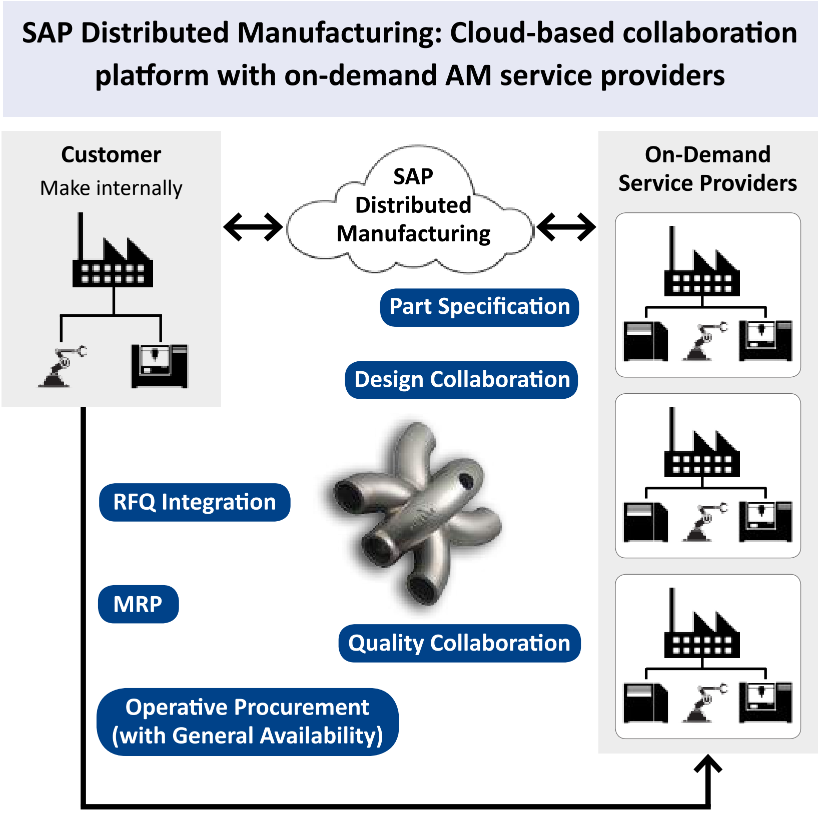


Fig. 3 Cloud-based part delivery covers RFQ, design, procurement and quality, in addition to manufacturing

The answer is the disruption portion of the scenario, rethinking manufacturing capacity and its ability to respond to the needs of particular customers. For these customers – after a successful validation period with early access customers and partners – SAP introduced a new solution in 2017 that delivers on its initial promise. SAP Distributed Manufacturing combines standardised, scalable business processes for digitising, approving, certifying and producing parts (Figs. 2, 3). Part of the SAP Leonardo IoT portfolio, it provides a network for discrete manufacturers to collaborate with Additive Manufacturing companies and service providers, materials providers, postal companies and global logistics networks. The solution's modules for Assessment & Digitisation, Collaboration & Approval and Production provide end-to-end capabilities from pre-production through order, manufacturing and delivery.

Linear AMS: Experienced service providers at the heart of the system

While additive in general and metal additive in particular continue to gain exposure, they are by no means a 'plug-and-play' solution for accelerating supply-chain efficiencies (Fig. 4). George Small, Principal Engineer at Moog's Space and Defense Division, puts it this way: "Our first forays into AM go back over fifteen years. With our background in manufacturing of complex parts, we could easily see the value of direct digital fabrication. Printing of polymer parts for fit checks, prototypes and tooling became commonplace at Moog. However, the real target for us was metal additive parts."

"Powder bed laser technology looked to be the most mature and suitable for our typical Moog applications," he continues. "But results of our early trials were disappointing to say the least. Delamination

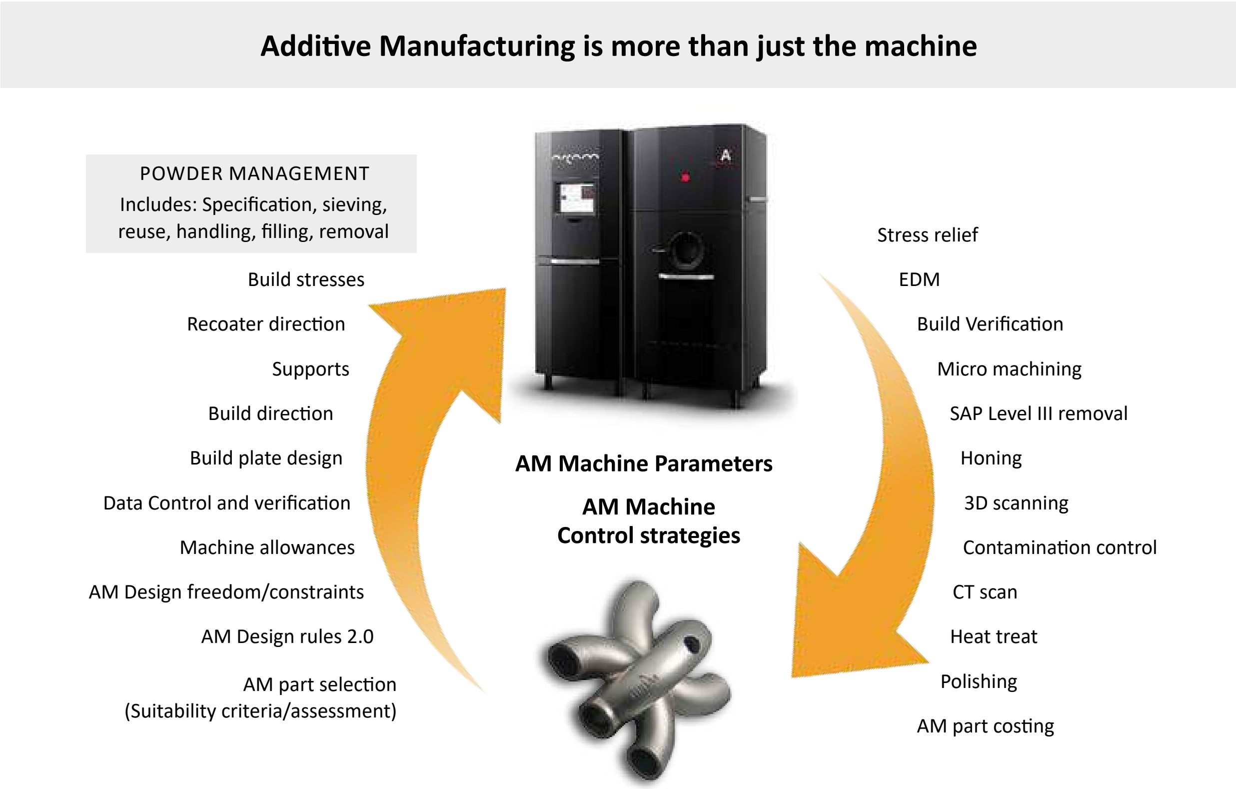


Fig. 4 The new metal AM infrastructure covers numerous pre- and post-processing functions. Blockchain-based part verification adds security and traceability throughout

between layers was common, porosity abundant and material properties lacking. Every few years we would try a few more parts at outside service vendors with comparable results. The technology did not seem ready for our demanding applications."

Additive Manufacturing allows production of parts with complexity that cannot be easily matched by traditional manufacturing methods. It can be used to produce impossible-to-machine features; it can produce parts without seams or joints; often, complex geometric or organic shapes are only possible and practical to produce using Additive Manufacturing methods. However, there are still challenges to be met in getting AM into widespread use (see Table 1).

All of this changed in late 2015, when Moog purchased a majority interest in Linear Mold & Engineering. Founded in 2003, Linear Mold, now Linear AMS, was an early adopter in metal AM, purchasing the second powder-bed fusion machine from EOS in North America (the first purchaser was GE).

"The acquisition of Linear brought more than metal AM capacity; it brought full CNC machine shop capabilities, including wire EDM and finishing capabilities"

The acquisition of Linear brought more than metal AM capacity; it brought full CNC machine shop capabilities, including wire EDM and finishing capabilities. It also brought the most experience in North America in progressing along the metal AM learning curve, including integrating computer-aided design into Additive Manufacturing, developing processing parameters and handling procedures for metal powders and troubleshooting thousands of builds.

Linear CAD Operations Manager Kevin Jonatzke's experience goes back to the days of rapid prototyping, predating metal AM. "I ran a prototyping company of my own, printing plastic parts," he explains. "What brought me to Linear, among other things, was the opportunity for design engineering – to take parts from the design stage and work them directly into production."

"However, it is increasingly difficult to sell a customer on rapid prototyping in manufacturing. Rapid prototyping serves a design function, producing 3D models of design iterations," Jonatzke continues. "Manufacturing has different expectations, requiring different strategies. There are a lot of variables in building a

Fig. 5 A small selection of Linear's fleet of 20 metal AM machines (Courtesy Linear AMS)

part and there is no automated CAD software that will take each part model and translate it into the best production strategy. Metal AM, for example, involves anchoring the part to the build plate. Are there constraints in the build direction? Do different support structures make a difference?"

"What we are moving into is taking designs for traditional manufacturing and optimising them for metal AM. It is definitely a team effort to take the same geometry and strength requirements from conventional manufacturing and approach them from a metal printing perspective. There are great customers, who help take on the challenges and new perspectives metal AM provides, and there are customers who have built parts and then refused to rebid on the project because of the difficulties. To my knowledge, there are not a lot of companies that share the kind of process knowledge that puts customers months, if not years, ahead of trial-and-error part design and development. As I said before, there is no automated CAD software that will build each part from a model. The difference is production experience."

Opportunities and benefits	Challenges and complexities
Supply chain optimisation	Lack of released standards
Greater geometric flexibility	Material properties, design allowables
Complexity comes for free	Process control understanding
Rapid turnaround, faster time-to-market	Powder specifications
Customisation and redesign opportunities	Thermal processing
Tooling elimination	Component design understanding
Operating cost and inventory reductions	Post-processing, including surface finishing
Sustainable and energy efficient	Non-destructive inspection of AM parts
Accurate and repeatable	Cyber security
Compatible with other processes	

Table 1 Opportunities and challenges for metal AM (Courtesy Moog Inc.)

Fig. 6 Linear AMS has extensive AM process knowledge (Courtesy Linear AMS)

Metallurgy and materials handling

Bob Henderson, Linear's Director of Additive Manufacturing, cites metallurgy expertise and material-handling procedures as factors to consider in establishing a complete production infrastructure. "We purchase a lot of 20 to 60-micron metal powder and how we handle it, in what conditions and how we process it makes a big difference in the final outcome."

"Many factors, such as how you sieve metal powders to the proper particle size, at what temperature and humidity you store and handle the metal powders, can make a big difference in part quality," he adds. "We have a measurement we call build failure. It is not a gold star for us, nor is it good for the customer, but having increased knowledge and tighter controls over the management of our powders helps us reduce our failure rate."

"Take residual stress, for example. Stress relief is one critical post-processing activity that will positively affect residual stress. Basically, it involves taking the chamber temperature up, then slowly bringing it down. Hand in hand with residual stress is porosity. The Hot Isostatic Pressing (HIP) process essentially squeezes the part like a sponge. Now you cannot cure every kind of porosity, but Linear continues to develop effectiveness tests that help us determine which process is more effective and why."

Henderson adds, "All of this is for solving real problems for real parts in real applications. We came up with a real beauty recently. There is a standard mechanical properties test that uses tensile test bars. As we were building metal parts, we also built a bunch of test bars along the perimeter of the coupon and then introduced a number of variables – interrupting the build for various periods of time, opening the chamber and releasing the argon gas and then restarting the process, that kind of thing. What we are doing is building a unique set of specifications on build interruptions backed up with data. This could go on for a couple of years, testing multiple materials on multiple machine types under multiple conditions."

High performance aluminium alloys: F357

A357 aluminium alloy is a popular choice in many industries, including aerospace, defence and automotive, due to its strength, weight, machinability and other performance characteristics. F357, the beryllium-free version of A357, has a tensile and yield strength comparable to A357, but eliminates the inherent safety hazard of working with beryllium. According to the United States Department of Labor, exposure to, contact with or inhalation of beryllium is known to cause lung cancer.

Unfortunately, design and mechanical engineers wishing to make F357 components have to rely on castings and their inherent trade-offs. Tooling to make castings is expensive and complex components can greatly drive up tooling costs, dampening innovation.

This situation has, however, changed significantly thanks to AM technology and Linear AMS, together with engineering support from parent company Moog Inc., is now successfully printing F357 on its Direct Metal Laser Melting (DMLM) equipment. "Not only is this a significant technical achievement, it is a real culture shift in the way Linear is now operating," states Chris Jastrzembski, Additive Manufacturing Account Manager. "With Moog's input, we are developing new material parameters constantly. Printing F357 is a direct result of that work."

That Linear AMS also has a full CNC machine shop for post-processing additively manufactured parts adds to the company's capabilities. "Securing and qualifying metal powders and printing new materials is a great example of the partnership between Linear's capacity and Moog's engineering support and deep involvement in aerospace and defence," Jastrszembski adds. "We are continuing to collect mechanical data and explore printing parameters based on powder density, surface finish, laser power, scan speed and many others."

There is definitely a buzz at Linear over printing F357 and continually exploring other materials, including copper grades used in combustion chambers and thermal transfer equipment. "It is very proactive as far as customers are concerned," Jastrszembski explains when asked about customer feedback. "They are finding they do not have to alter prints or drawings drastically to take advantage of 3D printing. From our perspective, pushing the envelope on new materials and metallurgical processing is not only exciting, it is affecting and improving what we are already doing every day with existing materials."

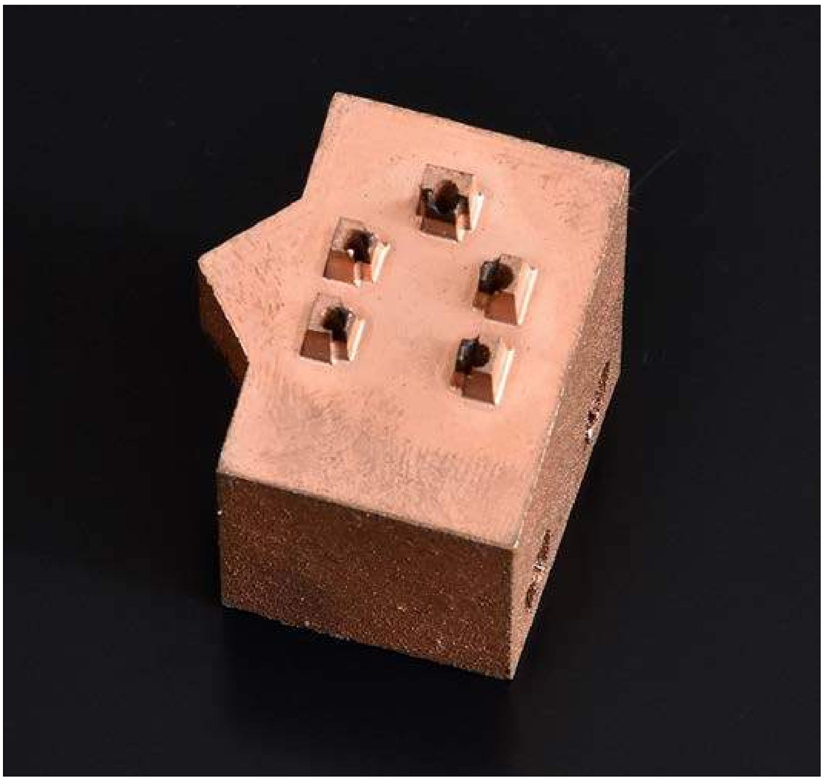


Fig. 7 A copper EDM sinker with internal channels (Courtesy Linear AMS)

The growth of copper as an AM material

"There is a lot of interest in thermal stabilisation projects for copper components, due to copper's excellent heat-transfer properties and electrical conductivity," states Paul Breeding, Director Of Engineering/ Additive at Linear. "Tie in all the advantages of metal AM in removing design constraints and expanding part configuration choices, compared to conventional milling and turning, and copper becomes a very exciting choice for particular parts."

Industries such as aerospace and automotive are breaking new ground in printing copper components. As recently as 2015, NASA announced its first full-scale additively manufactured copper part, a combustion chamber liner. "We are not trying to just make and test one part," a project leader reported. "We are developing a repeatable process that industry can adopt to manufacture engine parts with advanced designs. The ultimate goal is to make building rocket engines more affordable for everyone."

Process development is an ongoing mission that Linear AMS shares as well. "It is a very interesting time in the industrial space with Additive Manufacturing," Breeding continues. "Team building, participating in standards discussions and improving process controls are just some of our efforts aimed at bettering our engineering and metallurgical understanding of not only copper, but all the materials our customers want."

Conformal Cooling: building the unmachinable

Milacron Holdings Corp., a leading industrial technology company serving the plastics processing industry, has announced that its DME product brand, a leader in mould components, moulding supplies and industrial supplies, is partnering with Linear AMS to offer metal additively manufactured conformal cooling products to help improve productivity in the moulding industry.

TruCool® is a new line of DME products designed to help mouldmakers and moulders with mould cooling. DME's conformal cooling solutions through Linear use metal AM to produce highly complex cavities, cores and components with conformal cooling channels. The AM process achieves shapes, paths and channel geometries impossible to obtain with conventional tooling. "We build the unmachinable!" stated David Baucus, DME Product Manager, adding, "The conformal cooling solution places cooling channels at the optimal distance from the mould surface, consistently following the geometric shape of any mould insert for any customer part, allowing the mould to maintain a targeted, consistent temperature that allows for complete thermal control with cooling times reduced up to 100%. This technology also allows for conformal venting solutions for those hard to reach areas of trapped gases, when requested by the moulder."

"Conventional mould cooling has remained largely unchanged for decades. DME's partnership with Linear AMS is a huge step forward for the industry," added Peter Smith, DME President. Smith added, "Our real world, in-field results show a significantly reduced total cycle time – between 15 and 60% depending on part complexity, shortening the time needed to run the part and improving

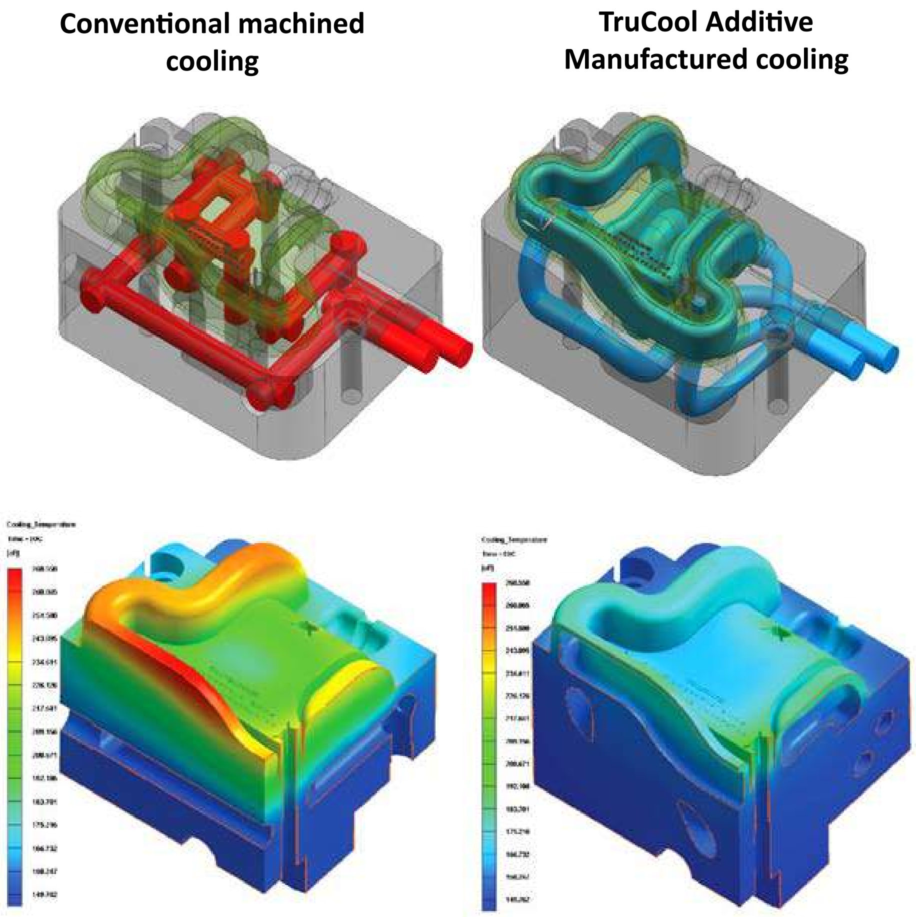


Fig. 8 Linear AMS is providing TruCool conformal cooling inserts for DME Milacron. TruCool conformal cooling provides superior heat transfer over conventional cooling technologies (Courtesy Linear AMS)

part quality. That is a significant cost saving every moulder would be interested in. Likewise, OEM/product designers will benefit from the technology as it broadens the scope of part design, allowing for advancements in plastic part production and application use."

"We have taken the lessons from over a decade of building DMLM parts and established design rules and process controls that enable us to make excellent quality components that meet or exceed customer expectations," states David Hodge, Linear AMS General Manager. "We are excited to partner with DME, a leader in the moulding industry, who shares our focus for serving customers with superior products. When a customer is moulding millions of parts, seeing significant process gains is a real eye-opener."

Digital part verification

Moog is contributing significant effort toward strengthening the metal AM infrastructure even further. By using Blockchain, the technology behind the digital currency Bitcoin, Moog Inc. and Identify3D (San Francisco, California, USA) are together launching Veri-Part™; a cloud-based, open-standard digital part verification system that is re-imagining and re-making the part verification process.

Watch The Antiques Roadshow more than once and you will hear the word 'provenance' pop up. Meaning to establish the true origin or source of an object (from the Latin *provenire*, 'to come forth'), a lack of or unknown provenance implies (a) questionable if not shoddy workmanship; (b) that the item is counterfeit and/or (c) that it is illegal.

Now, take an example from the real world. Last year, a nineteen-year-old turbine disk violently broke apart inside the engine of an American Airlines jetliner taking off from O'Hare International Airport in Chicago, sparking a massive fire and a wide-ranging probe into General Electric's CF6 engines. The 'uncontained' failure, which hurled fragments as far as half a mile from the scene, is certainly unusual given modern protective casings, but at least four other planes powered by the same GE engine family have experienced serious malfunctions since 2000.

Imagine if there were a perfect trail, entirely digital and immediately accessible, for checking all part approvals from design through production. Industries with critical part-performance requirements,

Fig. 9 Tooling has become an important market thanks in large part to conformal cooling (Courtesy Linear AMS)

including aerospace, defence, automotive, medical and more, have part-checking requirements built into the supply chain. Hundreds of millions of dollars are spent verifying part and process quality - with varying degrees of success - from antiquated and time-consuming job tickets and paper trails to complex, Big Data-inspired computerised systems requiring an extensive, customised and costly IT infrastructure. Manufacturing companies without the knowledge or resources to invest in part verification are effectively cut out from acquiring or growing any business in complex-part manufacturing.

"Many industries are fraught with counterfeit parts, from aerospace and defence to vitamins and supplements," explains Moog Director James Regenor. Every action in the supply chain – obtaining raw materials, confirming and finalising part design adjustments, manufacturing, post-processing, shipping – generates microbursts of data, energy and bandwidth. "Blockchain-based technology allows the capture of these data and the verification of each transaction digitally at every step of the process," Regenor continues. "Essentially, this creates a digital ledger system, available any time, to any participant, whenever needed."

Making and preserving truth

In a 2015 article, entitled "The great chain of being sure about things," *The Economist* wrote that "the cryptographic technology that underlies bitcoin, called the 'blockchain', has applications well beyond cash and currency. It offers a way for people who do not know or trust each other to create a record of who owns what that will compel the assent of everyone concerned. It is a way of making and preserving truths."

In a manufacturing world of digital part designs, whose files not only establish design provenance but also power CNC machining and Additive Manufacturing equipment, establishing and preserving truth along each step of design and manufacturing is an essential commodity.

According to *The Economist*, the blockchain began life in the mind of Satoshi Nakamoto, the brilliant, pseudonymous and so far unidentified creator of bitcoin – a "purely peer-to-peer version of electronic cash," as he put it in a paper published in 2008. To work as cash, bitcoin had to be able to change hands without being diverted into the wrong account and to be impossible for the same person to spend twice.

To fulfil Nakamoto's dream of a decentralised system, the avoidance of such abuses had to be achieved without recourse to any trusted third party, such as the banks that stand behind conventional payment systems. So the blockchain became this trusted third party; a database that contains the payment history of every bitcoin in circulation, providing proof of who owns what at any given juncture.

Fig. 10 Digital part verification presents the opportunity to transform safety and security in critical sectors such as aerospace (Courtesy Linear AMS)

This distributed ledger is replicated on thousands of computers – bitcoin's 'nodes' – around the world and is publicly available. However, for all its openness, it is also trustworthy and secure. This is guaranteed by the mixture of mathematical subtlety and computational brute force built into its 'consensus mechanism' – the process by which all nodes agree on how to update the blockchain in the light of bitcoin transfers from one person to another.

Adjusting blockchain to part verification essentially and efficiently digitises the paper trail for design through manufacturing. Hundreds of process participants – designers, engineers, raw material buyers, equipment operators, process specialists, schedulers, shippers and all the supervisors in between – can generate thousands of ledger pages across ad hoc networks, which effectively establish peer-to-peer trust as parts move through production. Part provenance is established every step of the way.

"Using VeriPart as the platform for a cloud-based project management system makes authenticity, status availability, quality and security immediately available up and down the network to any participant that needs it," states Regenor. "Such a process also becomes self-policing, quickly identifying under-performers and thereby strengthening the supply chain. Design and manufacturing owners retain their ownership and can aggregate and reward intellectual property from all stakeholders. VeriPart-verified parts are guaranteed authentic because all the materials, design changes and manufacturing processes are certified and traceable."

Take the engine disk example mentioned earlier. Now, imagine an aerospace Maintenance Repair and Overhaul worker being able to scan a metal AM replacement part and know 100% that it is not counterfeit and be able to look up the data to validate its origin and production.

Conclusion

Through network-wide software solutions, domestic and international logistics expertise and the ever-evolving capabilities of metal AM production, including seamless digital part verification, the technology's ability to disrupt the conventional manufacturing supply chain is very real. As demonstrated in this article, the infrastructure to support metal Additive Manufacturing as it embraces the potential of on-demand manufacturing is very much in place.

Authors

Bruce Colter
Director, Linear AMS
12926 Stark Road
Livonia, MI48150
USA
Email: bcolter@linearmold.com

George Small
Principal Engineer, Moog Inc.
400 Jamison Rd.
East Aurora, NY 14052
USA


ADDITIVE
MANUFACTURING AMERICAS 2017
6-8 DECEMBER • PASADENA

Metal Additive Manufacturing gains ground in the tyre industry

The global tyre industry and its supply chain met in Hannover, Germany, from February 14-16 for the Tire Technology Expo 2017. This exhibition and accompanying technical conference was held at the Hannover Messe for the second time and attracted 280 exhibitors and close to 5000 international visitors. Dr Georg Schlieper visited the exhibition on behalf of *Metal Additive Manufacturing* magazine and reports on the growing use of Additive Manufacturing in the tyre industry.

Some ten years ago leading French tyre manufacturer Michelin began to investigate metal AM technology for the production of tyre moulds. These preliminary tests were so successful that in September 2015 the Michelin Group announced the formation of a 50/50 joint venture with the Fives Group, also based in France, for the development of industrial metal Additive Manufacturing machines. It was stated at the time of the announcement that the new company, based in Clermont-Ferrand, France, was expected to "produce, on an industrial scale, mould parts that are unachievable using traditional means of production."

These developments were of course noted by manufacturers of tyre moulds, the majority of whom relied upon conventional manufacturing processes. As a result, many in the industry were drawn to investigate AM technology further, carrying out R&D activities in collaboration with manufacturers of metal AM systems. Some of these mould manufacturers spoke about their experience with *Metal Additive Manufacturing* magazine at the exhibition and some even exhibited tyre moulds featuring additively manufactured inserts. Two manufacturers of AM production equipment, EOS GmbH and SLM Solutions Group AG, were also represented at the show. The Additive Manufacturing technology currently applied by these companies is metal Powder Bed Fusion using laser beams.

Tyres for cars, motorcycles, trucks and agricultural vehicles are produced by what is a highly specialised industry sector. The last step in the production of tyres is the vulcanisation of the tyre in a closed mould. In this process, the rubber material of the tyre is cured and converted into an elastomer at elevated temperatures, with the mould giving the tyre its

Fig. 1 The Michelin Alpin 5 winter passenger car tyre is siped to full tread depth, to better preserve the tyre's winter performance during the whole life of the tyre (Courtesy Michelin)

Fig. 2 Fives Michelin Additive Solutions, a joint venture launched by Fives and Michelin, has introduced a range of metal AM solutions under its new AddUp brand. The company can now supply a complete industrial based system built around its new FormUp™ 350 machine, as well as offering support and advice on part production

final shape. Tyre moulds are usually not produced by tyre manufacturers themselves, but by specialised mould making companies once the mould design is agreed upon between the mould manufacturer and the customer.

The conventional manufacturing route for tyre moulds starts with a light metal casting consisting of a homogeneous, wear resistant aluminium-silicon alloy. The high heat conductivity of aluminium allows for a rapid removal of the heat during the vulcanising process and thus shortens the manufacturing cycle. Tyre mould segments are produced by casting or milling on 5-axis CNC machining centres, with much of the finishing operation carried out manually.

Tyre profiles are comprised of an array of broad and narrow grooves. Each tyre company has its own profile design that reflects its strategy on how to optimise the running performance, grip and durability of a tyre. The negative shape of the profile is represented on the inside of the tyre mould. Broad grooves can be integrated in the aluminium mould, but for narrow grooves with a width of less than approximately 3 mm, the hardness and stiffness of aluminium is insufficient. Instead, thin steel inserts called sipes are mounted in the aluminium mould.

"the preparation of the required tooling is a major time and cost factor. The tyre industry's interest in Additive Manufacturing has been focused on this problem from the very beginning"

The application of AM in the tyre industry

The conventional method for the manufacture and installation of sipes is extremely costly and time consuming. Sipes are made from steel sheets by stamping and cold bending. Thus, four to five sets of stamping and bending tools are required for a specific sipe geometry. Since each tyre mould contains various sipe geometries, the preparation of the required tooling is a major time and cost factor. The tyre industry's interest in Additive Manufacturing has been focused on this problem from the very beginning.

Fig. 3 shows an exhibit by Dahmen GmbH, a specialist in the production of tyre moulds by CNC milling based in Alsdorf, Germany at the Tire Expo 2017. It is a tyre mould segment illustrating the manufacturing steps that are required to install steel sipes in a conventional tyre mould. The raw profile is first milled into an aluminium block (1), then slots for the sipes are machined into the aluminium mould (2). The sipes are

Fig. 3 A conventional tyre mould segment from Dahmen GmbH. The lower images demonstrates the mounting of steel sipes (from right to left): (1) milled raw profile, (2) slots to accommodate the sipes, (3) sipes inserted manually, (4) sipes fixed by laser beam welding

then inserted by hand into the slots of the mould (3) and fixed at several points by laser beam welding (4). In this particular mould there are at least four different types of sipe; however, as the complexity of tyre moulds increases, so does the number of different sipes. The finishing operation includes manual grinding and the shot peening with glass beads of the entire mould.

Metal AM magazine interviewed several exhibitors at the event to find out what participants from the tyre industry thought about metal Additive Manufacturing. Their statements clearly show the progress achieved by metal AM along with the areas in which improvements are still necessary.

Sandor Barkoczi, Head of Design at Tauform Tyre Moulds Co., Budapest, Hungary, stated that some tyre mould manufacturers and tyre companies, following the example of Michelin, had made attempts to use metal Additive Manufacturing. The initial focus was on sipes in experimental and prototype moulds for applications where speed of manufacturing was more important than the dimensional accuracy and surface quality of the mould. Despite the advantages of Additive Manufacturing, namely design flexibility and manufacturing speed, Barkoczi realised that the dimensional accuracy and surface quality offered by AM was not yet sufficient and the cost was still very high. However, he acknowledged the progress that had been made in recent years by AM machine manufacturers and stated that he expected further progress in the years to come.

Patrick Dahmen, Managing Director of Dahmen GmbH, sees the opportunities for metal AM to replace the conventional sipes used in tyre moulds with more complex additively manufactured sipes, but he is more cautious with regard to the question of whether it is technically and economically feasible to replace the entire milled moulds with additively manufactured ones. After several initial investigations, Dahmen has come to the conclusion that the AM process, including mechanical and manual processing, is not yet faster than milling and incurs higher manufacturing costs. "Long-term studies on the stability and reliability of 3D printed moulds are missing," stated Dahmen. He expects that the temperature variations applied in tyre production might lead to unacceptable distortions of the mould. Furthermore, it was stated that the heat that is introduced by the laser beams in powder bed fusion inevitably leads to distortion due to non-uniform thermal expansion and contraction, which has to be compensated for by secondary operations.

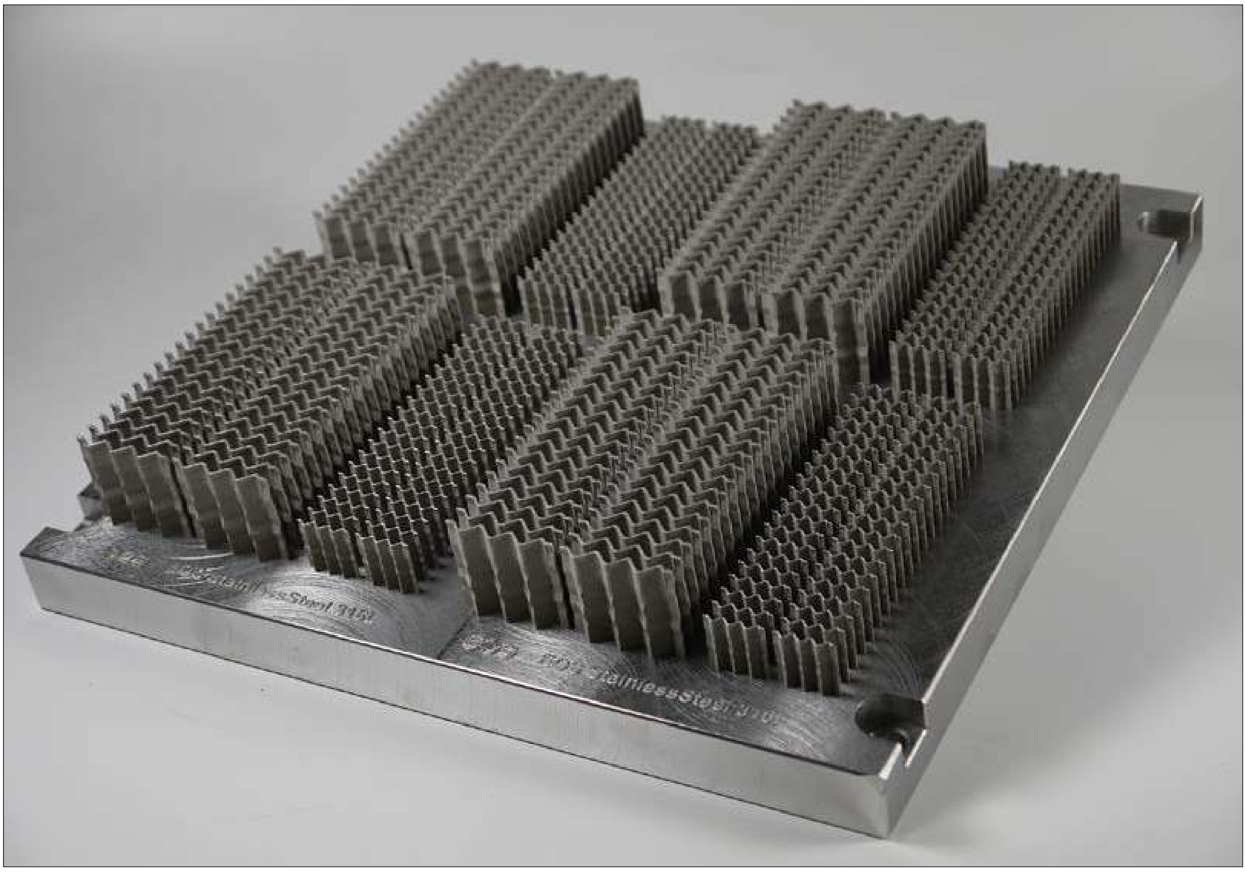


Fig. 4 A build plate with sipes (Courtesy EOS)

Since tyres require an exact runout, the shape requirements on the concentricity of a tyre mould are very high. Dahmen stated that out-of-round tolerances of directly milled tyre moulds, particularly moulds for high-performance tyres and prototype moulds, are in the range of 0.05 mm. Undoubtedly, it was stated, this tolerance requirement cannot currently be met by metal AM alone.

Jan Bambuch, President Sales at tyre mould manufacturer Pneuform a.s., Hulin, Czech Republic, acknowledged that metal Powder Bed Fusion is environmentally attractive because it produces practically no waste and, unlike casting technology, can use electric power supplies that are more readily available everywhere. Bambuch told *Metal AM* magazine that Pneuform had primarily used Additive Manufacturing for the production of sipes used in the rapid prototyping of moulds for snow tyres. He said that even today AM sipes of complex shape offer savings in cost and time in comparison to conventional production. He predicted that metal Additive Manufacturing will play an increasing role in tyre mould manufacturing in the future but cautioned that the surface quality of AM sipes is still far from that required by the tyre industry.

> *"Conventional processes are at their limits for realising more and more sophisticated mould designs, both with respect to costs and feasibility"*

EOS's view of the tyre industry

Augustin Niavas, Business Development Manager Tools at EOS GmbH, Krailling, Germany, has experienced an increasing interest in metal AM from the tyre mould industry over the last four years. Initial efforts were directed at sipes (Fig. 4) because this was where the greatest advantage was anticipated. "Conventional processes are at their limits for realising more and more sophisticated mould designs, both with respect to costs and feasibility," said Niavas. "Additive Manufacturing is the best solution for so-called 3D sipes, meaning sipes with an undercut."

For printing the entire mould, Niavas admitted, there is still much work to do for AM equipment manufacturers. Today, he sees a realistic chance of producing prototype moulds for snow tyres by AM. "The road to production is still long and it will take some time before AM is an established process for the tyre industry," he said. "We have to keep close contacts with the tyre industry so that we can improve our processes step-by-step towards the requirements of our customers."

For EOS, the reduction of manufacturing costs is at the top of the agenda for a further expansion of AM technology in the tyre mould market. Niavas does not expect a substantial price reduction for AM machines in the foreseeable future. Therefore, build speed is in his opinion the main parameter for reducing unit costs.

From a technical perspective, Niavas has identified a clear demand for reducing the cost of secondary operations on AM products. EOS, he explained, follows a strategy of cooperation with companies who bring expert knowledge into the partnership. One partner is Georg Fischer Automotive AG, who brings special expertise in the layout of fully automatic production cells. Niavas pointed out that optimising the part flow can offer a substantial cost reduction in secondary operations.

Of course, a considerable reduction of secondary operation costs can be achieved with closer dimensional tolerances and better surface quality in raw parts produced by AM. According to Niavas, much of the distortion that is associated with AM has already been compensated for through simulation software and he expects further substantial improvements in the dimensional accuracy of metal AM products in the near future.

The range of materials suitable for processing by metal Powder Bed Fusion has been extended in recent years. A number of steels and aluminium can now be produced. Since metal powder based processes cannot always reproduce the same alloys that mould manufacturers are accustomed to, it takes extra effort from AM equipment manufacturers to comply with customers' material

Fig. 5 Tyre mould with additively manufactured segments (Herbert)

specifications and reassure them that AM materials are as reliable as the materials they are familiar with.

According to Niavas, EOS has made significant progress over the last five years. The development of multi-laser printers represented a major step up in productivity, while the size of build chambers has been increased over the years and connectivity among groups of printers has been introduced, as well as process monitoring.

The perspective of SLM Solutions

Ralf Frohwerk, Global Head of Business Development at SLM Solutions, one of the leading developers and manufacturers of metal AM equipment based in Lübeck, Germany, said that 3D sipes, which can only be produced by metal AM technology, are particularly beneficial for the running performance of snow tyres. Tyre moulds consist of eight to sixteen segments whose size fits well into the build chambers of existing AM machines. In his opinion, close cooperation between the tyre manufacturer, the mould designer and the equipment manufacturer is important to identify the best concept for a tyre mould. Frohwerk agreed that the extremely high dimensional accuracy and surface quality required in the production of tyre moulds are the biggest challenge for Additive Manufacturing.

Frohwerk claimed that steel mould segments with sipes of as little as 0.3 mm thickness can today be printed as a whole using SLM Solutions' equipment. This avoids the costly procedure of stamping and bending the sipes, as well as inserting them into the body of the mould. Although the shape accuracy required by the tyre industry is still a big challenge, Frohwerk is optimistic as he looks back on the significant progress made in this respect during

Fig. 6 Close-up of the Herbert tyre mould

the last three years. He expects that metal AM technology will be further improved and the amount of secondary processing minimised in the near future.

According to Frohwerk, the present concept of an AM tyre mould is a twin shell design. The outer shell is a machined aluminium ring providing the required strength, stability and roundness to support the inner profile. Inside the supporting outer ring is the additively manufactured shell forming the tyre profile. This is as thin as possible for cost reduction. Herbert Maschinenbau GmbH, a leading German manufacturer of tyre moulds, exhibited a mould using this twin shell design at Hannover (Figs. 5, 6).

Conclusion

In conclusion, we found that in spite of some scepticism with regard to metal Additive Manufacturing in the tyre mould community, the technology has recently started to gain ground. The dimensional accuracy of additively manufactured products has continuously been improved and the tyre industry has recognised that the advantages of the technology can only be fully exploited if compromises are made with regard to the limitations of the AM process. Metal AM technology is already widely used as a rapid prototyping tool for developing new tyre mould designs and the unique freedom of design that it offers, allowing for the production of 3D sipes, is appreciated by the industry. For a deeper penetration of the tyre mould market it is essential that equipment manufacturers and users cooperate, learn from each other and work step-by-step to close the gap between the capabilities of Additive Manufacturing and the requirements of tyre mould manufacturers.

The author expresses his sincere thanks to all interview partners who have willingly and openly communicated their opinions on the issue of Additive Manufacturing in the tyre industry.

Author

Dr Georg Schlieper
Harscheidweg 89
D-45149 Essen
Germany
Tel. +49 201 712098
Email: info@gammatec.com

CALL FOR PRESENTATIONS

AMPM
Additive Manufacturing | With Powder Metallurgy

June 17–19, 2018 • San Antonio, Texas

Focusing on metal additive manufacturing, this conference will feature worldwide industry experts presenting the latest technology developments in this fast-growing field.

PERSPECTIVES FROM:
- End Users
- Toll Providers
- Metal Powder Producers
- Equipment Manufacturers
- R&D from Academia and Consortia

EXHIBITION:
- Trade Show Featuring Leading AMPM Suppliers

TOPICS WILL COVER:
- Materials
- Applications
- Technical Barriers
- Process Economics
- New Developments

Manuscripts are optional; however, all submitted manuscripts will be considered for the Best AMPM2018 Paper Award.

Held in conjunction with:

POWDERMET2018
SAN ANTONIO

Submit abstracts at AMPM2018.org before November 3, 2017

Metal Powder Industries Federation
105 College Road East • Princeton, New Jersey 08540-6692 U.S.A.
TEL: (609) 452-7700 • FAX: (609) 987-8523 • E-mail: dstab@mpif.org

Desktop Metal: A rising star of metal AM targets speed, cost and high-volume production

Over the past few months it has been hard to avoid hearing about Desktop Metal, Inc. at AM trade shows and in the growing sections of the industrial media. In the following article Terry Wohlers reports on a recent visit to the company's headquarters. Guided by Ric Fulop, Desktop Metal's founder and CEO, Wohlers' initial scepticism is put to rest as he discovers the company's Studio and Production systems. Together they offer a credible solution to both accessibility to AM technology and the challenges of speed, cost and high-volume production.

In April this year I visited Desktop Metal in Burlington, Massachusetts, a short distance northwest of Boston. Ric Fulop, founder and CEO, was my host. Prior to my arrival, I knew little about what the company was doing. I had bumped into a number of Desktop Metal employees over the past year and a half, but they were disciplined and shared little detail.

Based on what little I had heard and knew about Desktop Metal's technology, I was sceptical prior to my visit. What I saw was enlightening. After spending part of an evening and several hours the following day at the company's headquarters, I could tell it was developing something special that involved considerable invention and innovation. I saw new and creative ideas being applied to hardware, software, materials, sintering and support structure removal. I could tell that many people at the company had been working very hard and a lot had come together to make it work.

The people

Desktop Metal, like most other high-tech companies, is largely about technology, yet it is as much about people. Organisations need a leader and a figurehead, and Fulop is that person. When going to dinner, Fulop told me that he and Elon Musk, founder of Tesla and SpaceX, have shared some of the same investors, so he had got to know him reasonably well. This led, in part, to the 2017 Tesla Model S that we were riding in. I also learned that Fulop founded A123Systems, which had the largest

Fig. 1 The Desktop Metal Production System is described as being a hundred times faster than existing SLM technologies

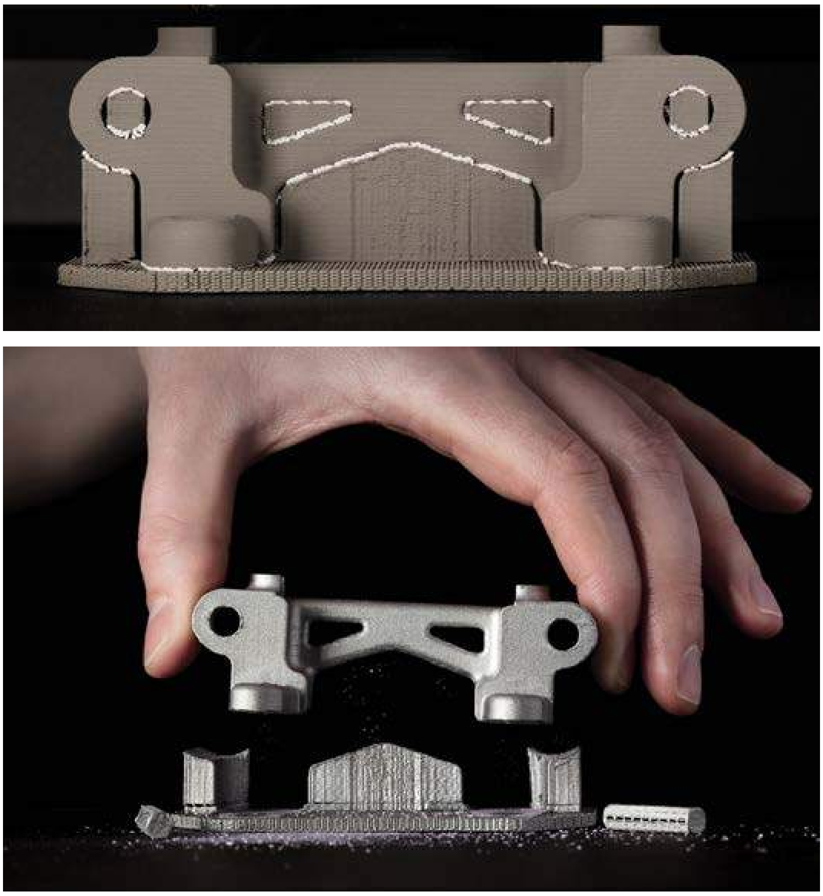


Fig. 2 Ceramic powder serves as the interface between the part surfaces and the support structures. Tapping the parts on a bench top and/or using a small ball-peen hammer is usually enough to remove the supports

Boston initial public offering in the past decade. He was an investor in Proto Labs and Markforged, as well as Onshape, a company started by SolidWorks founder John Hirschtick. Fulop is a graduate of MIT, speaks five languages and is a pilot.

The team of people that Fulop has assembled is impressive and represents some of the best minds in materials science, Powder Metallurgy, mechanical engineering, software development, inkjet technology and marketing. I don't recall a start-up in recent history that has brought together so many accomplished individuals. At the time of writing, the company employed a hundred engineers and fourteen PhDs, including four MIT professors. This talent has led Desktop Metal to 138 patent applications.

Desktop Metal co-founder Ely Sachs invented the MIT binder jetting process made popular by a number of licencees of the technology, among them Z Corp. (acquired by 3D Systems), ExOne (then Extrude Hone), Soligen, Specific Surface and Therics. The printing of pills and tablets by Therics was commercialised by Aprecia Pharmaceuticals in 2016. The FDA provided clearance to Aprecia's fast-dissolving tablet, making it the first prescription drug made by 3D printing.

On arriving at Desktop Metal's headquarters I was struck by the openness of the facility. Everyone, including Fulop, was working in the open on tabletops. I saw more than one stand-up meeting, which is often more efficient and productive than conventional meetings in conference rooms. Sofas, easy chairs, table foot-ball and ping pong tables contributed to the casual and informal nature of the work space. A catering company brings in food and servers daily for lunch, encouraging employees to stay on-site and spend more time with their colleagues. This approach encourages interaction and helps build relationships - it also saves time. Fulop and I had a stand-up and walk-around lunch, partly due to a plane I had to catch, yet I enjoyed it.

Support removal

The company has targeted a market which I believe is more than ready for a system that is relatively inexpensive and reduces time, effort and cost in removing support structures, sometimes referred to as anchors. The support removal process is one of the most significant developments at the company. With metal Powder Bed Fusion (PBF) systems, parts are welded to the build plate. Wire EDM, band saws and other tools and methods are used to remove the parts. The support structures must then be removed, which requires hours of additional time and usually a lot of manual labour. This process is also expensive.

The method developed by Desktop Metal is remarkably fast. Ceramic powder is used as an interface material between the part surface and support structures (Fig. 2). The powder is loose, but stays in place. Tapping a part on a bench top is often enough for the supports to fall away from the part. The surfaces where the supports attach to the part are not as good as up-facing surfaces, but are no worse than with PBF (Fig. 3). You almost need to see it or remove the supports yourself to believe it. I saw it twice and then I did it myself.

Materials

Desktop Metal is using metals that are identical to those used for Metal Injection Moulding and is working with AP&C, Carpenter, Sandvik and others for the supply of metal powders. The company produces special rods made up of metal and binder that fit into cartridges for the Studio machine.

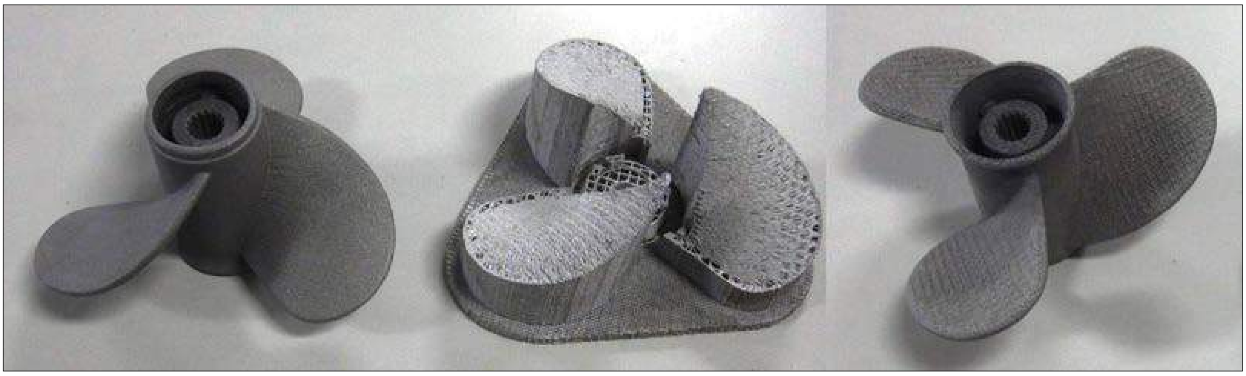


Fig. 3 The propeller on the left shows the up-facing surfaces, while the one on the right shows down-facing surfaces. The support structure is pictured in the centre

Initially, Desktop Metal expects to make thirty materials available, including some of the most popular alloys used in a number of industries. Among them are 6061 and 7075 aluminium, 316L stainless steel, Inconel 625, Ti64, H13 and A2 tool steel, and cobalt chrome. Others include Nvar 36, Kovar F-15, WC-3Co carbide, tungsten chromium and ceramic.

Production speed

Metal PBF systems do not produce parts quickly and system manufacturers are addressing the problem by applying additional energy, such as more powerful lasers and running two or four of them in parallel. This speeds up the process, but it makes the systems more complex and expensive, as well as more costly to operate.

Desktop Metal's Studio System, expected to ship in September 2017, is targeted at low-volume part production. It produces about 16 cm^3 (1 $inch^3$) per hour, which is not fast, but on par with other material extrusion systems. The company's much larger binder jetting Production System, planned for Q2 2018, is significantly faster. It can process up to 8,200 cm^3 (500 $inch^3$) per hour, which is nearly 100 times faster than laser-based PBF systems, according to Fulop. If this holds true, the Production System could turn out to be a workhorse for high volume production of metal parts.

Furnace cycle

Parts produced in both systems are processed in a sintering furnace. Desktop Metal offers a microwave-enhanced furnace that accelerates the heating. The microwave part of the system heats the metal from the inside, while the thermal subsystem heats from the outside. Together, they ramp up the temperature more quickly, provide uniform heating and enhance the microstructure of the metal, Fulop explained.

Depending on the parts and materials used, the furnace cycle can take 2-18 hours. Temperatures range from 600°C to 1,400°C (1,112°F to 2,552°F). The Studio System produces 'green' parts that require debinding in the furnace, while the Production System produces 'brown' parts, which do not require debinding, thus reducing thermal processing time.

The sintering cycle results in part shrinkage of about 15%. Fulop explained that, as with Metal Injection Moulding, shrinkage is predictable and is taken into account in advance. If this is indeed the case, and customers agree, it should not present a problem for production applications. Geoffrey Doyle, Head of AM Corporate Development at Jabil, explained to me that engineers at his company have positively reviewed the systems from Desktop Metal and they do not view this aspect of the process as a concern. Jabil is one of the world's largest contract manufacturers with more than a hundred manufacturing plants and 175,000 employees globally.

On several occasions Fulop told me that the process is dimensionally accurate to within 0.2%. This translates to +/- 0.02 mm per 10 mm (0.002 inch per inch). For a dimension that is 330 mm (13 inches) in length, the longest that can be built on the Studio System, one can expect an accuracy of +/- 0.66 mm (0.026 inch), according to Fulop.

Design, engineering and software development

The inside of the Studio machine is cleanly designed. A precision machined metal casting serves as the main chassis for the print heads. In addition to mechanical and electrical engineers, the company employs three full-time industrial designers. I spent some time with them and they know what they are doing. To them, functionality and access to the inside of the machine are as important as product styling and aesthetics.

Rick Chin, a long-time senior employee at SolidWorks and someone I've known for many years, heads up software development. He showed me the build preparation software, which is straightforward and provides visual feedback that you normally do not see in other systems. I was also shown some new software that could someday have a significant impact on the way products are designed, but this currently remains confidential.

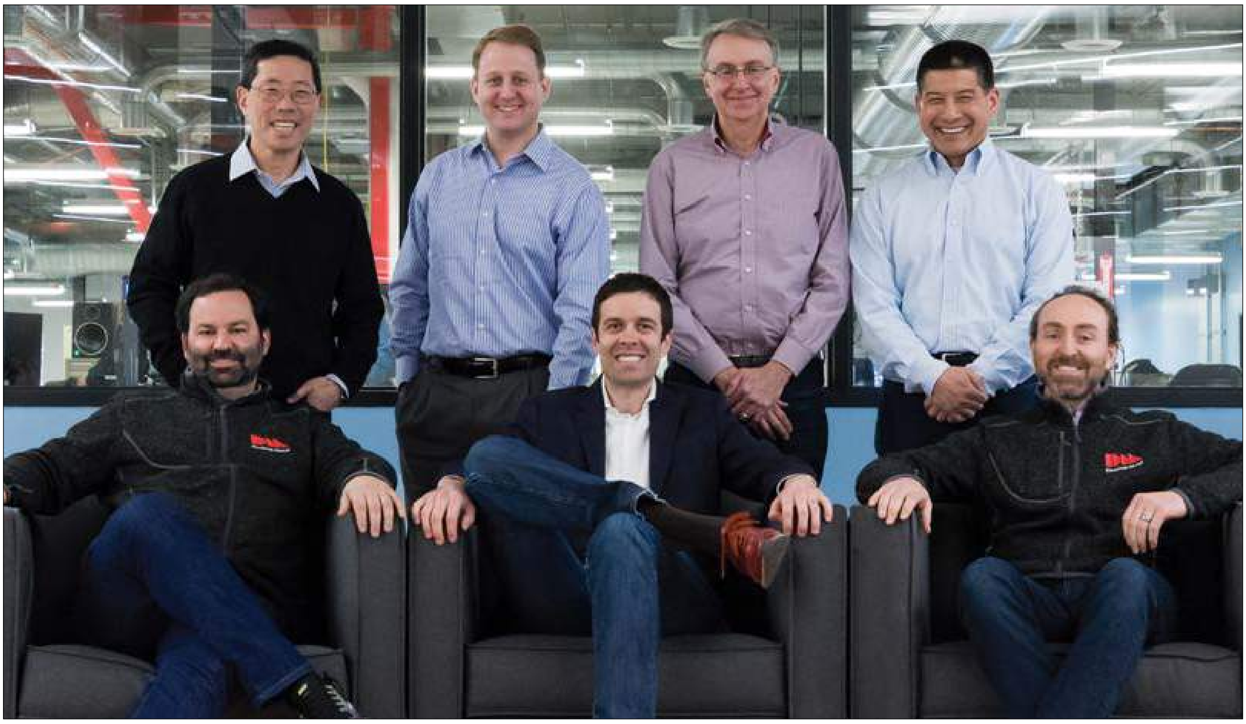


Fig. 4 The Desktop Metal co-founders. Sitting: Ric Fulop (CEO), A John Hart (MIT professor) and Jonah Myerberg (CTO). Standing: Yet-Ming Chiang (MIT professor), Chris Schuh (MIT professor), Ely Sachs (MIT professor and inventor of binder jetting) and Rick Chin (VP software)

Commercialisation and roll-out

Fulop has cherry-picked some of the best engineers for Desktop Metal, but it does not stop there; he has also secured strong and experienced people to help market, sell and distribute the company's products. It is too early to know how the market will warm up to the company and its products, but it looks like Desktop Metal is on the right track.

Fulop stated that both systems are much less expensive to buy, own and operate than the metal PBF systems on the market. The Studio System is $49,900, while the Production System is $360,000. Both systems require furnaces for thermal processing. In the case of the Studio system, a $9,900 debinding unit and a $59,900 sintering furnace are required. I liked the Studio System, but I am most interested in the possibilities associated with the Production System.

Fulop and his team are on to something that could become big. As the saying goes, the devil is in the details, but it looks like they are paying attention to them. In 2016, an estimated 957 AM systems were sold that produce metal parts, according to our research for Wohlers Report 2017. This figure could easily grow to five digits with the availability of AM systems that are much faster and lower in cost to purchase and operate. I am not suggesting that Desktop Metal will achieve this milestone, but Fulop and his team are working hard to be first to produce and ship machines in significantly higher volumes than previously seen.

"Fulop has cherry-picked some of the best engineers for Desktop Metal, but it does not stop there; he has also secured strong and experienced people to help market, sell and distribute the company's products"

Author

Terry Wohlers
Wohlers Associates, Inc.
Fort Collins
Colorado 80525
USA
www.wohlersassociates.com

Contact

Desktop Metal
63 Third Avenue
Burlington, MA. 01803
USA
Tel: +1 978 224 1244
Email: sales@desktopmetal.com
www.desktopmetal.com

Rapid + TCT 2017: Moving towards affordability and accessibility at North America's largest AM exhibition

North America's annual Rapid event has for 27 years been the region's leading exhibition on Rapid Prototyping and Additive Manufacturing technologies. This year's event, Rapid + TCT 2017, took place in Pittsburgh from May 8-11 and attracted a record 6,000 attendees from more than 45 countries. *Metal AM* magazine's Emily-Jo Hopson attended the event and reports on a theme that is becoming ever more important to the industry as it looks towards new markets - affordability and accessibility.

In May this year *Metal Additive Manufacturing* magazine headed to the Rapid + TCT 2017 conference and exhibition, held in Pittsburgh, Pennsylvania, USA. Taking place in the John Lawrence Convention Center, the event saw a 35% increase in attendees compared to the previous year, while the exhibitor count alone grew by 42% to 329 exhibiting companies - no doubt aided by a 124% increase in overall floorspace. The event also hosted a number of eminent speakers, among them America Makes' Rob Gorham, GE's Philippe Cochet and renowned industry analyst Terry Wohlers.

Exhibiting on booth 951, the *Metal AM* magazine team was consistently impressed by the quality of visitors received, with both senior industry leaders and an array of newcomers to the technology stopping to talk. A common theme amongst many of those who spoke with us when picking up a copy of the magazine shared the same need; a gateway to understanding and adopting metal Additive Manufacturing into their processes. Those who approached us did so from varied engineering and product development backgrounds, recognising the advantages potentially offered by metal Additive Manufacturing over other materials and processes.

Also encouraging was the number of student visitors on the *Metal AM* booth, from PhD candidates involved in high-level research projects with industry suppliers and producers to high school and undergraduate students seeking advice on career paths into AM.

In a panel discussion on new frontiers in metal 3D printing, Ric Fulop, Founder and CEO of Desktop Metal, stated, "In five to ten years, major universities will offer comprehensive courses on Design for Additive Manufacturing." Philippe Cochet, GE's Chief Productivity Officer, echoed this prediction with his statement in the keynote presentation, 'Brilliant Factory: A new era of manufacturing', that any fulfilment of AM's potential for

Fig. 1 Terry Wohlers was among a number of eminent conference speakers

Fig. 2 A view of the Rapid 2017 exhibition. The event saw a 35% increase in attendees compared to the previous year

'Industry 4.0' must be supported by a learning framework for students and staff.

Whether these predictions are to come to fruition or not, it is clear that the ease of access to metal Additive Manufacturing technology is a primary concern for established businesses and would-be engineers alike. This is an issue which of course extends beyond education alone; the overall accessibility and affordability of metal AM was a theme that was seen reinforced across the week's event, with an increasing number of companies competing to provide the most fluid, easy-to-use technologies at the most affordable price.

Desktop Metal: making waves at Rapid debut

According to Desktop Metal, its forthcoming Studio and Production systems mark a 'fundamental shift' in the way products will be developed and brought to market, reducing production costs and increasing speed, safety and flexibility. Designed as the first 'office-friendly' metal Additive Manufacturing system, the Studio System is claimed to be significantly cheaper than existing technologies and is sold as a complete platform, including a printer, debinder and microwave-enhanced sintering furnace.

The Production System, meanwhile, is designed for the volume Additive Manufacturing of metal parts and, according to Desktop Metal, will be the fastest AM system available for large volumes of high-resolution metal parts. Using the company's proprietary Single Pass Jetting technology, the Production System is claimed to operate at speeds up to one hundred times faster than most laser-based Additive Manufacturing systems, having the potential to dramatically reduce cost-per-part and allow metal AM to compete with high volume production processes such as casting.

Metal AM magazine spoke to Jonah Myerberg, Desktop Metal's Co-Founder and CTO, about the company's Rapid debut. "The Desktop Metal team is very excited to be at Rapid," he stated. "This was a very long time coming and I think we've made a big first impression on the industry - we really wanted to put our brand out there. What we've shown here really is reflective of our vision from when we started the company, and even before."

Accessibility and affordability: bringing AM to a wider market

By using what it calls Bound Metal Deposition technology, Desktop Metal states that its Studio System will eliminate the need to restrict metal Additive Manufacturing systems to large industrial facilities. In addition, by using cloud-based software to link stages of the workflow, the system could help eliminate the need for dedicated operators, making it possible to print designs directly from PC-based CAD software.

The system also features Desktop Metal's proprietary Separable Supports, a type of support structure which can be removed safely and easily by hand, along with swappable print cartridges for rapid material changes. It is reportedly compatible with a large variety of metal alloys, making it possible to prototype parts in the material that will be used in mass production, for example.

Fig. 3 Desktop Metal's Studio system

Each of these features is designed to contribute to bringing metal AM to the wider market. This is a mission fueled in no small part by Myerberg's frustrations as an end-user of the technology as far back as 2005 when he and Ric Fulop, Desktop Metal's CEO, worked together at battery company A123 Systems, Boston, Massachusetts, USA, producing batteries for use in Formula 1 cars, power tools and hybridised power plants, among other applications.

When the team first began investigating the metal AM market with a view to developing their own technology, Myerberg told *Metal AM* magazine, "the scaling of metal Additive Manufacturing was taking place on kind of a different plane; the machines were getting larger and they were getting more expensive, and to mass produce metal parts by AM you had to buy thousands of machines, instead of buying one machine that produced thousands of parts. We thought it was headed in the wrong direction. That wasn't the right type of technology to get involved in. So, we said we should start a company and do it right."

"We went into MIT's Material Science Labs and grabbed really smart, bright professors, including Yet-Ming Chiang, Chris Schuh, John Hart, Ely Sachs and a number of strong PhDs of engineering and materials, and started looking at all of the processes that could make additive with metal really accessible to engineers; steering it in the other direction – let's make the machines smaller, let's make them safer, less complicated, let's make something that would fit in your office."

The company's name evokes the same accessible, user-friendly experience. "Ric wanted it to be a desktop environment," explained Myerberg. "He wanted it to be familiar to the user, and safe, and for engineers to feel that they could have the system next to their desk and work on prints throughout the day, not have to suit up and go down to the lab each time a prototype was being built."

"In the past eighteen months we've been able to put together a brand new printer, a brand new furnace, a debinding centre and new software"

Desktop Metal was founded in October 2015 with a strong group of initial investors, including GE and Stratasys. "Thanks to the funding and because of the amount of pre-existing technology, we were able to move very quickly," stated Myerberg. "In the past eighteen months we've been able to put together a brand new printer, a new furnace, a debinding centre and new software."

Fig. 4 Components on display on the Desktop Metal booth that demonstrate the company's unique support technology

Providing a fully integrated workflow, Myerberg said, is key. "It's very important. We didn't want to just launch a printer, or give people the ability to print green bodies and not finish them. That was a frustration for us with the laser bed fusion processes. These metal AM processes alone don't give you the full range of products that you need to finish the part. As an end user of 3D printing, I hated that. Tell me the whole story - in addition to this DMLS machine, what else do I need? A furnace to heat treat? HIP to densify? It was the same with other processes - if you don't tie the furnace and the sintering process to the geometry of the part you print, you could be in trouble. We wanted to change the way people looked at and worked with metal Additive Manufacturing," Myerberg concluded. "We built the company around that."

Working with established AM leaders

During Rapid, Desktop Metal announced a new partnership with Sandvik Osprey and extended its existing partnership with Stratasys. Sandvik Osprey Ltd, based in Neath, UK, was named as a preferred supplier of metal powders and will supply the company with high performance alloys for each of its systems, "We are excited to be working with Desktop Metal and its world-class team of experts," stated Richard Park, Managing Director of Sandvik Osprey. "We look forward to supporting the growth in demand for consumers of the new Desktop Metal technology who we expect to come from all major industrial sectors. Our strength in materials science and atomising technology is a perfect complement to Desktop Metal's strengths in machine design and process knowledge."

"As one of the early investors in Desktop Metal, we realise customers are seeking additional ways to incorporate metal into their essential design and manufacturing processes"

Sandvik Osprey has a production capacity of over 4.5 million kg (10 million lbs) and a product database exceeding 3,000 alloys. The company offers a comprehensive range of products from stainless steels to nickel base super alloys, cobalt alloys, tool steels, low alloy steels, copper and aluminium alloys and is also able to customise materials according to customer preferences.

Desktop Metal also extended its existing partnership with Stratasys, designed to accelerate accessibility and adoption of metal Additive Manufacturing. Following the release of the Stratasys FDM-based F123 Series, Stratasys stated it believed that customers would benefit from the complementary nature of its technology and Desktop Metal's – including the ability to expedite product development cycles by producing both plastic and metal prototypes in an office-friendly environment.

"Stratasys has always been focused on providing customers with cutting-edge Additive Manufacturing innovations," stated Ilan Levin, CEO, Stratasys. "Today our offerings are used by customers worldwide – across automotive, aerospace, healthcare, education and consumer products – to achieve rapid prototyping, tooling and manufacturing processes. As one of the early investors in Desktop Metal, we realise customers are seeking additional ways to incorporate metal into their essential design and manufacturing processes. Today's announcement takes this commitment one step further – empowering global manufacturers and engineers to expedite product development cycles by producing both plastic and metal parts in office-friendly and production-based environments."

System shipments

The first round of Desktop Metal's Studio System machines will be shipped to their users in September 2017. "The next thing we want to do is support our customers," Myerberg told *Metal AM*. "It would be really tempting to dive right into the next technology that we have; our team back in Boston, including Ely Sachs, is working on the next big thing in metal AM and they're very excited about it – but the team that designed this printer is not going to be transitioned onto those projects until our customers are happy. Over the course of the next six months, we're going to build printers, refine software and launch the products, and support the customers throughout."

Xact Metal: Targeting R&D centres and SMEs with an afforable laser-based system

Established as a metal Additive Manufacturing systems provider in early 2017, Xact Metal debuted with the XM200 machine at Rapid, joining the list of companies competing to make their metal AM systems affordable for small-to-midsized companies, research labs and universities. "Priced at $120,000, the XM200 is our first industrial 3D printer, offering outstanding performance and affordability," stated Juan Mario Gomez, Xact Metal's CEO. "We believe it will make a big impact on customers' Additive Manufacturing needs."

Matt Woods, Xact Metal's Chief Technology Officer, laid the foundation for the venture when he recognised the need for higher performance, more sustainable and more affordable Additive Manufacturing. Xact Metal, states the company, will change the perception that AM is only for capital-rich companies. The company has received funding from Ben Franklin Technology Partners and operates out of Penn State University's Innovation Park, Pennsylvania, USA.

Fig. 5 Xact Metal debuted with the XM200 machine at Rapid + TCT 2017

Metal AM visited Xact Metal at Rapid to view the system. The XM200 features a build volume of approximately 2,048 cm^3 (12.7x12.7x12.7 cm / 5x5x5 in), a 250 W fibre laser and a patent-pending high-speed scanner which fuses at speeds of up to 1.5 m/s. In addition, Woods explained that its laser beam is fitted so as to be constantly orthogonal across the entire powder bed surface, enabling the system to produce consistent fusing characteristics throughout the complete build area.

"The XM200 is designed with the needs of customers in mind," stated Woods. "The large build volume gives great flexibility to print a variety of parts. The system is highly accessible and easy to use and its modern software architecture is streamlined, intuitive and supportive of visual workflows. And with a compact footprint, the XM200 allows customers to put one or several systems in their work areas." Orders for the XM200 printer are now being taken, with shipments starting September 2017.

Xact Metal also offers an on-demand direct metal printing service, Xact Fusion, allowing end-users to source custom-designed parts. Using Xact Fusion gives customer access to the XM200's build volume for printing in 316L stainless steel, while Inconel 718 superalloy, titanium 6Al 4V, aluminium Si10Mg and maraging steel are in development.

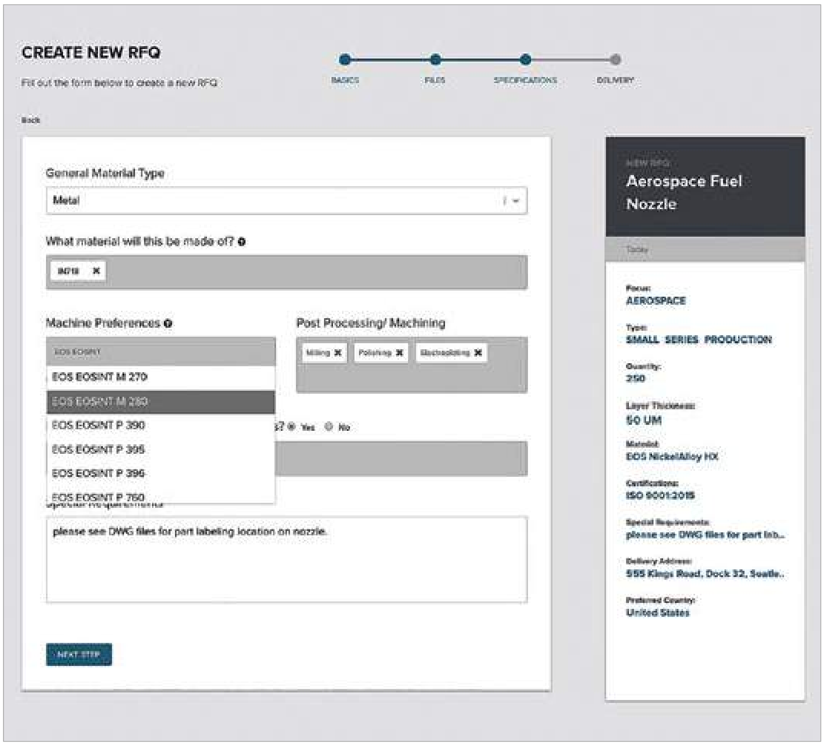


Fig. 6 A screenshot of the LINK3D system. LINK3D believes that the ever-expanding growth of metal AM creates a crucial need for companies to have access to the right partners when designing and manufacturing additively made parts

LINK3D: Using RFQ technology to reduce the barriers to AM

After two years of research and development, software company LINK3D, New York, USA, used Rapid 2017 for its official launch. The company's secure internet-based platform, also titled LINK3D, aims to help connect engineers to Additive Manufacturing service providers. Its proprietary technology provides engineers with a fully automated Request-for-Quote (RFQ) process to identify vetted Additive Manufacturing partners from around the world and, according to LINK3D, offers the largest network of AM machine and material representation available.

LINK3D believes that the ever-expanding growth of metal AM creates a crucial need for companies to have access to the right partners when designing and producing AM parts. Using intelligent data-driven algorithms, the new platform aims to facilitate these connections, with a particular focus on the larger industries such as aerospace, automotive, medical, consumer goods, defence and electronics. "Our mission is to make Additive Manufacturing accessible to anyone, anywhere, at any time," stated Shane Fox, LINK3D's CEO. "We serve a diverse group of industries, focused on metal and polymer production."

The LINK3D team is comprised of several additive experts who have built and maintained global partnerships with AM service providers in more than twenty countries, giving engineers access to over 241 unique metal and polymer materials and 163 unique machine models.

Metal AM visited LINK3D's booth at Rapid, where we spoke to Shane Fox and Vishal Singh, CTO, about LINK3D's aims. "I was studying the industry, looking for gaps," explained Fox. "I was looking at intellectual property security and barriers to entry. I was looking at why companies that on paper are perfect candidates for additive weren't adopting it and the price of the market throughout the whole eco-system, among other things. I found that there was no secure network that allowed engineers to connect in real-time to industrial grade service providers – not desktop or prototyping houses – at a secure level."

"We launched the API in February 2017 and have 140+ industrial grade service bureaus on our system in 29 countries. This gives us access to over 670 machines; of those machines, 60% are metal." In addition, he said, "Almost all of our service bureaus have some kind of industry-grade certification – these are companies that know how to bring parts to market."

Fox and Singh gave *Metal AM* a demonstration of the platform's capabilities, inputting the requirements for an imagined FDA certified project. On inputting the FDA requirement, the RFQ form smartly adjusted to reflect the needs of that project, removing redundant fields and adding those specific to FDA certified projects, allowing the user to select further certification requirements. All files uploaded by the user during this stage are securely encrypted using standard military grade encryption and stored on LINK3D's server, making the process suitable, in theory, for even classified projects. "We're really trying to separate ourselves from the Buy Your Part Now websites and focus on the industrial grade," added Fox.

In tandem with its mission of increased accessibility, LINK3D has a second function as a type of data bank, collecting and collating data to enable the team to learn more about the way clients and manufacturers communicate and the ways in which processes are handled, Fox explains. "We're collecting some really interesting information. In a matter of two weeks, some of our clients gave us permission to watch them communicate with their service providers. In doing so, we're finding out things we didn't know; it's an education on the potential of the tools and the fixes."

Fig. 7 The InstAMetal interface is expected to allow GKN to quote and accept orders 24 hours a day, seven days a week, while ensuring that all designs are optimised for Additive Manufacturing

Among the less than two dozen beta testers invited to test the platform was Dr Gavi Feuer, a Biomedical Engineer. "As an engineer in the Additive Manufacturing industry," he stated, "one of the biggest challenges is to find the right partners to produce your designs. LINK3D is a truly unique tool that reduces search time, increases selection parameters and adds confidence to the final decision-making process regarding pricing when choosing the appropriate manufacturing partner."

GKN InstAMetal: Intuitive quoting and design experience for metal AM

Also launched during Rapid was InstAMetal, GKN Sinter Metals' new e-commerce platform for Additive Manufacturing, currently in its beta phase. Developed in conjunction with 3YOURMIND, Berlin, Germany, the InstAMetal interface is expected to allow GKN to quote and accept orders twenty-four hours a day, seven days a week, while ensuring that all designs are optimised for Additive Manufacturing.

Described as an "intuitive quoting and design experience for metal AM", InstAMetal is expected to introduce a number of tools to aid customers with feasibility analyses of parts to be produced. Its digital management tools also guarantee higher machine up-time and ensure accurate production and streamlined workflows. "For businesses to stay competitive as they move towards small-batch and just-in-time production, they will need to ensure that high-quality components are prepared correctly – every time," stated Aleksander Ciszek, CEO of 3YOURMIND. "By adding our eCommerce platform to GKN's industrial production, we are making huge strides towards companies utilising the potential of Industry 4.0."

According to the company's website, GKN's primary goal is to make their technology easily accessible, with a single online entry point to a distributed network of digitised AM production centres. Using this system, engineers and designers can access a real time comparison of delivery time and costs from GKN's services. The automated quoting process also helps engineers make intelligent decisions when selecting materials and production facilities to keep projects on-time and on-budget.

The platform will also enable GKN to load-balance their production resources. Using InstAMetal's queue optimisation, the company can ensure that machines are being used to capacity and transfer priority projects between facilities.

CGTech Vericut: Hybrid simulation technology

CGTech, Irvine, California, USA, introduced its new Additive Manufacturing simulation capabilities at Rapid. The addition of an additive module to the company's propriety Vericut software enables users to simulate

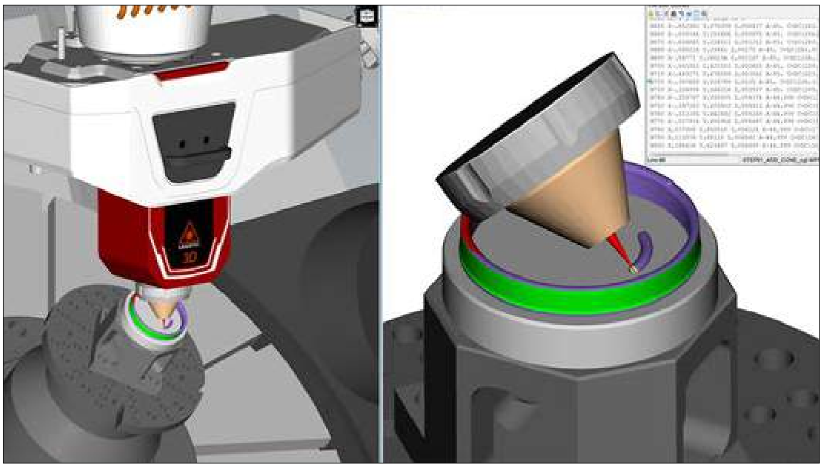


Fig. 8 Vericut Additive module verifies laser functions, detects collisions, and checks material deposition

the machining capabilities, both additive and traditional, of hybrid CNC machines.

Launched in 1988, Vericut is a software platform designed to simulate CNC machining in order to detect errors, potential collisions or areas of inefficiency. It is used by companies, universities and government agencies in more than 55 countries. By simulating CNC processes, it enables users to eliminate the process of manually proving-out NC programs and reduces scrap loss and rework. The software also optimises NC programmes to save time and produce a higher quality surface finish and is reportedly capable of simulating all types of CNC machining. It can also be integrated with all leading CAM systems.

Now, CGTech also works with its customers and technology partners to solve AM challenges including accurate laser cladding and material deposition, detecting collisions between the machine and additive part and locating errors, voids and misplaced material.

"Additive Manufacturing applications create new possibilities for manufacturers," stated Gene Granata, Vericut Product Manager. "Adding this technology to Vericut provides unique solutions that address the needs of our customers in the rapidly expanding AM market." Scheduled for release in early Autumn 2017, Vericut 8.1 will add the ability to identify potential problems that can occur when integrating additive methods. The simulation uses the same post-processed NC code used to drive the CNC machine, allowing users to virtually experiment with combining additive and subtractive metal processes to determine optimal safe hybrid machining production methods.

"This gives our customers a competitive edge to redefine current production technology," continued Granata. "Vericut's realistic simulation of the entire hybrid process enables customers to verify that the part will be built correctly, without causing damage to the part, machine, or expensive laser equipment."

Tooling U-SME: A focus on training and development

In the field of additive education, Tooling U-SME, SME's workforce development segment, launched a portfolio of Additive Manufacturing learning and development solutions, for which the first certification exams took place at Rapid. During the event, SME also announced that it had received an additional grant of $300,000 from Arconic for the expansion of its PRIME (Partnership Response in Manufacturing Education) initiative, founded in 2011 to build a collaborative network of students, educators and industry professionals to prepare students for careers in manufacturing.

"Additive Manufacturing is a rapidly developing market and the evolution of the technology is quickly outpacing product design and development," stated the team behind Tooling U-SME. "As a result, there is a recognised need for continuous training and development to ensure that the manufacturing workforce keeps up with the latest advancements."

According to 'Wohlers Report 2017', the Additive Manufacturing industry achieved revenues of $6.063 billion in 2016 – and with growth of 4.3 times that forecast over the next five years, the market is estimated to reach about $26.2 billion by 2022. "Restructuring the workforce to accommodate increased Additive Manufacturing operations is a major concern for companies that want to ramp up work in this market," stated Jeannine Kunz, Vice President of Tooling U-SME. "More and more, manufacturers are increasing the number of additive-made parts in products, so having a workforce with the right skills to use this new technology is an increasingly important priority for companies and schools."

As a founder of Rapid + TCT, SME has been at the forefront of Additive Manufacturing for almost three decades. Its partnership with America Makes led to the development of the Additive Manufacturing Leadership Initiative, a collaborative working group representing SME, America Makes, the National Coalition of Advanced Technology Centers, the Milwaukee School of Engineering and Technician Education in Additive Manufacturing and Materials. The new Additive Manufacturing Fundamentals Certification is reportedly the first and only nationally normalised, stackable or sequential credential process in Additive Manufacturing and serves as a prerequisite for the next phase, the Additive Manufacturing Technician Certification, which SME

Fig. 9 Exhibitor count grew by 42% to a total of 329 exhibiting companies

stated will be rolled out later in 2017. These stackable certifications may lead to Additive Manufacturing apprenticeships such as those supported by Tooling U-SME through the U.S. Department of Labor’s Registered Apprenticeship Program.

“Tooling U-SME works with companies and educational institutions to build holistic workforce learning and development solutions that align to our certification and apprenticeship programs,” added Kunz. “Through our turnkey training, online classes, instructor-led training and supporting video materials, we’re able to provide the incumbent and future Additive Manufacturing workforce with industry-leading training that will ensure their success in the market.”

Preparation for the Additive Certifications is supported by eight online classes offered by Tooling U-SME. These classes were developed in conjunction with Cuyahoga Community College in Cleveland, USA.

Conclusion

Whilst this report does not hope to cover all of the innovations presented at Rapid, it is clear from this small sampling that there is strong recognition among metal AM solutions providers of the need to make the technology more approachable for prospective users.

By making metal AM technology more accessible and affordable, the workflow more fluid and the supply chain more connected, the industry stands to achieve significant gains in its user base. This is clearly evidenced by the rapid growth of companies which approach the market with accessibility at the core of their aims.

Author

Emily-Jo Hopson
Assistant Editor
Metal Additive Manufacturing
Tel: +44 1743 211994
emily-jo@inovar-communications.com

Rapid + TCT 2018

Rapid + TCT 2018 takes place in the Fort Worth Convention Center Fort Worth, Texas, USA, from April 23-26, 2018.

www.rapid3devent.com

The inspection and quality control of metal AM parts with X-ray Computed Tomography (micro CT)

X-ray Computed Tomography (micro CT) is just one option for the inspection of metal AM parts. Other options include using eddy current, ultrasonic technology, white-light interferometry and non-interferometric optics. However, given recent developments, it is micro CT that has the most potential in view of its unique capability for the inspection of complex internal structures and geometries without destroying the part. The capabilities of this inspection method are presented by Andrew Ramsey and Herminso Villarraga-Gomez of Nikon Metrology Inc.

X-ray Computed Tomography (micro CT) is the only non-destructive testing method that is able to effectively inspect - with measurement strategies from coordinate dimensional metrology - volume defects and complex geometry inside a part. Eddy current testing can only inspect local defects near the surface of a part, while ultrasonics can inspect only simple geometries near the surface with some reach inside the volume. Optical and interferometric methods can only inspect features at the surface of the part. While the latter (interferometric) techniques are very good at achieving higher resolutions (up to a few nm), the micro CT technique can cover, in a single scan, external and internal surfaces, with micrometre-level resolution and, in some cases, at higher resolutions below the micrometer level (on the order of a few hundred nanometers).

The growing interest in micro CT comes at a time when interest in Additive Manufacturing is redefining the manufacturing landscape. Consulting firm IDC states that global spending on AM equipment, both desktop and industrial, reached about $11 billion in 2015 and is forecast to reach $27 billion by 2019. Another company, Marketsand-Markets, is predicting that Additive Manufacturing will experience 30% compound annual growth and reach $30 billion by 2022. In its April 2016 study, "3D Printing Comes of Age in US Industrial Manufacturing," Price Waterhouse Coopers (PWC) stated that, compared to two years ago, more manufacturers (52% this year compared to 38% in 2014) expect Additive Manufacturing to be used in high-volume production in the next three to five years.

Fig. 1 A Nikon Metrology XT H225 ST X-ray CT system

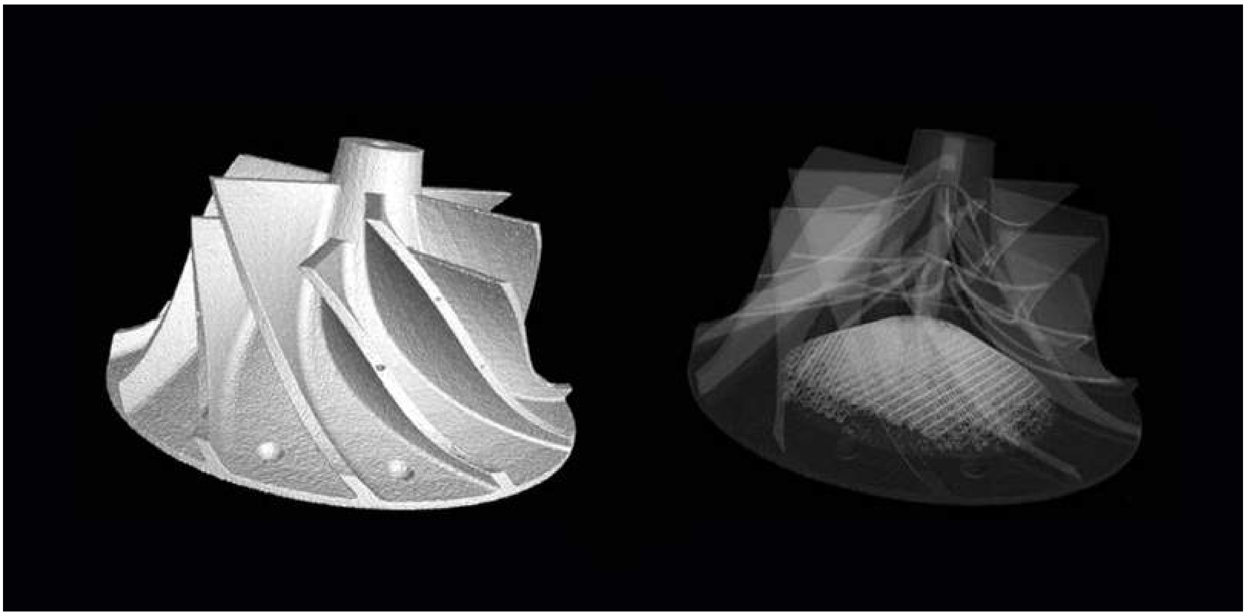


Fig. 2 Scans can reveal external and internal features for checking

Metal AM parts are increasingly being considered for the reduction of component weight without compromising strength, for example in aerospace applications where decreased weight leads to increased efficiency. For such safety-critical aerospace components, as well as applications in automotive, energy and medical devices, it is essential to know whether voids or inclusions are present, how large they are (both individually and in total) and where they occur. Additionally, it is critical to know whether the dimensions of the part conform to those of the design.

In such cases, X-ray Computed Tomography is a powerful tool. By supplying a full 3D density map of a sample, micro CT gives all this information in an easy-to-read visual format.

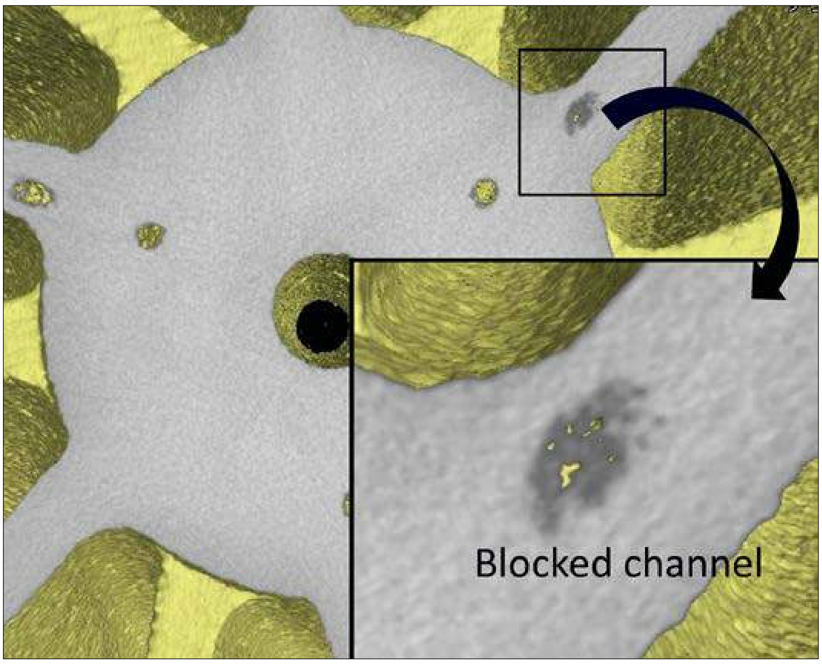


Fig. 3 Blocked channels are revealed without destroying the part [1]

Welds need to be inspected, so why not AM parts too?

Using conventional manufacturing processes, one would always inspect a weld for voids and inclusions. In metal Additive Manufacturing, the whole sample is essentially one large weld, so not to inspect it for voids, inclusions and dimensional accuracy would be a huge leap of faith in the process. Because of the complex nature of metal Additive Manufacturing processes such as Powder Bed Fusion, where for example there is the risk of risk of loose, partially melted powder in the build chamber, the position and nature of defects is often totally random.

With traditional manufacturing processes, a few radiographs at specific orientations can often give peace of mind. However, with layer-based Additive Manufacturing processes the whole part needs to be inspected. When checking the structural integrity of these parts, it is primarily the following issues that are of concern:

- Powder residues blocking channels
- Defects (voids and inclusions) – porosity, contamination, cracking

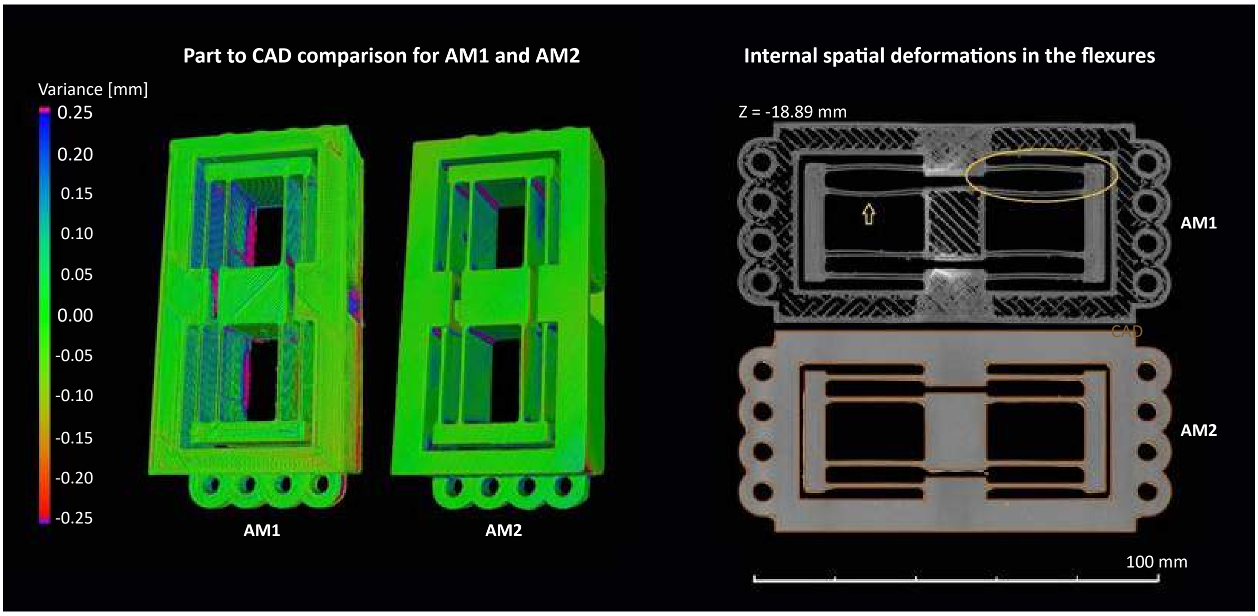


Fig. 4 Left: part-to-CAD comparison for FDM and STL versions of the same part, right: Flexure deformations revealed by CT scans

- Departure from the CAD model – dimensional analysis, wall thickness measurements, warping.

As an example, a mould made by Selective Laser Melting was designed to make a small knocker for a watch mechanism. Micro CT could determine the cooling and flow channels built in by the metal AM process to an accuracy of 5-10 µm, depending on acquisition parameters. From flow and cooling simulations, this is known to be of sufficient accuracy for the purpose.

In fact, micro-CT can find defects within samples down to a resolution given by the number of pixels across the detector. Given a sample 100 mm across and a detector 2000 px across, the limiting resolution would be 50 µm. Resolution is also limited by the focal spot size of the X-ray source, which may range from 80 µm for high energies down to less than 1 µm for low energies. Defects below the nominal resolution may also be spotted if the contrast with the surrounding material is great enough. For example, given a 3 µm X-ray focal spot, we can still see a 0.5 µm gold foil edge-on.

The size of sample which can be scanned with CT depends on the material it is made from and the energy of the X-ray source, measured in kilovolts (kV). Larger, lower density samples can be scanned, as can smaller, higher density samples. Typical largest samples are:

- 225 kV – aluminium piston heads; diesel injectors
- 450 kV – aluminium cylinder heads; aircraft turbine blades

Maximum part size also tends to be limited by the size of the detector, but also by the penetrating power of the X-rays. This decreases as material density and atomic number increases. Much greater thicknesses of polymeric materials can be penetrated than steel, and much more steel than tungsten.

CT scanning case study

An investigation into the micro CT scanning methods for a flexure mechanism fabricated by Additive Manufacturing offers insight into the capabilities of the process [2]. Whilst this research was in relation to polymeric products, the principles and benefits apply equally to metal AM applications. A first flexure sample (AM1) was manufactured by Fused Deposition Modelling (FDM). A second sample (AM2) was manufactured by Stereolithography (STL). For reference, the FDM and STL processes have, in general, printing resolution of approximately 100 µm and 0.5 µm, respectively.

Micro CT scans show variance analysis for both AM1 and AM2 flexures against the original CAD model (Fig. 4, left). From the measurements, it can be seen that deviations from the nominal geometry (CAD model) rise up to ±0.25 mm and larger when using the AM1 process. In contrast, the AM2 process generated part-to-CAD deviations mostly between ±0.1 mm, with a few exceptions, particularly around surface edges or corners. In addition to external checks, a cross section of AM1 shows residual internal and spatial deformations (Fig. 4, right). On the other hand, the manufactured part generated by the AM2 process does not reveal the presence of major deformations in the thin-walled flexure leaf structures.

Rules of micro CT and when to break them

High-accuracy micro CT technology has continued to evolve over the past ten years. Applications are diverse and growing across the automotive, aerospace, energy, medical and

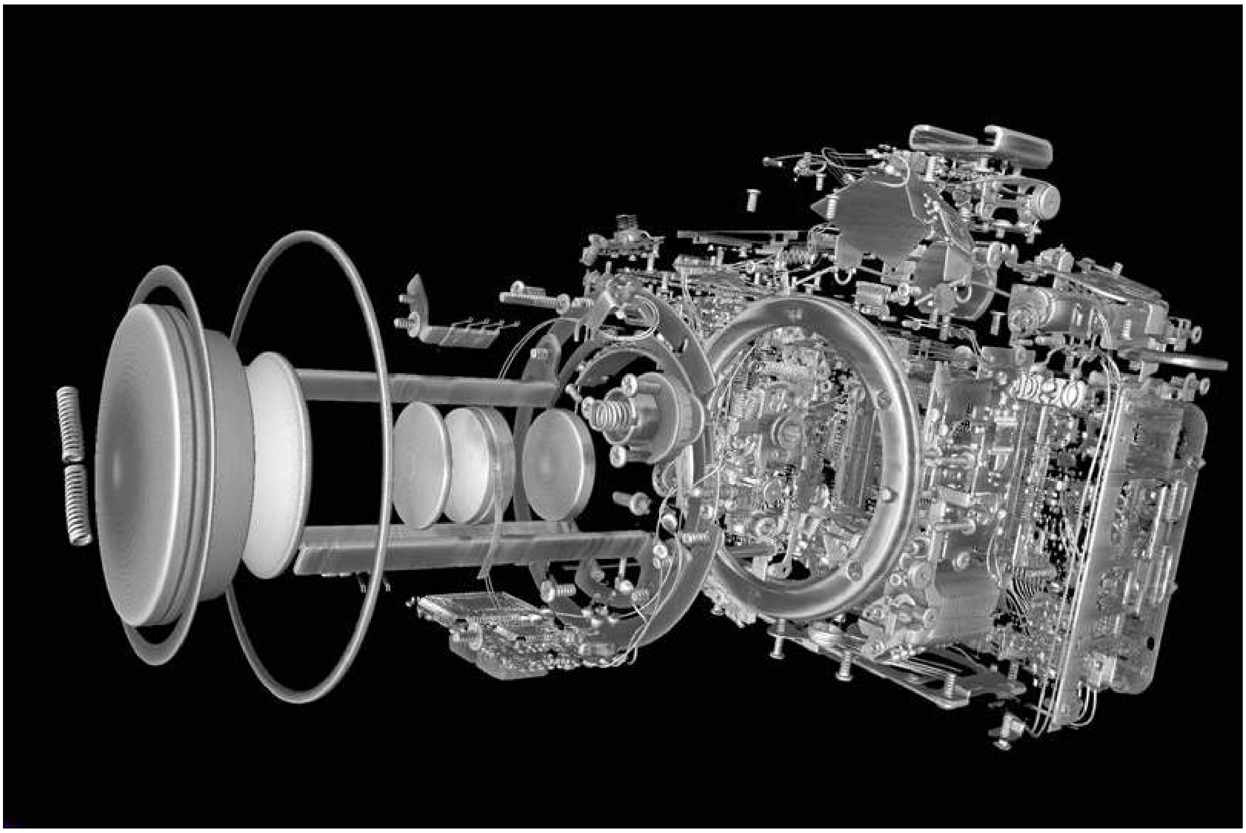


Fig. 5 CT scan of a Nikon SLR camera demonstrating what can be achieved with the technology

consumer sectors, dealing with metals and exotic alloys as well as plastics and other workpiece materials. Accompanying software tools enable the analysis of part volume against the CAD model, either via direct volume-to-CAD comparisons, or through geometric dimensioning and tolerance measurements. With costs now low enough to make it competitive with other techniques, micro CT can now be considered for application in many broader metrology applications.

A better understanding of the rules of micro CT not only opens the door to production cost savings and productivity improvement, but knowing when to break them can provide even further process flexibility. The rules for good micro CT are as follows:

1. Penetrate the sample from all angles
2. Minimise noise in each projection image
3. Use filters to reduce beam hardening
4. Always use 360° rotation
5. Use the detector's full dynamic range
6. Keep the object in the field of view

X-ray basics

X-rays are at the short end of the electromagnetic spectrum with an average wavelength between 10^{-8} and 10^{-12} metres, around the size of water molecules, compared to radio waves whose wavelengths could span a soccer field. There are no radioactive sources in micro CT; rather electrons are produced from a hot filament similar to a light bulb and accelerated at high voltage, reaching speeds of roughly 80% of the speed of light. They are fired at a metal target through a magnetic lens that focuses the beam energy into a spot between 1-5 μm in diameter. The sudden deceleration of the charged electrons when they hit the metal target produces more than 99% heat and less than 1% X-rays.

When the electrons hit the target, X-rays are created by two different atomic processes:

1. With enough energy, the electron can knock an orbital electron out of the inner electron shell of a metal atom. As a result, electrons from higher energy levels fill up the vacancy and X-ray photons are emitted. This process produces an emission spectrum of X-rays at a few discrete frequencies, sometimes referred to as characteristic emission lines

2. Bremstrahlung (decelerating or "braking" radiation in German): This is radiation given off by the electrons as they are scattered by the strong electric field near the high-Z (proton number) nuclei. These X-rays have a continuous spectrum. The intensity of the X-rays increases with decreasing frequency

X-rays travel in straight lines through the object being inspected

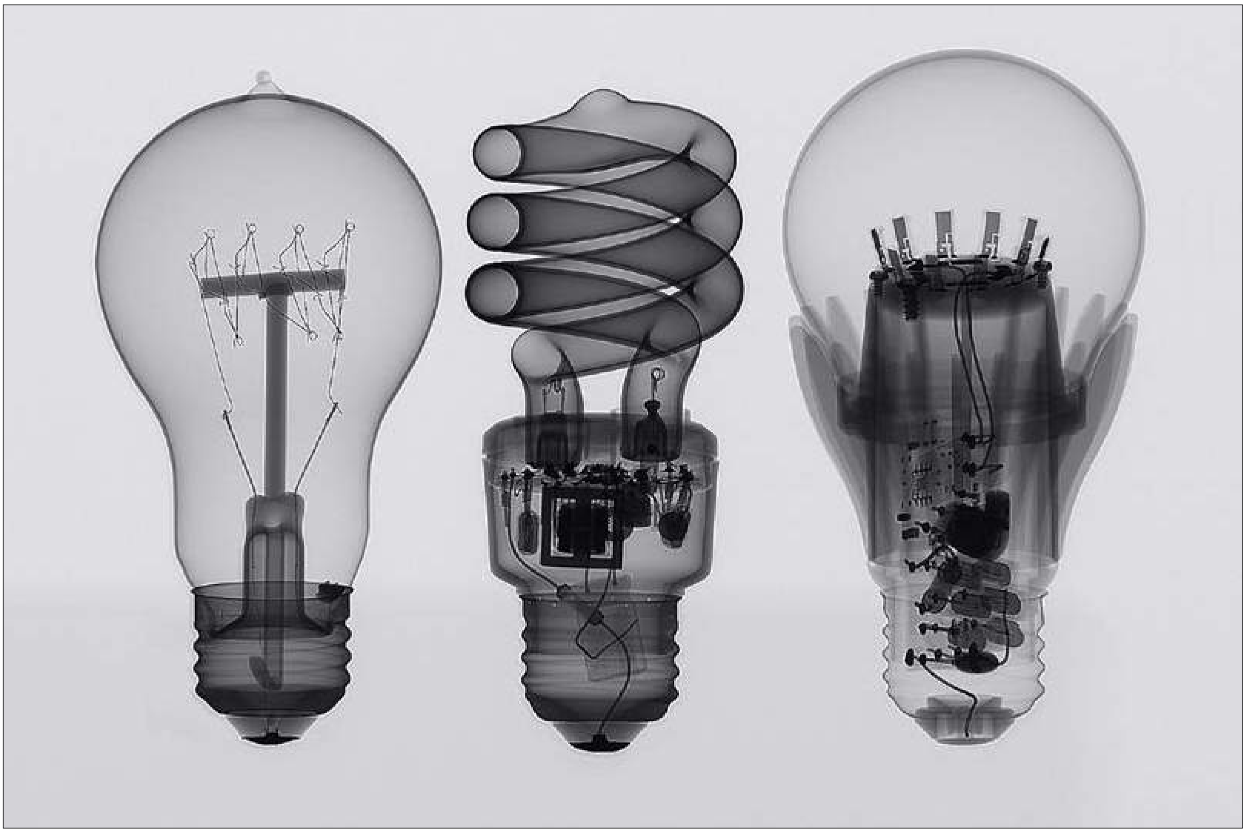


Fig. 6 CT image by Herminso Villarraga-Gómez demonstrating the capabilities of micro CT technology. From left to right: an Edison-style incandescent bulb, a fluorescent light bulb and an LED bulb

and onto a detector. The object will absorb some of the X-rays (denser objects absorbing more), leaving only a portion to reach the detector. At low X-ray energies (<60 kV), differences of absorption along the X-ray path to the detector are detected and shown as a shadow image. At higher X-ray energies (60-225 kV), absorption and scatter occur. This scatter reduces contrast in the image. With X-ray energies above 225 kV, scatter becomes an increasing problem for an area detector. Above 225 kV, scatter can be rejected from the detected signal by a linear detector, although throughput decreases (fewer images per hour). At greater than 300–400 kV, scatter is the dominant contrast mechanism, i.e., more X-rays leave the beam from scatter than from absorption.

Amorphous silicon flat-panel detectors have a fluorescent screen, which converts the X-ray energy into light to form an image on an array of light-sensitive diodes. Electronics allow this image to be read by a computer. These panels can have pixel sizes over a wide range and sensitivities up to 16 bits (64 k grey levels).

The sensitivity of the detector relates in part to the size of the X-ray source. A lot of typical high-power X-ray sources are minifocus, in the range of 1 mm across. This limits the resolution of images to that of the detector: a very fine detector is needed to get high resolution and no magnification is possible. Microfocus means the size of the X-ray source is only a few microns across. With a microfocus source, a standard medical detector can be used and geometric magnification can be used to gain a higher-resolution image (Fig. 7)

Micro CT overview

Combine the penetrating power of X-rays and the ever-increasing data-processing power of the computer and Computed Tomography is the result. The fundamental setup includes an X-ray source, the object being measured and a detector. A rotating platform for the object being imaged aids comply with Rules 1 (penetrate the sample from all angles), 4 (always use 360° rotation), and 6 (keep the object in the field of view).

"Combine the penetrating power of X-rays and the ever-increasing data-processing power of the computer and Computed Tomography is the result"

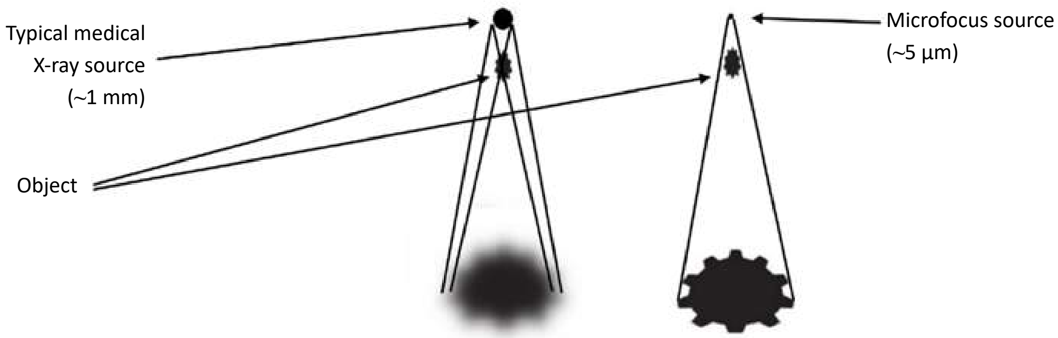


Fig. 7 A minifocus source (around 1 mm) allows no magnification, whereas a microfocus source (1-5 µm) can be magnified to produce higher-resolution images

Thousands of digital images can be produced from a single sample and each two-dimensional pixel in each image contributes to a three-dimensional 'voxel' as computer algorithms reconstruct 3D volumes. For example, with 3000 images, each voxel in the resulting billion or so in the volume is processed 3000 times. The result is a 3D volumetric map of the object, where each voxel is a 3D cube with a discrete location (x,y,z) and a density. Not only is the external surface information known, such as with a 3D point cloud from laser scanning, but internal surfaces and additional information about what is in between the surfaces from the fourth dimension (density) is provided. Furthermore, 'slices' produced by the process and accompanying software can yield much information without destroying the part.

Image intensity, then, becomes the basis for measuring the sample. In CT, what is being measured is the linear attenuation of the X-rays, or how much one unit of length of material reduces X-ray intensity.

Unfortunately, imperfections or 'artefacts' can occur in CT data and can affect measurements considerably. Recall rule 2: "Minimise noise in each projection image." Noise can appear as speckles in slice images, but can be minimised by maximising the X-ray dose.

There is also non-linear detector noise in the projection images that stays in the same position for all projection images. As images form, this noise is reconstructed as circular rings, i.e., 'ring artefacts'. Noise in the reference images gives the worst ring artefacts because it is re-used to correct each projection image and therefore amplified. Noise in the black reference image is more significant than noise in the white reference image because the signal is lower in the black image, so the signal-to-noise is also less.

Ring artefacts are stronger nearer the axis of rotation because fewer reference image pixels are used. They can be minimised by averaging many frames when collecting black and white reference images.

"Thousands of digital images can be produced from a single sample and each two-dimensional pixel in each image contributes to a three-dimensional 'voxel' as computer algorithms reconstruct 3D volumes"

Beam-hardening is the self-filtering of the X-rays by the sample, so the X-rays have a higher energy inside the sample and are therefore more penetrating. Because of this, the measured X-ray linear attenuation is lower inside the sample than at the edges, thus giving rise to beam-hardening, or 'cupping' artefacts.

Beam-hardening can be reduced by pre-filtering the X-ray beam (placing a filter over the output window of the X-ray source, as per rule 3). It can also be corrected, to some extent, by using the beam-hardening correction filters in the CT software. This works best with single-material samples.

It is important to use the full range of the detector, as per Rule 5. Higher dynamic-range detectors (more bits) help detect small differences in intensity due to low-density materials, such as plastics, in the presence of high-density materials, such as metal.

Streak artefacts are caused by beam hardening or lack of penetration of the X-ray beam through the sample. Lack of penetration can be solved by increasing the X-ray energy (kV) – unless, of course, you are at the maximum for the system.

Streak artefacts can be reduced by filtering the beam, applying a beam-hardening correction, or by using a detector with a high dynamic range. Scattered radiation can be reduced by collimating the X-ray beam and the detector to detect only those X-rays that travel in a straight line from the source to the detector.

Following the rules will give the best-possible CT results for full metrology purposes and is general good practice. However, if you need qualitative information (is a crack present or not, what is the sample's porosity, how many densities are present, is an electrical connection made or broken), or the information needed will not be affected by the artefacts, then rules can be broken.

Rule 1: Penetrate the sample at all angles; Rule 6: Keep the object in the field of view

If the material not in view is relatively homogenous and uniform in shape, then it will only add a small ring at the edge. Internal features will be easily visible and usable. This allows us to zoom in and see more detail. If the feature being analysed is near the centre of the scan, or if the size of the feature is much larger than a single pixel, then the number of projections can be reduced to speed up the scan.

Rule 2: Minimise the noise in each projection image

If time is limited, reducing the noise in the black and white reference images will reduce the overall noise significantly without greatly increasing the length of the whole scan.

Rule 5: Use the whole dynamic range of the detector

When inspecting very low density specimens, very low energy X-rays are used to give good contrast in the images. To fill the dynamic range requires long exposures. Halving the exposure only loses one bit of information but saves a lot of time.

Conclusion

The rules of CT come out of the theory of CT reconstruction. Following the rules means you will most likely generate the best-quality CT data. However, sometimes breaking the rules can save a lot of time without compromising significantly on image quality.

Micro CT is now much faster and more suitable for production-line use. Moreover, CT scanning of similar parts can be automated for loading and unloading. Scan times down to a few tens of seconds per part are possible. Users gain:

- Better insight into the inside of metal AM parts
- Faster optimisation of the main prototyping and production processes
- Quality control – much higher confidence in incoming and outgoing parts
- Reduced costs by avoiding destructive testing

As AM continues to rewrite the manufacturing rulebook, X-ray Computed Tomography can be a powerful partner for non-destructively assuring geometrical tolerances and the assessment of internal defects.

Authors

Andrew Ramsey
Herminso Villarraga-Gomez
Nikon Metrology Inc.
12701 Grand River Ave,
Brighton, MI 48116, USA
Andrew.Ramsey@nikon.com
Herminso.Gomez@nikon.com
www.nikonmetrology.com

References

[1] Villarraga-Gómez et al (including Ramsey A.), Assessing the Structural Integrity of Additive Manufactured Metal Parts with X-ray CT, Proc. ASPE/euspen 2016 Summer Topical Meeting, Raleigh, NC, Volume: 64, June 2016. www.researchgate.net/publication/304539205_Assessing_the_Structural_Integrity_of_Additive_Manufactured_Metal_Parts_with_X-ray_CT

[2] Herminso Villarraga et al, Assessing Additive Manufacturing Processes with X-ray CT Metrology, as presented at the 2015 ASPE Spring Topical Meeting, Raleigh, NC USA. www.researchgate.net/publication/283119260_Assessing_Additive_Manufacturing_Processes_with_X-ray_CT_Metrology

Markforged: Taking a different approach to metal Additive Manufacturing

In January this year Markforged Inc., based in Cambridge, Massachusetts, USA, announced its Atomic Diffusion Additive Manufacturing (ADAM) process along with the Metal X production system. The company is more widely known for its successful development of composite printing technology, introduced in 2014. In the following report Ian Campbell and Terry Wohlers discuss 'indirect' metal AM systems and outline the advantages and disadvantages of such systems in relation to commercial production.

Metal Additive Manufacturing has received a great deal of attention in the past few years and some may see it as a fairly recent development. However, commercially available metal AM systems have been around for over two decades. The earliest commercial systems were often referred to as 'indirect' metal AM because the parts they produced were not made in a direct process from a single material. Instead, 'green parts' were produced that were a mixture of a metal powder and a binder material such as a polymer. These parts were thermally processed to remove the binder, resulting in about 40% porosity. During this thermal stage of the process, sintering would fuse the metal particles. At the same time, infiltration of a lower melting point metal, such as bronze, would fill much of the porosity.

One such system was DTM's Powder Bed Fusion process, commonly known as Selective Laser Sintering (SLS). A special metal version of SLS was called RapidTool, which used RapidSteel powder consisting of polymer-coated steel particles. The laser melted and fused the polymer, resulting in a green part that was later sintered. The resulting part was made up of about 60% steel and 40% bronze. Fig. 1 shows a part made by the RapidTool process.

Fig. 1 A RapidTool part (Courtesy Land Rover)

Producing dense metal parts

Using Powder Bed Fusion and other AM processes to directly build dense metal parts offers significant advantages over RapidTool-like processes. It is a simpler procedure overall with no requirement for binder

Fig. 2 A pulley manufactured using Markforged's Metal X system

Fig. 3 The Metal X system

burnout, sintering or infiltration. The high-power lasers or electron beams used result in parts that are often 99% dense or higher and typically offer properties that are superior to castings and similar to those of wrought materials. The range of alloys available is also steadily increasing and already includes many of the most often used for aerospace, medical, dental and other applications. However, the high-power energy sources in the systems, coupled with their relatively slow processing speed, result in expensive parts. Additionally, the size and shape of the metal powder must be carefully controlled, making them expensive. Therefore, the main drawback of direct metal AM is cost, with most systems priced in the region of $250,000 to more than $1.5 million. This is well beyond the reach of many companies and educational institutions.

'Indirect' metal AM systems are still available today and one of the most established is the binder jetting system which has been sold by ExOne since 2001, originally under the ExtrudeHone name and ownership. Available alloys include stainless steel, Inconel, cobalt–chrome, bronze, iron and several refractory metals. Similar to the early SLS RapidTool system, parts from these machines must go through a thermal debinding and sintering process. Some also require infiltration by a secondary metal, such as bronze. Systems from ExOne are priced from $430,000 to $1.1 million.

"The material mix is deposited in a manner similar to most material extrusion machines. The part then goes through a one-step thermal process in a vacuum furnace to achieve up to 99.7% of full density"

The Metal X system

The Metal X system from Markforged uses an 'indirect' metal AM process that the company has named Atomic Diffusion Additive Manufacturing (ADAM) and is based on material extrusion. It has a base price of $99,500. The system uses a combination of metal powders and polymer that are formed into rods that are held in a cartridge near the top of the machine. The metal powders are the same as those used in metal Powder Bed Fusion but are 'locked' into the polymer. Consequently, they do not become airborne, so toxicity and flammability risks are greatly reduced. The material mix is deposited in a manner similar to most material extrusion machines. The part then goes through a one-step thermal process in a vacuum furnace to achieve up to 99.7% of full density, according to Markforged.

The build volume of the Metal X system is 250 x 220 x 200 mm (9.8 x 8.7 x 7.9 in) and the layers produced are 0.05 mm (0.002 in) in thickness. Example brake levers, made in 17-4 stainless steel, are shown in Fig. 4. Both are sintered to 99.7% density. Build time was five hours per lever, plus four hours of thermal processing and the material cost for each lever is $34.

Fig. 4 Stainless steel brake levers manufactured using Markforged's Metal X system

The ADAM process is capable of building fully enclosed lattice/mesh structures, resulting in parts with high strength-to-weight ratios. Powder bed systems have the draw-back of trapping the unprocessed material in such enclosed structures, making it difficult or impossible to remove. This sets the ADAM process apart from Powder Bed Fusion and aerospace and other industries may find this capability interesting and useful.

The company is initially offering 303 and 17-4 stainless steels and is testing other materials. These include Inconel 625 nickel-based superalloy, Ti-6Al-4V titanium alloy, 6061 and 7075 aluminium and A2 and D2 tool steels.

Thermal processing

A consideration when evaluating this system is that the thermal post-processing and the associated removal of the polymer binder causes parts to shrink by 20%. Greg Mark, CEO of Markforged, states that parts shrink uniformly and this shrinkage is taken into account during the production process. Research and experience from other powder-based processes that require similar thermal processing, such as Metal Injection Moulding, suggest that whilst shrinkage is uniform, designers may need to consider changing wall thicknesses and other features that could cause distortion. Thermal processing and cooling also adds significant time to an already relatively slow build rate. In the brake lever example, about 44% of the process time, excluding time for finishing, is the thermal cycle.

Mark and his team have developed an interesting approach to help overcome dimensional inaccuracy as a result of thermal processing. A high-resolution laser scanner built into the print head scans the thermally-processed part and makes adjustments to the data. The machine then prints a second part that is more dimensionally accurate.

Conclusion

The Metal X system offers a more reasonable cost basis for companies wanting to get started with metal AM. It may be suitable for applications in final part production and could compete with CNC machining for quantities of tens or even hundreds, if the parts are small. Other applica-tions may include the production of prototypes and possibly tooling such as plastic injection moulds.

It is too early to draw definitive conclusions about the new Metal X system. It shows promise and offers the possibility of fully enclosed lattice and mesh structures. Shipment is expected in September 2017; until then, we will not know where the machine offers a good fit. Even so, it provides an alternative that will hope-fully create additional competition.

Authors

Ian Campbell and Terry Wohlers
Wohlers Associates, Inc.
Fort Collins
Colorado 80525
USA
www.wohlersassociates.com

Contact

Kerry Murphy, Manager Corporate Communications
Markforged, Inc.
10 Fawcett St.
Cambridge
MA 02138
USA
Tel: +1 617 666 1935
Email: Kerry@markforged.com
www.markforged.com

World PM2016: The non-destructive evaluation of internal defects and powder characterisation in AM

WORLDPM2016 congress and exhibition

A collection of papers at the World PM2016 Congress, held in Hamburg, October 9-13, 2016, addressed the issues of non-destructive examination (NDE) of internal defects in additively manufactured parts and the control of AM processing through appropriate powder characterisation analysis. Dr David Whittaker presents *Metal Additive Manufacturing* magazine's final report from the congress.

Non-destructive evaluation of internal defects in additively manufactured aluminium parts

A paper, from Lars Pejryd and Patrik Karlsson (Örebro University, Sweden), Sebastian Hällgren (Saab Dynamics and Örebro University, Sweden) and Magnus Kahlin (Saab Aeronautics and Linköping University, Sweden), addressed the issue of NDE of internal defects in additively manufactured aluminium alloy, AlSi10Mg.

To enable the full industrial application of AM, robust methods for the detection of potential internal defects are required. X-ray computed tomography (CT) is potentially one of the few tools for non-destructive evaluation (NDE) of internal features and defects. The applicability of CT and other NDE methods is, however, not fully understood. In the reported work, aluminium alloy parts, with different sizes of controlled internal defects in the form of slots of varying width, 0.1–0.4 mm, were manufactured by Selective Laser Melting (SLM). The parts were produced either with a solid form or with internal networks. Both of these sample types contained the pre-designed defects and were used to evaluate the ability to detect the defects by CT, ultrasonic inspection and Eddy Current Testing (EC).

After the sample build process, two surfaces were machined to R_a 3.2 in order to improve ultrasonic and eddy current inspection. Three external half-spheres were added on top of the parts (relative to the build direction) for CT measurement calibration. In order to create the internally latticed part, additional geometries were designed by performing two subsequent boolean operations, using the software Magics. Lattice pattern, G_structure10, with structure

Fig. 1 The city of Hamburg hosted World PM2016, with an Official Reception taking place at the Handelskammer

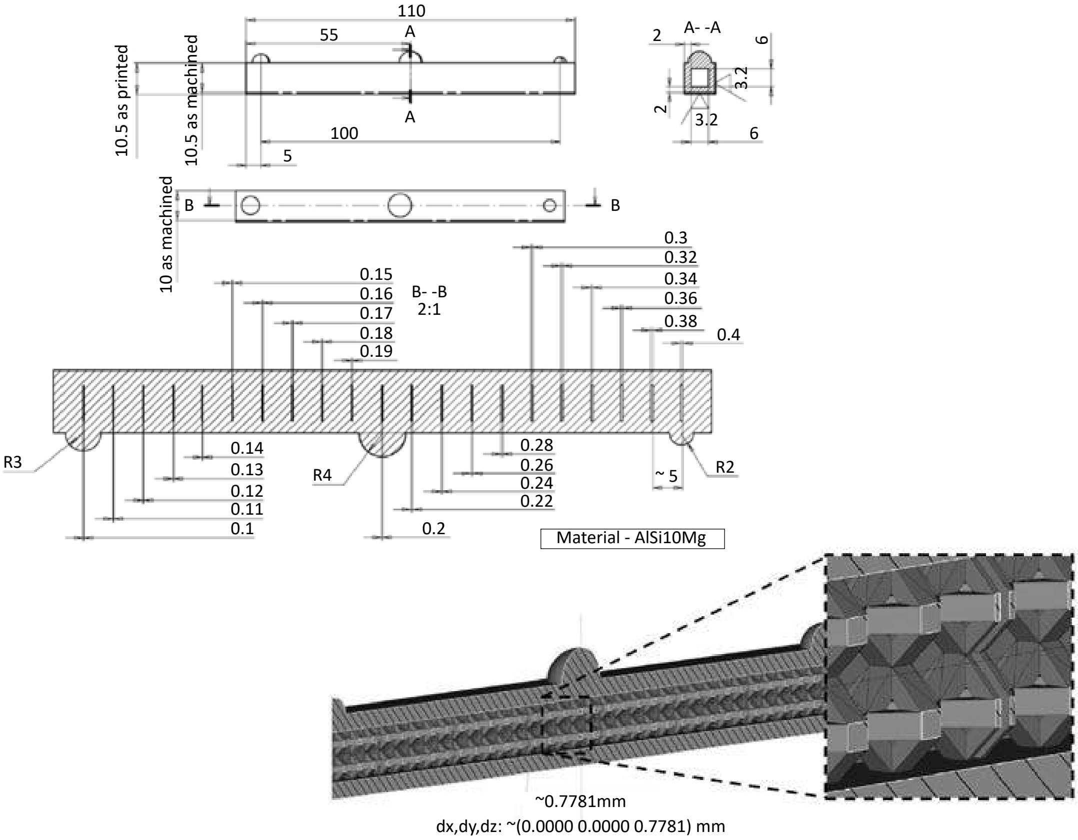


Fig. 2 Design of the test object, in AlSi10Mg, without internal lattice network (top) and cut view of the internally latticed part (bottom left) and close-up of the lattice with a slot cutting through it (bottom right). The network strut's square cross section dimension was measured to be nominally 0.78 mm [1]

dimensions x,y,z = 3.0 mm being chosen (Fig. 2). Both sample types were designed to contain the same type of pre-designed defects.

Computed tomography was performed using an industrial CT system with a 225 kV X-ray micro-focus source. No physical filtering was applied to the X-rays. The scanning parameters used in the work resulted in a voxel size (i.e. the dimension of the volumetric pixel unit) of about 80 µm for scans of the complete sample and 27 µm for scans of only selected portions of the sample (at higher magnification). A filtered back-projection algorithm was used to reconstruct the investigated 3D volume based on the X-ray projections obtained. For separation of the aluminium material and air to determine the interfaces, thresholding of the reconstructed volume was carried out using

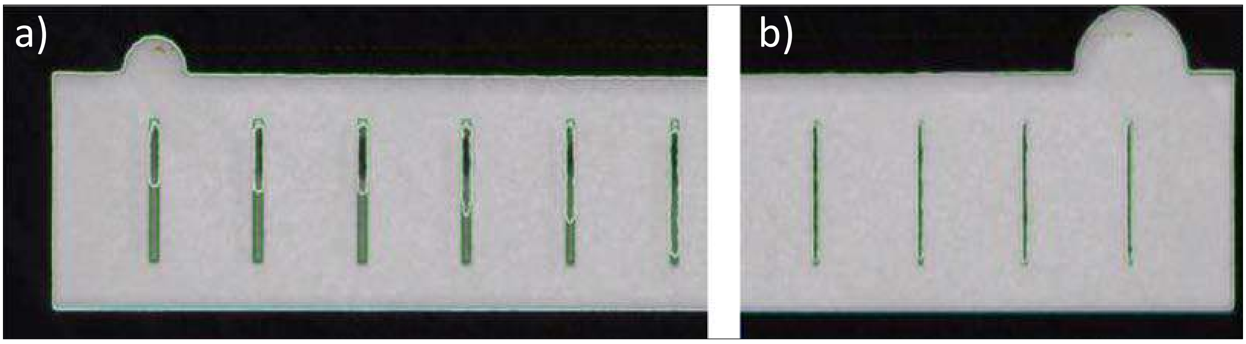


Fig. 3 Magnification of regions of interest in a sample without internal network (a) The end of the sample with large width (as designed 0.40–0.30 mm). (b) The end of the sample with small width of the slots (as designed 0.13–0.10 mm). The green lines indicate the expected dimensions from the CAD source file [1]

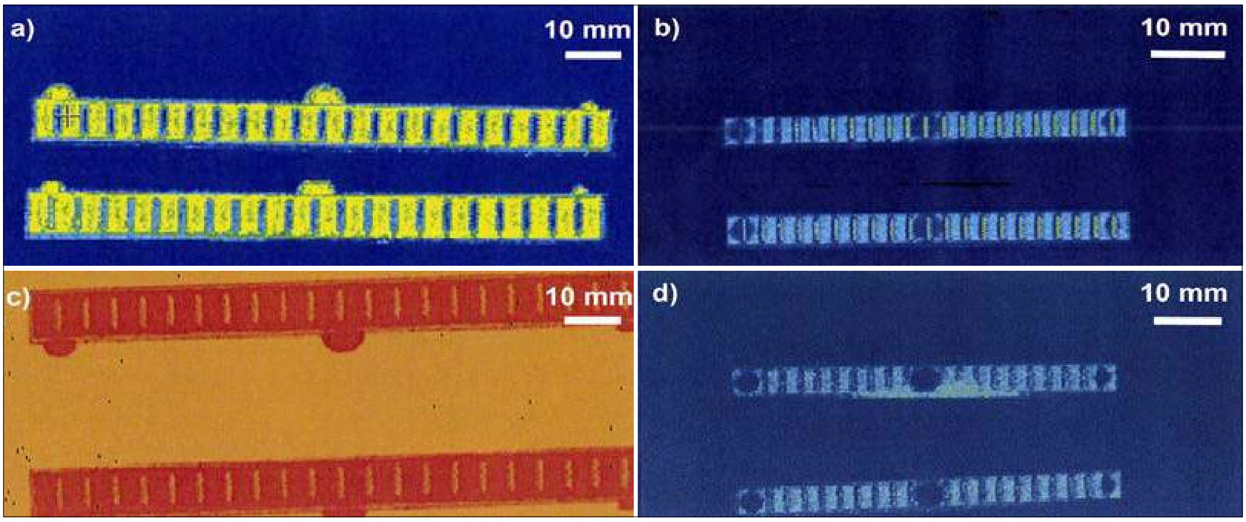


Fig. 4 Ultrasonic inspection of the machined surfaces (a,b) and rough surfaces (c,d) of the test pieces where (a,c), (b) and (d) are the side, bottom and top surfaces respectively. The upper test pieces shown in the images (a-d) were heat treated prior to the ultrasonic inspection [1]

commercial software with adaptive surface determination methods. The data were then used to determine the geometry and dimensions of the defects produced. Two types of approaches, defect determination and actual/nominal comparison, were used for the evaluation of the presence and size of non-melted areas in the form of slots.

Ultrasonic inspection was performed using immersion testing with both the transducer and the test sample placed in a water tank. During ultrasonic inspection, an ultrasound pulse is sent through the sample and the received echo is analysed. A 20 MHz probe and a focal depth of 31.75 mm between the transducer and the part were used.

Electromagnetic inductive inspection was performed through eddy current testing. During eddy current inspection, an alternating current is applied to a coil resulting in a magnetic field, which induces a current and magnetic field in the test artefact. A defect in the test artefact will change the induced current and this will then will be registered. A Phasec 3D flaw detector and frequencies between 700 Hz and 3 kHz were used, giving a penetration depth of 2-4 mm in aluminium materials.

For solid samples with slots, CT evaluation could detect all of the defects/slots that were designed to be included in the sample (Fig. 3). The slots were shown to contain unmelted powder and porosity between powder particles. For the wider slots, this is clearly shown as regions of lower density than the surrounding solid material. From Fig. 3, it is clear that, for wide slots, powder is accumulated in the lower part of the slot and two different areas with different densities can be detected. All of the designed defects were easily detected by visual inspection of the reconstructed CT data.

The external half-spheres were used as reference objects and the distances between the manufactured slots and the volume of the slots were measured. Defect determination using the mode "Void" and the algorithm VGDefx in the software identified the complete volumes of unmelted powder. This includes both the volumes of higher and lesser density of the larger slot, as can be seen in Fig. 3a (as the green line) for the larger slots. Using the enhanced mode and basing the analysis on surface determination, the volume identified varies and is not consistent along the sample. For the larger slots, the defect is identified as the volume with the lowest density (the white lines in Fig. 3) and, therefore, only parts of the low density volumes/slots are considered.

The analysis mode "actual/nominal", where the reconstructed CT volume is compared to the as-designed CAD file, is not designed to analyse internal defects. This was confirmed by attempts to use this mode on the sample without internal networks, but with manufactured internal slots. In this case, no clear measurement values of the internal defects/slots were obtained.

Manual measurement of the widths of the slots resulted in deviations from the CAD values, ranging from +110% for the small width features to +10% for the larger features. The uncertainties of the measurements are similar for all slot widths measured. This gives an indication of the geometrical accuracy limits of small size features in SLM processing of aluminium.

The ultrasonic inspection of the samples, without internal network structures, resulted in defects that were detected by applying the probe on both the machined surfaces, Fig. 4(a,b), and the as-printed surfaces, Fig. 4(c,d). However, ultrasonic inspection of the top surface of the sample, with an as-printed surface roughness, resulted in poor resolution due to a low signal-to-noise ratio, Fig. 4(d). In comparison to defect detection using CT, ultrasonic inspection showed lower resolution.

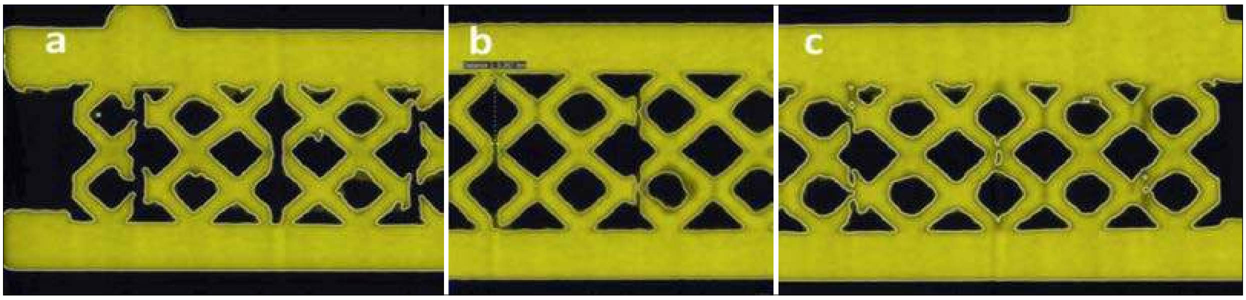


Fig. 5 Magnification of regions of interest in a sample with internal network. a) The end of the sample with large width (as designed 0.40–0.36 mm), b) The middle part of the sample, c) The end of the sample with small width of the slots (as designed 0.12–0.10 mm) [1]

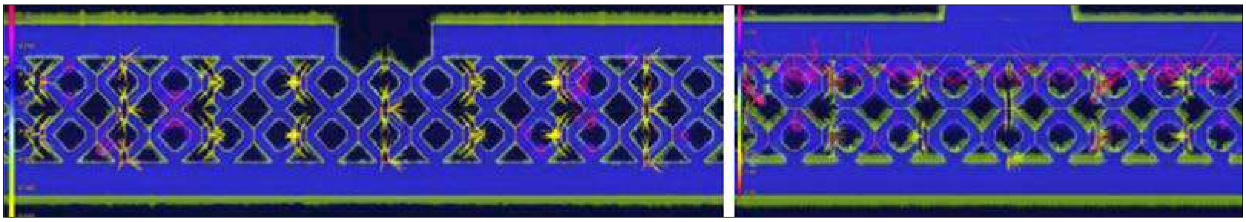


Fig. 6 Regions of interest in a sample with internal network, using the analysis mode actual/nominal comparison in the CT analysis software [1]

For samples with internal networks, CT evaluation, Fig. 5, was not as straightforward as for solid samples. Visual evaluation of the CT data showed clear slots for the wider slots. Since the sample was designed as an "open structure", the unmelted powder was easily removed after the build process. Therefore, slots, which are wide enough to allow powder to run freely and which are connected to the open parts of the network structure, will not contain powder after the build process. This results in a larger contrast between the solid parts of the sample and the intended defects, as compared to the solid sample case, where the unmelted powder remains in the slots. However, it was much more difficult to detect narrower slots in this sample. Below 0.28 mm, the slots begin to be semi-closed due to partial melting of the intended openings.

Analysis methods in the CT software, such as defect determination, are not directly applicable for these types of structures. In this mode, the analysis tool is searching for defects inside solid volumes, thus, in this case, inside the network struts. For the semi-closed areas, no internal defects could be detected using this mode. Thus defects between unmelted powder particles were below the detection limit of the set up. With the use of the "Actual/nominal" comparison, Fig. 6, comparing the CAD file of the designed object to the CT data, some help in identifying defects could be obtained. However, no usable numbers for comparison could be obtained.

Resolution and detectability is an important question in quality assurance and detection of defects using CT is highly dependent on the CT system, the material studied and the magnification that can be used (and, therefore, the voxel size that can be obtained). In previously reported work in the literature, for Ti6Al4V samples built using electron beam melting (EBM), CT scans with a voxel size of 10 µm showed that, with such a magnification, it was not possible to detect pores smaller than 25 µm and it was concluded that this could probably be considered as the low end of the detectability range for current industrial CT systems. In the current analysis, where the voxel sizes were between 27 and 80 µm, the detection limits for defects were larger. Intentional defects down to 100 µm could, however, be detected. Additionally, the dimensional accuracy of CT measurements is not yet fully understood.

Overall, the authors concluded that, for components with internal networks, more work is needed to develop CT inspection methods to enable automation or to assist a trained operator. At present, CT does, however, seem to be the most promising method for inspecting components with internal networks.

The ultrasonic inspection of samples with internal network structures indicated substantial difficulties in detecting the constructed defects. The inner structures were barely visible in the results from ultrasonic inspection. Hence, in comparison to ultrasonic inspection, CT is superior in the detection of complex inner structures and defects. Ultrasonic and eddy current methods have been shown to be not applicable for these types of designs, as current methods cannot handle the analysis of signal paths in network structures.

Evaluating flowability of Additive Manufacturing powders using the Gustavsson Flow Meter

Control of a number of the characteristics of the 'raw material' powders is of prime importance in ensuring an adequate control of the subsequent AM processing and two papers at the congress addressed this issue. The first of these papers specifically focused on characterisation of powder flowability and was provided by a Swedish consortium, Pelle Melin, Ola Lyckfeldt and Annika Strondl (Swerea), Peter Harlin (Sandvik Materials Technology), Håkan Brodin (Siemens Industrial Turbomachinery) and Henrik Blom (Carpenter Powder Products). Control over powder flowability is important in ensuring consistency in the re-coating process after each layer build in powder bed AM technologies.

In the reported work, the nickel-based alloys, Hastelloy X (HX) and Inconel 939 (IN939), were assessed in both the 'virgin' and 'used' conditions. When a component is built in an SLM machine, the fused powder is replaced with virgin powder and the remaining powder is typically mixed with the virgin powder for the next run. The used powder degrades somewhat and the resulting mixture is therefore slightly different compared to the virgin powder. The flowability often changes, reflecting altered surface characteristics and the formation/scattering of agglomerates, but, most importantly, the Particle Size Distribution (PSD) also changes. The way in which the PSD changes is dependent on the technology. A spreading type of powder dispensing favours small particles in the build chamber, as the large particles are pushed on top. Hence, larger particles are enriched in the used powder. A pouring type of powder dispensing could favour some particle range depending on flow inside the pouring device. At the same time, the chemical properties are degraded, mainly in terms of oxygen content, which increases with continual usage. Bulk density comparisons for the analysed powders are listed in Table 1. The increased density levels of the used powders should be noted.

The flow characteristics of these powder batches were assessed using two funnel-based flow meters (the Gustavsson and Hall flow meters) and the Freeman FT4 powder rheometer.

For AM, powders with a fine sieving fraction are beneficial because these enable better dimensional accuracy and finer surfaces. However, it is well known that flowability is poor for finer powders and they are typically more difficult to dispense. The most widely used flow assessment method, the Hall flow meter, is lacking in applicability for such fine powders.

The Gustavsson flow meter is a better method for fine metal powders, which are not free-flowing. As can be seen in Fig. 7, the angle is steeper in the Gustavsson flow meter, compared to the Hall funnel. The hole at the bottom is also smaller, in order to obtain the same flow time as the Hall flow meter, for the reference powder Chinese emery.

In the Freeman FT4 powder rheometer, flow energy is measured on a defined volume (25 ml) of powder by recording the resistance to a rotating blade moving downwards and upwards within the powder bed using a certain helix motion pattern. Eight repeated measures, with a conditioning cycle in between each measurement, were conducted and

Powder		CBD, g/ml	BDtap50, g/ml
HX	New	4.52	5.03
	Used	4.67	5.13
IN939	New	4.45	4.81
	Used	4.56	4.92

Table 1 The powders used in the reported study. CBD is the conditioned bulk density; BDtap50 is the bulk density after 50 taps [2]

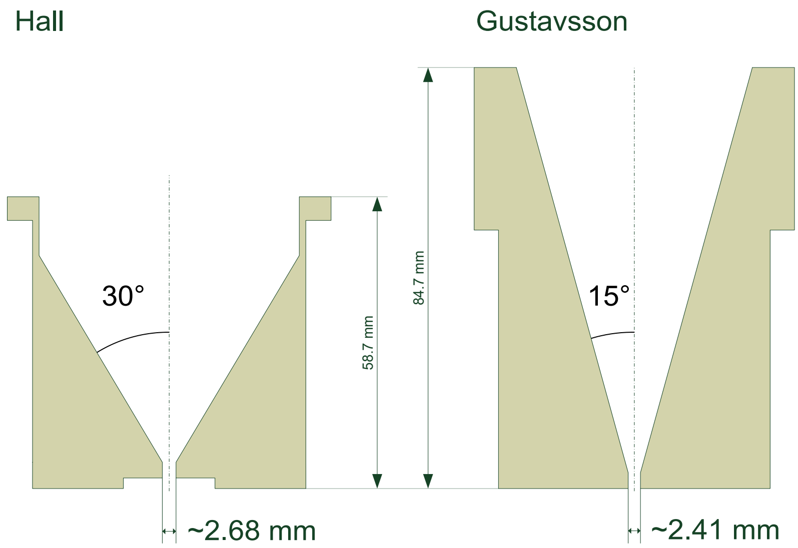


Fig. 7 The cross section of (left) the Hall flow mater and (right) the Gustavsson flow meter [2]

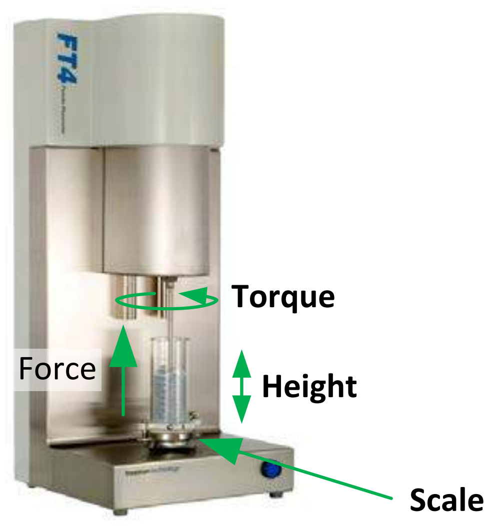


Fig. 8 Freeman rheometer FT4. Resistance to flow is measured as the powder is in motion [2]

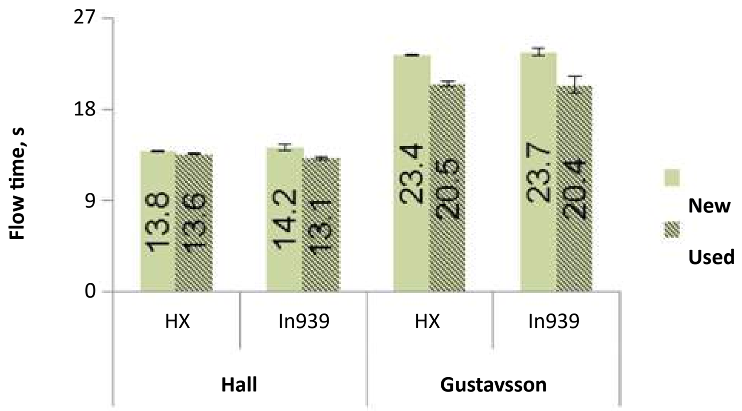


Fig. 9 Results for Hall and Gustavsson flow times. Non-dried powders were analysed [2]

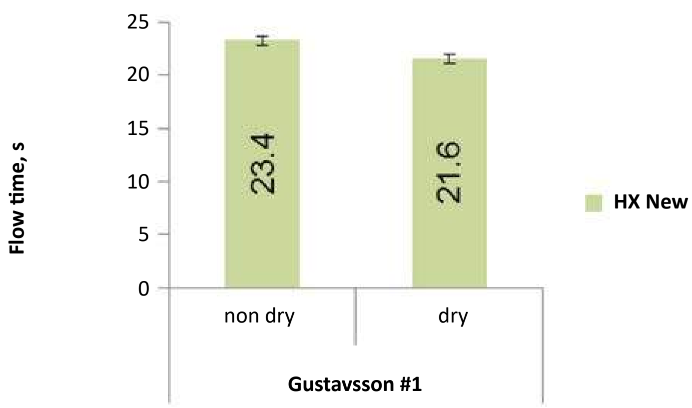


Fig. 10 Results of Gustavsson flow time for non-dried and dried HX powder. Drying was done by maintaining 70°C overnight, in normal atmosphere [2]

the 7th value was used in the reported results. With the Freeman method of measuring flow, the pushing and shearing behaviour of the powders are determined. In contrast, with the Hall and Gustavsson methods of measuring flow, the free-flowing aspects of the powders were measured. See Fig. 8 for an illustration of the rheometer.

All of the studied methods of characterising the flowability were able to distinguish between used and virgin and dried and non-dried HX and IN939. However, for the Hall flow meter, the differences were small, close to the magnitude of variability between separate runs. Used powder (Fig. 9) and dried powder (Fig. 10) flowed more rapidly. Furthermore, the Hall flow meter is only designed for free-flowing powders and flow could sometimes not be started with a single tap and some powder remained in the funnel after the flow stopped. As such, the measurement standard (ISO 4490 or ASTM B213-11) could not be correctly applied. The Gustavsson flow meter was more successful and robust. Some of the measurements for the Hall flow time in Fig. 9 were in fact from only two runs and, therefore, not according to the standard.

The comparison of the results from the funnel methods and the Freeman method displayed something of a paradox. In the Freeman rheometer, the used powders appeared to have worse flow characteristics, while, in the Hall and Gustavsson flow meters, the used powders appeared to have better flow characteristics. This difference may be partly related to the fact that the funnel methods are constant mass methods, while the Freeman rheometer is a constant volume method. The used powders showed higher bulk densities (Table 1) owing to having more fines and wider particle size distributions. A higher density means there is a smaller volume to pass through the funnel and hence a faster time is recorded. In the Freeman rheometer, a higher density powder means there is a higher mass and therefore more particles should be sheared. However, this is not the complete explanation as, if the conditioned bulk density from Table 1 is used, the Hall and Gustavsson mass flow rates can be recalculated to volume flow rates and, on comparing these volume flow rates from the Hall and Gustavsson flow meters, the used powders still exhibit a better flowability. As such, what is really a better flowability is a matter of definition and the different methods do not actually measure the same aspects. It can be postulated that shear cell testing could be a better representation for the spreading type of dispensing in AM; while the funnel methods could represent flowability in a better manner in the pouring type of dispensing.

It may be concluded that, for pouring type dispensing, the Gustavsson funnel may be the preferred flowability assessment method, as the Freeman FT4 is an advanced instrument, which requires knowledge and correct handling, whereas Gustavsson flow time can, on the other hand, be applied in a fast production setting and can be used by most staff without much training. Use of the Freeman rheometer may, however, be justified when characterising flow in an AM system that uses a spreading type of dispenser.

Powder		EOS	Concept Laser	SLM Solutions	Arcam
D_{10}	μm	21.9	20.2	28.2	51.4
D_{50}	μm	31.9	29.8	36.6	73.2
D_{90}	μm	46.3	43.7	49.2	107.8
Flowability	s	39.3	53.2	31.7	21.8
Apparent density	g/cm³	2.46	2.54	2.45	2.59
Tap density	g/cm³	2.83	2.83	2.73	2.81
Al-content	%	6.49	6.38	6.37	5.75
V-content	%	4.09	3.91	3.90	3.97
Fe-content	%	0.24	0.22	0.22	0.21
O-content	%	0.188	0.147	0.143	0.116
N-content	%	0.010	0.009	0.016	0.017

Table 2 Determined properties of Ti-6Al-4V powders provided by equipment manufacturers EOS, Concept Laser, SLM Solutions and Arcam [3]

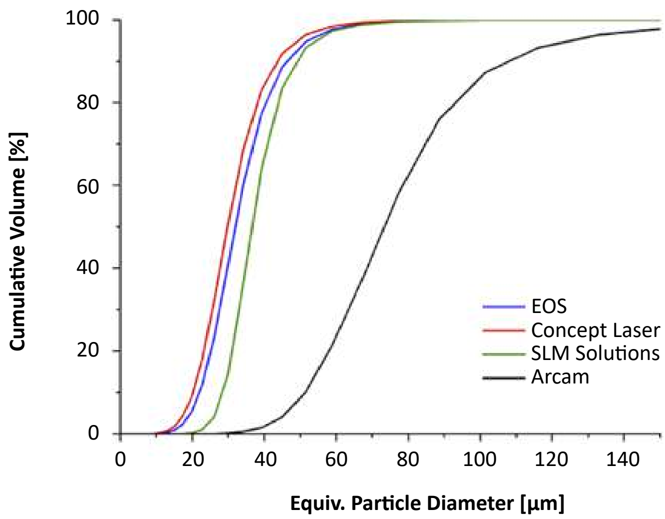


Fig. 11 Particle size distributions of Ti-6Al-4V powders [3]

Powders for Additive Manufacturing

A further paper, from Alexander Kirchner, Burghardt Klöden, Thomas Weißgärber and Bernd Kieback (Fraunhofer IFAM, Dresden, Germany), presented a comprehensive set of characterisation analyses for powders used in Selective Laser Melting (SLM) and Electron Beam Melting (EBM) processing.

Metal powders have crucial significance as the feedstock for both SLM and EBM. To ensure problem-free processing, a number of properties such as flowability, particle size and shape, apparent density and level of impurities have to be within certain ranges. Since, to date, powders have been largely supplied by the equipment manufacturer, systematic examinations are not available.

Therefore, four powders provided by manufacturers of SLM and EBM machines were analysed in the reported study. EOS Titanium Ti64 had a nominal particle size of 20-45 μm, Concept Laser CLM (15-45 μm), SLM Solutions Ti-6Al-4V (20-63 μm) and Arcam Ti-6Al-4V (45-105 μm).

To characterise the particle size distributions of these powders, a laser scattering analyser was used. For these measurements, the powders were dispersed in water using ultrasound. Flowability was characterised for 50 g of powder by means of a Hall flowmeter. Apparent density was determined by the funnel method and tap density was measured using a Scott volumeter Elemental composition was analysed using an inductively coupled plasma optical emission spectrometer (ICP-OES) and interstitial impurities were determined using a LECO analyser. Density was measured using a gas pycnometer with helium. Imaging of powder particles was carried out using a scanning electron microscope.

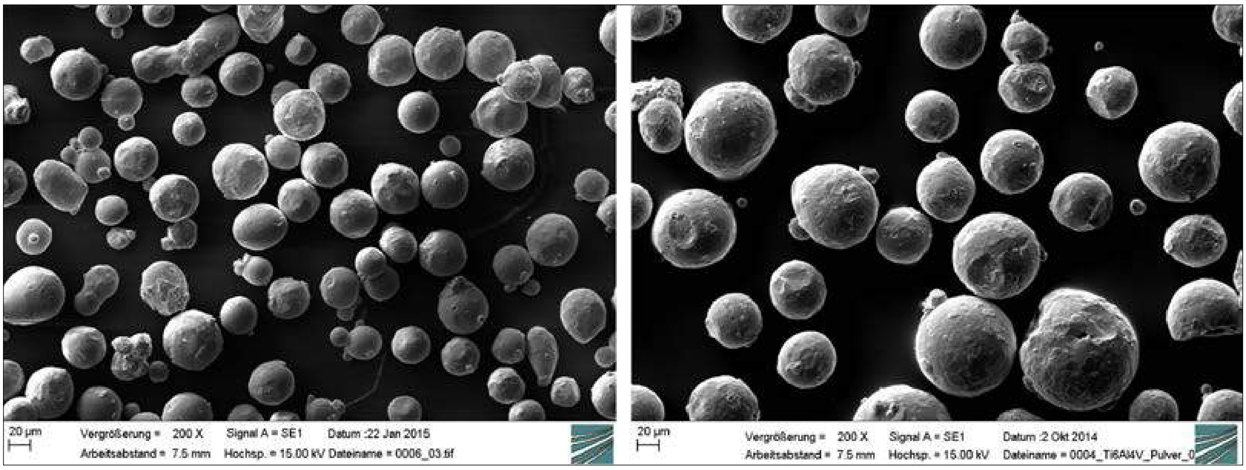


Fig. 12 Scanning electron micrographs of custom-specified Ti-6Al-4V powders for SLM (left) and EBM (right)

The SLM machines used in the study were an EOS Eosint M270, a Concept Laser M2 cusing and an SLM Solutions 250HL. EBM studies were carried out using an Arcam A2X machine.

The characterisation results for the Ti-6Al-4V powders provided by the equipment manufacturers are given in Table 2. The measured particle size distributions are shown in Fig. 11. Using electron microscopy imaging, all powders were found to be highly spherical with very few satellites. Despite this very beneficial particle shape, all SLM powders require tapping to achieve a continuous flow in the Hall test. The apparent densities of the SLM powders were in the range 2.45 to 2.54 g/cm³ and the tap densities in the range 2.73 to 2.83 g/cm³. From these numbers, the Hausner ratios can be calculated to be in the range 1.15 to 1.11. All of these values are significantly below 1.25, pointing to sufficient flowability. The pycnometric density of all SLM powders was measured to be 4.40 g/cm³, indicating negligible internal porosity.

In comparison the EBM powder was characterised by a larger particle size. Consequently, flowability, apparent density and tap density were all higher than those of the SLM powders. The chemical compositions of all the powders tested fell within the ASTM B265 specification of Titanium Grade 5.

On the basis of these characterisation results, a custom powder specification was generated and custom specified Ti-6Al-4V powders were produced by electrode induction-melting gas atomisation (EIGA) using argon by TLS Technik, Germany.

In view of the distinct particle size differences between SLM and EBM powders, two powder fractions were specified. The finer fraction with a nominal size between 20 and 63 µm was to run on all SLM machines, while the coarser fraction between 40 and 120 µm was destined for the EBM process. The specified flowability of the SLM powders had to be aligned with the highest flowability measured for the powders supplied by the equipment manufacturers. Also, the elemental composition was specified to be tighter than ASTM B265 to take into account two effects. Firstly, the selective evaporation of aluminium from the alloy melt leads to a depletion in the manufactured Ti-6Al-4V part, and, secondly, there is oxygen uptake during the build process. Repeated heating leads to oxygen accumulation in the powder, potentially limiting the commercially important number of re-use cycles. In addition, the allowable internal porosity was tightly limited, since some of the gas-filled porosity translates into the final material. The results of the characterisation analyses of the two fractions, manufactured according to the custom specification by TLS, are presented in Table 3.

"The powder chemical composition leaves enough latitude to account for preferential aluminium evaporation and oxygen accumulation, as a consequence of recycling, to be within the ASTM B265 specification"

With a median D_{50} of 44.1 µm, the custom SLM powder is coarser than any of the previously analysed SLM powders and its flowability is, at 31.4 s, at the high end of the previously analysed range. The particle size distribution of the custom EBM powder is practically identical to the Arcam powder, but its flowability is inferior. The likely reason for this can be seen in Fig. 11. Both the custom SLM and EBM powders are less spherical than the previously characterised powders. This also affects both apparent and tap density, which are slightly reduced. The powder chemical composition leaves enough latitude to account for preferential aluminium evaporation and oxygen accumulation, as a consequence of recycling, to be within the ASTM B265 specification.

The custom SLM powder, after adjustments to the scan parameters, ran without issues on the three different SLM machines. The custom EBM powder was processed using Arcam standard parameters. No problems regarding powder feeding and raking were encountered. The built Ti-6Al-4V materials exhibited good mechanical properties.

Powder 'ageing' through repeated uses was monitored over a number of build series on different machines. After processing virgin SLM powder on an SLM Solutions machine, a number of subtle changes in powder properties were detected. While the median particle size stayed practically constant, the number of particles smaller than 30 µm was reduced over the first three cycles. Flowability was increased continuously such that, after six cycles, flow time was reduced to 28.6 s. While the effect on apparent density was negligible, tap density increased to a level of 2.73 g/cm³. A moderate increase in impurities was detected. The oxygen content rose to 0.138 % within six cycles or an average increase of 0.003%/cycle.

In the case of EBM, a small shift in particle size distribution of approximately 2 µm towards larger particles was measured after processing the powder for 13 cycles. No reduction in flowability was detected. As before, no change in apparent density was detected, but there was a small increase in tap density. The increase in oxygen content after 13 cycles was 0.027%, corresponding to 0.002%/cycle.

Powder		SLM	EBM
D_{10}	µm	32.8	52.9
D_{50}	µm	44.1	73.7
D_{90}	µm	62.5	104.6
Flowability	s	31.4	28.3
Apparent density	g/cm³	2.32	2.37
Tap density	g/cm³	2.64	2.70
Al-content	%		6.42
V-content	%		4.20
Fe-content	%		0.22
O-content	%	0.119	0.118
N-content	%	0.005	0.005

Table 3 Determined properties of custom specified Ti-6Al-4V powders [3]

The authors' overall conclusion was that their defined approach to custom powder specification was found to be suitable, on the basis that the powders' performance in both SLM and EBM machines was as requested. Mainly subtle changes in the powder properties after multiple reuse cycles were detected. Because these 'ageing' effects depend on many factors, such as machine type, build geometry and processing parameters, they may not be readily applicable to every powder-bed-based additive manufacturing process and need to be checked individually.

In common with the previous reviewed paper, it was also concluded that, particularly for the finer SLM powders, the Hall flowmeter might not be the most suitable characterisation method for flowability

References

[1] Non-Destructive Evaluation of Internal Defects in Additive Manufactured Aluminium, L Pejryd *et al*, as presented at the World PM2016 Congress, Hamburg, October 11-14 2016, and published in the Proceedings by EPMA, UK.

[2] Evaluating Flowability of Additive Manufacturing Powders, Using the Gustavsson Flow Meter, P Mellin *et al*, as presented at the World PM2016 Congress, Hamburg, October 11-14 2016, and published in the Proceedings by EPMA, UK.

[3] Powders for Additive Manufacturing, A Kirchner *et al*, as presented at the World PM2016 Congress, Hamburg, October 11-14 2016, and published in the Proceedings by EPMA, UK.

Author

Dr David Whittaker is a consultant to the Powder Metallurgy industry.
Tel: +44 (0)1902 338498
Email: whittakerd4@gmail.com

Proceedings

The proceedings of the World PM2016 technical sessions and poster program are published in digital format by the European Powder Metallurgy Association. For more information visit www.epma.com

PM Titanium 2017

4th International Conference on Titanium Powder Metallurgy & Additive Manufacturing

PMTi 2017 — **8-10 September 2017·Xi'an, P.R. China**

Organisers

State Key Laboratory of Porous Metal Materials

Northwest Institute for Non-ferrous Metal Research, P.R. China

State Key Laboratory for Powder Metallurgy

Central South University, P.R. China

Honorary Organisers

- **Chinese Materials Research Society**
- **The Non-ferrous Metal Society of China**
- **National Natural Science Foundation of China**
- **Materials Australia**
- **Japan Society of Powder and Powder Metallurgy**
- **Society of Materials New Zealand Incorporated**
- **Powder Metallurgy Association of South Africa**
- **Helmholtz-Zentrum Geesthacht, Germany**

Call for Abstracts

The content has to be related to powder metallurgy of titanium but not limited to:

→ Titanium powder production and characterisation

→ Titanium powder metallurgy processes

→ Titanium additive manufacturing processes

→ Ti-based materials and applications

Conference Chairs

Chair	**Huiping Tang**	Northwest Institute for Non-ferrous Metal Research, P.R. China
Co-chair	**Yong Liu**	Central South University, P.R. China
Co-chair	**Peng Cao**	The University of Auckland, New Zealand

International Advisory Board

Leandro Bolzoni	The University of Waikato, New Zealand
Hilda Chikwanda	Council for Scientific and Industrial Research, South Africa
Thomas Ebel	Helmholtz-Zentrum Geesthacht, Germany
Zak Z. Fang	University of Utah, USA
Stefan Gulizia	CSIRO Manufacturing Flagship, Australia
M. Ashraf Imam	George Washington University, USA
Katsuyoshi Kondoh	Osaka University, Japan
Louis-Philippe Lefebvre	National Research Council Canada, Canada
Ian Mellor	Metalysis, UK
Aamir Mukhtar	TiDA Limited, Tauranga, New Zealand
Elena Gordo Odériz	University Carlos III of Madrid, Spain
Ma Qian	RMIT University, Australia
Xuanhui Qu	University of Science and Technology Beijing, P.R. China
Iain Todd	University of Sheffield, UK
David van Vuuren	Council for Scientific and Industrial Research, South Africa
Deliang Zhang	Northeastern University, P.R. China

Contact Details

E-mail: **secretariat@tipmam2017.org**

Website: **www.tipmam2017.org**

Conference Venue

industry events

2017

7th International Conference on Additive Manufacturing Technologies
September 7-8, Bangalore, India
www.amsi.org.in/

PM Titanium 2017
September 8-10, Xian Shi, China
www.tipmam2017.org

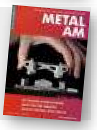
AM Ceramics
September 11-12, Vienna, Austria
www.am-ceramics.dkg.de

EMO Hannover 2017
September 18-23, Hannover, Germany
www.emo-hannover.de

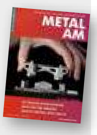
TCT Show - Birmingham
September 26-28, Birmingham, UK
www.tctshow.com

EURO PM2017 - Congress & Exhibition
October 1-4, Milan, Italy
www.europm2017.com

IN(3D)USTRY - From needs to solutions
October 1-6, Barcelona, Spain
www.in3dustry.com

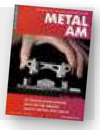


Additive Aerospace Summit
October 18-20, Los Angels, United States
www.infocastinc.com/event/additive-aerospace/

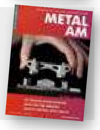


International Conference on Sintering 2017
November 12-16, San Diego, United States
www.ceramics.org/international-conference-on-sintering-2017

formnext powered by TCT
November 14-17, Frankfurt, Germany
www.formnext.com

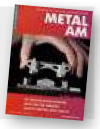


Additive Manufacturing Americas 2017
December 6-8, Pasadena, United States
www.amshow-americas.com



2018

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

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

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

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

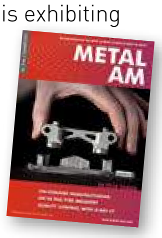
Event listings and Media Partners

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



advertisers' index