Vol. 6 No. 1 SPRING 2020

THE MAGAZINE FOR THE METAL ADDITIVE MANUFACTURING INDUSTRY

METAL AM

in this issue

SPEE3D: AM GOES SUPERSONIC

ALTERNATIVE PERSPECTIVES ON AM

VENTURE CAPITAL INSIGHT

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
www.metal-am.com

Managing Director, Features Editor
Nick Williams
nick@inovar-communications.com

Publishing Director, News Editor
Paul Whittaker
paul@inovar-communications.com

Deputy Editor
Emily-Jo Hopson-VandenBos
emily-jo@inovar-communications.com

Assistant Editor
Kim Hayes
kim@inovar-communications.com

Production Manager
Hugo Ribeiro
hugo@inovar-communications.com

Advertising
Jon Craxford, Advertising Sales Director
Tel: +44 (0)207 1939 749
Fax: +44 (0)1743 469909
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. 6 No. 1 Spring 2020

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

METAL
ADDITIVE
MANUFACTURING

What's in a name?

For an industry that is working hard to get its message across to a global audience, Additive Manufacturing (or should we say 3D printing?) appears to have a problem when it comes to the basics of process names and overall transparency.

Potential adopters of AM, in the early stages of their journey at least, have to navigate their way through a host of often elaborate proprietary process names, some of which are technically confusing and others fantastical.

Whilst every company has the right to distinguish itself from its competitors in the battle to survive in the fast-paced AM environment, perhaps the time has come for the industry to embrace a greater level of transparency. Customers soon come to understand that most companies are simply developing variants of the same small number of processes.

Over a year ago, we as a publishing house recognised the confusion that we had inadvertently perpetuated, since our *Metal AM* website launched in 2014, by not applying any 'standard' process names in news stories and articles, but instead using each company's proprietary process name.

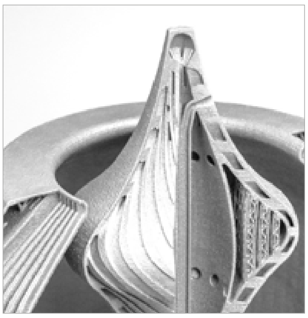
We therefore took the decision to bring clarification wherever possible, whilst in parallel respecting the proprietary names created by individual companies. Our leads in this matter are ISO/TC 261 and ASTM Committee F42 and their Standard ISO/ASTM 52900 Additive Manufacturing — General Principles — Terminology.

With the encouragement of many in the industry, we will continue to support the efforts being made to move towards global standardisation of terminology used in metal AM. As one European researcher recently commented, "There's not enough coffee in this world to sort out this terminology mess in AM... there may not even be enough whiskey..."

Nick Williams
Managing Director

Cover image
An aluminium bronze propeller manufactured by SPEE3D's Cold Spray process. The part weighs 1.4 kg and took sixteen minutes to build (Courtesy SPEE3D)

METAL ADDITIVE MANUFACTURING


28

36

65

83

115

Contents

Regular features

industry news

Boeing 777X takes flight with 300 additively manufactured parts in each GE9X engine

Boeing's new 777X wide-body passenger jet underwent its maiden flight on January 25, taking to the skies powered by two GE9X engines from GE Aviation, said to be the largest and most powerful commercial jet engines ever built. According to Eric M Gatlin, Additive Manufacturing General Manager at GE Aviation, each of the engines contains around 300 additively manufactured components.

GE Aviation has been working on the GE9X since 2013, and prior to the maiden flight the company stated it had carried out seventy-two test flights of the new engine, totalling more than 400 hours, on its Boeing 747 flying testbed. To date, the GE9X programme has reportedly completed more than 4,100 hours of ground and air testing, as well as 6,500 cycles.

The GE9X's fan casing is over 3.4 m (134 in) in diameter, as wide as the body of an entire Boeing 737, and houses parts made from the a wide range of materials, including lightweight and heat-resistant ceramic matrix composites, and components made by Additive Manufacturing.

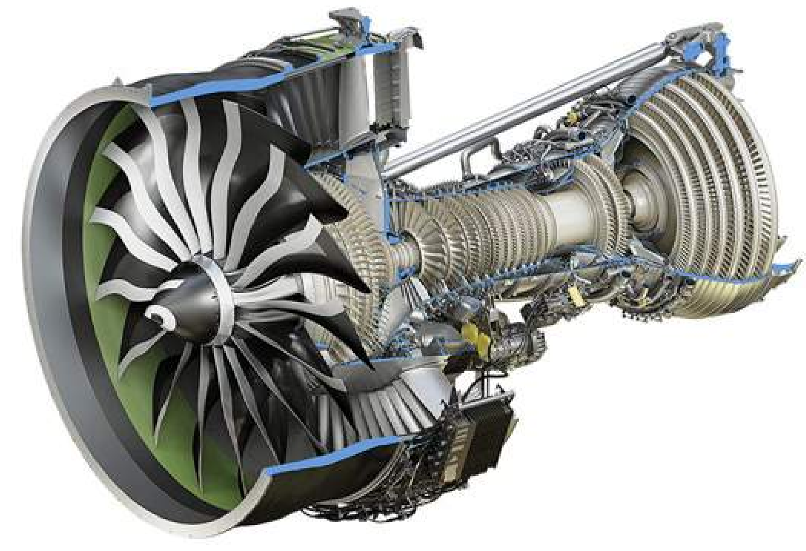
Almost 300 AM parts are reported to be in each GE9X engine, including many that combine multiple parts into one component, as well as parts that cannot be made in any other way. AM parts are produced at GE's Avio Aero facility in Cameri, Italy and GE's Additive Technology Centre in West Chester, Ohio, USA, and are reported to include fuel nozzle tips, low-pressure turbine blades, heat exchangers and inducers.

The inducer, used to remove dust, sand and other debris in the engine, is one such part which is difficult to make without using AM, and has never been used inside a commercial GE jet engine before. "The inducer cannot be manufactured any other way, except by 3D printing," stated Zach Studt, Senior Manufacturing Engineer at GE Aviation. "In this way, additive is unlocking performance of the engine. A different manufacturing process can deliver a better product. Going forward, most engines will probably come with some version of that inducer."

The titanium aluminide (TiAl) blades on the low-pressure turbine of the GE9X are also produced by metal Additive Manufacturing. The TiAl blades are said to be roughly half the weight of traditional nickel-alloy turbine blades, and are produced at Avio Aero using Arcam EBM systems.

GE Aviation is reported to be wrapping up certification testing for the GE9X and expects the engine to be certified later this year. It has built ten compliant engines, eight of which will go on flying test airplanes, plus two spares, for Boeing. GE has received orders for more than 700 GE9X engines.

www.geaviation.com
www.ge.com/additive
www.boeing.com



Boeing's new 777X wide-body passenger jet is powered by two GE9X jet engines (Courtesy GE Aviation)

F1 Alfa Romeo race car features 143 metal AM parts

Additive Industries, Eindhoven, the Netherlands, has reported that the recently-unveiled Alfa Romeo Racing Orlen F1 race car features 143 metal additively manufactured parts. The new C39 race car was introduced at the Barcelona F1 race track in Spain on February 19, 2020, where it underwent on-circuit testing prior to the start of the 2020 F1 season.

Of the 143 metal additively manufactured parts, fifty-eight are made from titanium, nineteen from a high-performance aluminium alloy and sixty-six from AlSi10Mg. The parts were produced by Sauber Engineering on Additive Industries MetalFAB1 systems. Sauber Motorsport AG, which manages and operates the Alfa Romeo Racing Orlen team, operates four MetalFAB1 systems at its Sauber Engineering facility and is a Technology Partner of Additive Industries.

The additively manufactured parts include chassis inserts, cooling circuit piping, safety structures, electronic component installations and more. Using Additive Manufacturing, Additive Industries stated that a highly beneficial 2% weight saving was achieved.

www.additiveindustries.com
www.sauber-group.com
www.alfaromeo.com

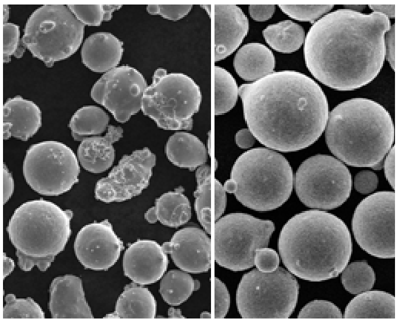
The C39 F1 race car features 143 additively manufactured parts, saving 2% of the car's weight (Courtesy Alfa Romeo Racing Orlen)

ASL commissions new 400 kg gas atomiser specifically for AM and MIM powders

Atomising Systems Ltd. (ASL), Sheffield, UK, has expanded its capacity through the installation of a new 400 kg gas atomiser aimed specifically at the Additive Manufacturing and Metal Injection Moulding (MIM) powder markets.

An additional melter is now being installed for greater flexibility and capacity. The in-house-designed atomiser, equipped with ASL's proprietary anti-satellite and hot gas system, produces high yields of MIM and/or AM powders, enabling ASL to continue to serve its expanding AM and MIM customer base.

Paul Rose, Commercial Director, stated, "The addition of another atomiser, along with the associated sieving and classification equipment, means that we are able to keep pace with the growth of our existing client base and the requirements of new clients, especially in the AM and MIM sectors."



Powder from a conventional gas atomiser (left) vs powder from ASL's atomiser with anti-satellite system (right) (Courtesy Atomising Systems Ltd.)

Rose added, "In these sectors, the benefits of ASL's Anti-Satellite technology are clearly recognised through the excellent powder shape and flow properties."

www.atomising.co.uk

BEAMIT plans expansion with additional fifteen machines from SLM Solutions

BEAMIT, Italy's largest Additive Manufacturing service bureau, has signed a letter of intent to purchase fifteen Additive Manufacturing machines from SLM Solutions over the next three years. The order is said to comprise a range of systems from SLM Solutions, including the SLM®280, SLM®500 and SLM®800 models.

"Through the replacement of single-laser products with SLM Solutions' multi-laser technology we are able to increase our productivity and provide competitive pricing to our customers," stated Mauro Antolotti, Chairman and Founder of BEAMIT. "By partnering with SLM Solutions, we can meet our customer's requirements to build high quality parts at increased productivity and expand our facilities."

The commitment is reported to be in line with the expansion of BEAMIT's plant, which will be more than twice the size of the previous facility.

Meddah Hadjar, CEO of SLM Solutions, added, "We are very pleased to deepen our cooperation with BEAMIT and to be a long-term partner in its additive growth. It shows the trust and the confidence in our machines and in our multi-laser technology. We are looking forward to a successful future and collaboration not only on these products but also for future NextGen products and technology developments."

www.slm-solutions.com
www.beam-it.eu

Pratt & Whitney announces first MRO application for AM aero-engine component

Pratt & Whitney will use an additively manufactured aero-engine component for the first time in its MRO of commercial engines (Courtesy Pratt & Whitney)

Pratt & Whitney, an aerospace manufacturer and division of United Technologies Corp., will use an additively manufactured aero-engine component for the first time in its maintenance, repair and overhaul (MRO) of commercial engines. The AM component is anticipated to be part of the repair process by mid-2020 at Pratt & Whitney's repair specialist in Singapore, Component Aerospace Singapore.

The use of Additive Manufacturing is the result of a collaborative effort by the company's engineering experts, Component Aerospace Singapore, and the Land Systems division of ST Engineering, Singapore, to deliver faster and more flexible repair solutions to support Pratt & Whitney engines. Pratt & Whitney states that the part will first be used in a fuel system on one of its engine models. The alternative material solution is expected to reduce dependency on current material supply from conventional fabrication processes such as forging and casting.

"Thanks to the out-of-the-box thinking by our employees at Component Aerospace Singapore, we are now another step closer to scaling the technology to meet our growing aftermarket operations, and industrialising 3D printing for the industry," commented Brendon McWilliam, Executive Director, Aftermarket Operations, Asia Pacific. "This groundbreaking innovation is part of the wider technology roadmap by Pratt & Whitney to introduce advanced technologies that integrate artificial intelligence (AI), robotics and automation across our operations as part of our digital transformation. We are well-placed to better meet today's demands and anticipate tomorrow's customer needs, without compromising our high standards of quality and reliability."

"3D printing will be a game-changer for the MRO industry worldwide, especially in servicing even more commercial engines. This technology enables greater flexibility in our inventory management," added Chin-Huat Sia, Principal Engineer, Component Aerospace Singapore. "Following this trailblazing initiative, both Pratt & Whitney and ST Engineering will examine how Additive Manufacturing can be applied for other aviation components and other engine types, and further developed to enable hybrid repairs and realise the full potential of 3D printing for commercial aftermarket operations."

According to Pratt & Whitney, its engineering team extended ST Engineering's application of Additive Manufacturing methods for ground transport systems to produce the aero-engine component. Both organisations worked closely to ensure that in-house quality and process systems are certified to Pratt & Whitney's requirements for aftermarket applications.

"To 3D print an aero-engine component for a working air turbine engine is a first for us," explained Tan Chor Kiat, Senior Vice President, Kinetics Design & Manufacturing, ST Engineering. "This also demonstrates our advanced capability to offer a full turnkey manufacturing solution which not only includes production-level 3D printing, but also post-processes such as heat treatment and machining. Our customers expect high standards of quality from us."

www.pw.utc.com | www.stengg.com

Ricoh's new resin-coated powders and cross-linking ink to expand range of metals for Binder Jetting

Ricoh, based in Kanagawa, Japan, has developed a new resin-coated metal powder and cross-linking 'ink' for use in the Binder Jetting process. Said to increase the diversity of metals available for Binder Jetting and improve the quality of components, the new range is aimed at those adopting Binder Jetting as a manufacturing process.

The metal powders are coated with a uniform layer of binder resin around 100 nm in thickness, in a process developed from coating technology acquired through electrophotography. A cross-linking material in the ink is said to work with the resin to form the green part.

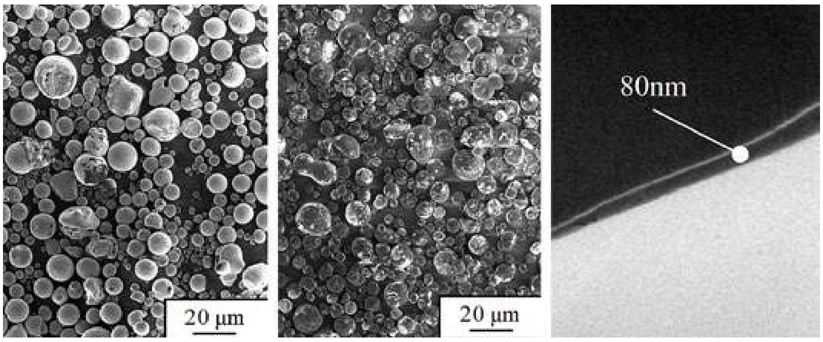
According to Ricoh, a key advantage of the new material is to remove the risk of dust explosions associated with fine powder particles and potentially explosive powders, such as aluminium and titanium. Fine powders tend to offer improved sinterability and can lead to higher achievable density and low surface roughness. However, fine powders can be more explosive than coarse powders.

The new powders are coated with resin selected to improve both the minimum ignition energy and explosible concentration, important parameters in avoiding dust explosion. The resin-coating is said to prevent the propagation of fire between particles. This allows the use of fine powders and results in improved surface finish, reducing the need for additional post processing steps.

A further advantage of Ricoh's new process is the ability to control the permeability of the ink toward the powder bed. If permeation is less than expected, for example, it can cause increased porosity in the green part and if the ink permeates too far, it affects the dimensional accuracy of the parts produced.

The control of ink permeability is a key factor for the achievement of the correct density and accuracy for a part. Using its new materials, Ricoh stated that it has achieved the adjustment of the contact angle between the ink and powder surface, and a level of control over permeability through a selected combination of surfactant and coating resin.

www.ricoh.com



SEM images of a) uncoated powder, b) coated powder, c) cross-section of coated powder of stainless steel 316L (Courtesy The Ricoh Company, Ltd.)

PIM binder specialist eMBe rebranded Krahn Ceramics, targets filament-based AM

Germany's eMBe Products & Service GmbH has been rebranded as Krahn Ceramics GmbH following the company's acquisition by Krahn Chemie GmbH in May 2019. The company's headquarters have also been relocated from Thierhaupten to Hamburg and its machines and equipment integrated into a new technical centre in Dinslaken, Germany.

Krahn Ceramics states that it sees its role as a project partner for those looking to process ceramic and metal powders both by Powder Injection Moulding (PIM) and filament-based Additive Manufacturing. The company reported that it can support its customers through all stages of the production process, from raw materials supply to the finished component.

Services offered to Krahn Ceramics' customers range from consulting to laboratory services, tailor-made product development and small-series production. Dr Stefan Stolz, the company's Managing Director, stated, "The feedback we received at the Formnext trade fair confirmed that the market has a great interest in such a broad-based technology partner and source of inspiration. We are very much looking forward to realising the numerous product ideas of our customers together."

"In addition to the European market, we also have an eye on the USA and Asia," he added. "There, we can draw on established structures and networks of the Otto Krahn Group, among other things. This means that we have internal access to a lot of market-relevant information in order to be able to develop business."

www.krahn-ceramics.com

ExOne qualifies fifteen new materials for use on its Binder Jet AM machines

The ExOne Company, based in North Huntington, Pennsylvania, USA, has qualified fifteen new metal, ceramic and composite materials for Binder Jet Additive Manufacturing on its machines, bringing the company's total supported materials to twenty-one. Among the materials qualified by ExOne to date are ten single-alloy metals, six ceramics and five composite materials. Over twenty-four additional powders are also said to be approved for R&D environments, including aluminium and Inconel 718.

"From the outside, it may look like ExOne's metal printers jumped from six to twenty-one qualified materials overnight. In reality, ExOne's engineering team and our customers have been moving so fast to print new materials since 2013 – the breakthrough year when we began printing dense single-alloy metals – that we haven't slowed down to update the market on our progress," stated John F Hartner, ExOne CEO, in a message following the announcement.

"When we took the time to re-evaluate where we were over the last few months, the numbers surprised even us," he commented. "ExOne customers were printing an astonishing number of materials – fourteen – that had not yet worked all the way through ExOne's rigorous qualification process. That included six single alloys, six ceramics, and two ceramic-metal composites."

"At the same time, we were ready to announce new materials, such as M2 tool steel, had achieved our highest qualified status, and other materials, such as aluminium and titanium, were qualified for controlled R&D printing. So, a major reset was needed," he stated.

Partners that have assisted ExOne in qualifying materials include Global Tungsten & Powders, H.C. Starck Solutions, NASA, Oak Ridge National Laboratory, SGL Carbon, the U.S. Army, the U.S. Department of Energy, the University of Texas at El Paso, and Virginia Tech.

ExOne has qualified fifteen new materials for use on its AM machines, bringing the total to twenty-one (Courtesy The ExOne Company)

New materials qualification system

As of February 25, 2020, ExOne reported that it has three material qualification levels that recognise different degrees of material readiness for customers with different application needs, namely:

Third-party qualified materials

These materials have passed rigorous ExOne tests over multiple builds, and have verified material property data from an independent third party.

Customer-qualified materials

These materials have been qualified by ExOne customers with their own standards and are being successfully additively manufactured today for their own applications.

R&D-qualified materials

These materials have passed a preliminary qualification phase by ExOne and are deemed printable, supported by ongoing development.

ExOne's family of metal AM machines includes the Innovent+, an entry-level system used globally for R&D, design and small part production; the X1 25Pro, a mid-sized production AM machine that is large enough for most metal parts manufactured today; and the X1 160Pro, the company's largest metal AM machine, slated for delivery later this year.

www.exone.com

Saratech acquires AM business from TekPro Group

Saratech, a provider of product development software, engineering services and Additive Manufacturing solutions located in Mission Viejo, California, USA, has acquired the AM sales sector of Southern California-based TekPro Group.

"I am very pleased to welcome TekPro, a company with a tremendous amount of 3D printing experience, to Saratech," stated Dr Saeed Paydarfar, Saratech CEO. "3D printing technology is quickly becoming a very relevant technology for product development. 3D printing allows creative, cost-effective, time-effective, and performance-effective solutions."

The acquisition is expected to boost technical and sales resources to Saratech's Additive Manufacturing business. "We are delighted to add our 3D printing expertise to Saratech's robust product lifecycle management and engineering services. We can now offer end-to-end solutions improving our customer's product development cycle, resulting in reduced cost and faster time to market," added Jack Lisinski, President of Tekpro Group.

Saratech offers Siemens CAD/CAM/CAE/PDM software solutions and a range of AM systems, including HP, Markforged, and BigRep for both prototyping and production.

www.saratech.com

Aurora Labs raises $1.82 million following private investment

Aurora Labs, Bibra Lake, Australia, has successfully raised $1.82 million following investment from Dutch entrepreneur Tjeerd Barthen. Aurora intends to use the funds to accelerate commercialisation of its rapid manufacturing technology (RMP-1) Additive Manufacturing machines as well as for working capital.

Barthen, who founded a successful healthcare business that was later acquired by management and private equity, now invests globally in disruptive technologies with scalable opportunities.

"I have followed the growth of the sector for some time and quickly identified Aurora Labs as a technological leader with the potential to revolutionise manufacturing. I look forward to following the team on their journey," Barthen stated.

The deal will see 13,000,000 shares issued to Barthen at $0.14 per share. The placement shares will reportedly comprise approximately 12.5% of the company's total pre-placement issued share capital and approximately 11% on a fully-diluted basis, and will rank equally with existing ordinary shares.

www.auroralabs3d.com

Markforged achieves ISO 27001 certification

Markforged, Watertown, Massachusetts, USA, has achieved ISO 27001 certification. The certification demonstrates that it has met rigorous international standards in ensuring the privacy, confidentiality, integrity, and availability of the entire Markforged ecosystem, which includes its Eiger cloud AM platform, AM hardware, fleet management software and information governance policies.

ISO/IEC 27001:2013 is an Information Security Management System (ISMS) standard published in October 2013 by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). According to Markforged, it is the only AM platform to have achieved this certification.

The company explains that its cloud-first software strategy is enabling enterprises around the world to quickly adopt AM across a broadening set of applications and use cases, from production assembly to defence, military and aerospace.

"We believe that every product and engineering decision we make has a security component to it, and our customers and their data are at the centre," commented David Benhaim, CTO, CISO, Markforged.

www.markforged.com


3YOURMIND
Software
to Optimize
AM Workflows
Trusted by
Industry Leaders
3YOURMIND
Piston-Bolt
Create New
Requests
Orders
Settings
Help
QUICK LINKS
About
Terms
Customer Support
193792-Pistonbolt-1
PA12Polishing, Coloring Ivo
$16.61
193792-Piston-2
PA12Polishing, Coloring Ivo
$97.92
193792-Stand_M8_F
PA12Polishing, Coloring Ivo
$52.25
193792-Rod_Clamp-
PA12Polishing, Coloring Ivo
$22.65
193792-Rod-5
PA12Polishing, Coloring Ivo
$53.31
Joe Ortega
j.ortega@jrparts.com
Printing Service
On Point Plastics
Subtota
$1,941
Let's meet
AMUG: booth D6
Rapid+TCT: booth 1026
3yourmind.com/customers

Ametek to sell its Reading Alloys business to Kymera

Titanium is widely used in medical applications (Courtesy Reading Alloys)

Kymera International, a speciality materials company headquartered in Raleigh, North Carolina, USA, has entered into a definitive agreement with Ametek, Inc., Berwyn, Pennsylvania, USA, to acquire its Reading Alloys business, a provider of highly engineered materials for mission-critical applications in numerous markets. Founded in 1953, and acquired by Ametek in 2008, Reading Alloys designs, develops and produces master alloys, thermal barrier coatings and titanium powders. The business is a preferred supplier for producers of high-quality titanium and superalloy mill products that are used in aerospace and aircraft applications.

Kymera has been owned by affiliates of Palladium Equity Partners, LLC, New York, USA, a middle-market private equity firm with approximately $3 billion in assets under management, since 2018. The transaction is expected to close in the first quarter of 2020. The terms were not disclosed.

"Reading Alloys is an outstanding company with highly skilled people and an excellent product and endmarket portfolio that we believe fits in perfectly with our existing business," stated Barton White, CEO of Kymera International. "For Kymera, we believe this is a transformative acquisition that will give our combined company strong technical and commercial resources to help fuel our growth in the aerospace, defence, medical and industrial markets."

Adam Shebitz, Managing Director of Palladium, commented, "The acquisition of Reading Alloys, Kymera's second to date, is right on strategy as the Kymera management team continues to build the company into a leading speciality materials producer. Kymera represents another great example of Palladium's value creation framework, which pulls on both organic and M&A driven levers. We are excited about this opportunity to enhance the Kymera platform with Reading's value-added products, growing end-markets and its talented employees."

www.kymerainternational.com
www.readingalloys.com
www.ametek.com

ASTM International launches personnel certificate programme in AM

The ASTM International Additive Manufacturing Center of Excellence (AM CoE) has announced its Additive Manufacturing certificate programme will take place from March 10–12, 2020, at the National Center for Additive Manufacturing Excellence (NCAME) at Auburn University, Alabama, USA.

The standards organisation is said to have conducted an extensive landscape analysis to understand the existing gaps in AM education and workforce development and to develop a comprehensive course that will fill the current gaps according to Dr Mohsen Seifi, ASTM International's Director of global AM programs. As a result, he explains that the course covers all basic concepts of the AM process chain while also equipping attendees with core technical knowledge related to best practices, including standardised methodologies.

ASTM International states that the programme is open to anyone with an interest in Additive Manufacturing and welcomes participants from government, industry, academia, as well as those with prior experience in AM. The standards organisation and TÜV SÜD, a testing and certification organisation headquartered in Munich, Germany, recently signed a Memorandum of Understanding to jointly develop other types of advanced educational certificate offerings in AM tailored to specific roles for various industry sectors.

Course modules will be taught by globally-recognised experts from industry, regulatory agencies, and academia. Specific modules will include terminology, AM process overview, design and simulation, feedstock, post-processing, mechanical testing, non-destructive inspection, safety issues and qualification & certification.

"With more and more industry sectors adopting Additive Manufacturing technologies, there is a growing demand for an educated workforce to support the expanding field," stated Dr Nima Shamsaei, Director of the National Center for Additive Manufacturing Excellence (NCAME) at Auburn University. "This is a groundbreaking first step in meeting that need. To fill the AM knowledge gap, we need world-class training from industry leaders who can equip the future workforce with highly valued technical knowledge."

Seifi commented, "The AM CoE has made education and workforce development a major priority for creating a culture that accelerates AM adoption." He added that the programme requires attendees to pass an exam to earn the 'Basic AM Certificate' that serves as a foundation and prerequisite for future specialised role-based AM certificates through the AM CoE.

www.amcoe.org | www.astm.org
www.eng.auburn.edu

YOUR AM TOOLBOX

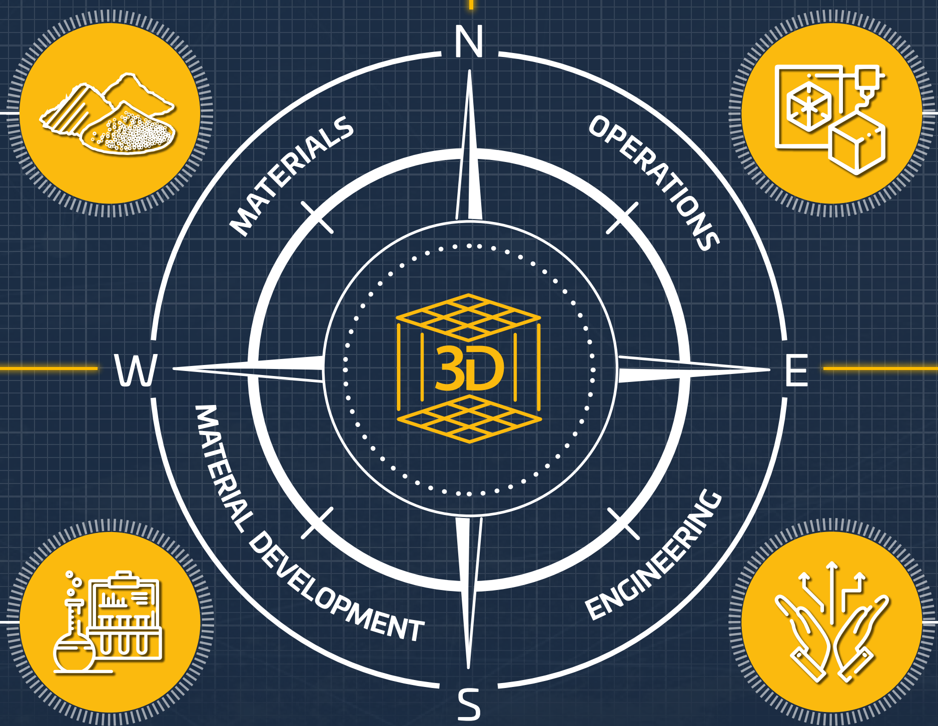
GKN ADDITIVE MATERIALS

- Low alloy water atomized steels, stainless steels and dual phase - structural steels
- Titanium-, Copper, Aluminium- and Nickel alloys, NiTi – Shape Memory alloys
- Magnetic alloys – Fe-Si

GKN ADDITIVE COMPONENTS

- High performance powder bed processes from 1 - 50.000 pcs
- Fully connected global print network
- MyAMQuality!

PRODUCT & PROCESS



- Inhouse testing capabilities for mechanical and physical properties
- Printing studies for Laser AM and Binder AM; Powder morphology
- ASTM standardized methods to certify chemical composition

- Design for AM
- Application know-how
- Simulation and validation

ENGINEERING SERVICES

DESIGN CONCEPT

MATERIALS → **PART**

REGISTERED AS 9100 · ISO TS16949 · QUALITY MANAGEMENT SYSTEM IATF 16949

GKN ADDITIVE

GLOBAL PRINT NETWORK

R&D and manufacturing locations accross Europe, North America and Asia form our Global Print Network. It is part of GKN Additive‘s completely digitized value chain from powder to part.

GKN Additive is your supplier for advanced metal AM components and materials for prototypes, medium series and the aftermarket. Our goal its to push 3D printing to its limits to make it simpler, faster and more accessible for you.

www.gknpm.com/additive

Markforged adds pure copper to its Metal X rapid Additive Manufacturing system

Markforged, Watertown, Massachusetts, USA, has added pure copper to the range of materials processable by its Metal X rapid Additive Manufacturing system. The company stated that the inclusion of copper will drive new manufacturing and supply chain efficiencies for customers, leading to reduced lead times and part costs, as well as eliminating the need for costly inventory.

Copper is the latest metal to join the company's lineup of materials, which also includes aerospace superalloys like Inconel 625, 17-4 PH Stainless Steel, H13 Tool Steel, D2 Tool Steel, and A2 Tool Steel.

"Copper powers our world," stated Greg Mark, Markforged CEO and Founder. "It's everywhere. It builds our cars, enables phones, and keeps electrical equipment running. Copper has traditionally been an expensive and challenging material to machine and incompatible for 3D printing in a pure form with other techniques. Now, we've made it easier and cheaper to produce. Markforged 3D printed Copper will be a game-changer for the automotive and electronics industries, and it will open the door to innovation across many more."

Mark added, "Every automotive factory in the world uses copper for welding. Complex production parts are required to weld tight spots of the car body. They cost thousands of dollars to make and can have months-long lead times. But Markforged is changing all of that by enabling manufacturers to produce parts in-house so they get them faster and for significantly lower costs. With our 3D printed parts, automotive manufacturers can print the parts they need on-demand instead of holding significant inventory and will be able to design new kinds of welding shanks that were never before possible."

Markforged states that its AM systems are deployed at nine out of the ten highest-valued auto manufacturers globally, and the company has partnered with one of these customers to conduct in-depth weld testing using copper. The results reportedly showed the same resistance as traditionally manufactured spot welding shanks, and the automotive manufacturer now plans to extend the use of the Additive Manufacturing parts to the production line and has reported reduced part lead times by twelve times and part costs by six times.

"I've always been impressed with the technology behind the Markforged Metal X system, and our experience with 3D printed copper has been incredible – especially when looking at its conductivity and structural stability," commented the Maintenance Manager of the unnamed automotive manufacturer. "And now that we've successfully evaluated weld testing, we plan on expanding our metal 3D printing capacity for this and other metal components."

www.markforged.com

ALD's Heat Treatment Services division to open facility in China

Heat Treatment Services (HTS), a division of ALD Vacuum Technologies GmbH headquartered in Hanau, Germany, has announced that it will establish a new heat treatment services centre in China, officially registered as ALD Thermal Treatment (Suzhou) Co., Ltd.

This will be the fourth ALD Heat Treatment Services plant globally, with the others being in Germany, USA, and Mexico. The new centre will be equipped with ModulTherm, ALD's heat treatment system, and will serve the domestic industry. The new production hall will be erected next to the company's subsidiary ALD-C&K Vacuum Technologies (Suzhou) Co., Ltd.

ALD-C&K produces, sells and services ALD equipment and is also experienced in the commissioning and maintenance of heat treatment systems. The close cooperation between these two units is expected to contribute to the performance of the new heat treatment services centre. Start of production is scheduled for Autumn 2020.

www.heat-treatment-services.com

Honeywell Aerospace to qualify Velo3D's Sapphire AM system for aircraft parts

Velo3D, Campbell, California, USA, has partnered with Honeywell Aerospace, headquartered in Phoenix, Arizona, USA, to qualify Velo3D's Sapphire™ metal Additive Manufacturing system as a viable platform for the production of aircraft components.

The Sapphire system was reportedly selected for its unique ability to additively manufacture highly complex geometries without support structures, said to enable customers to benefit from substantial time, cost and quality improvements.

The Sapphire system will reportedly be located in Honeywell Aerospace's Phoenix facility. The qualification process is underway and focused on Inconel, a nickel-based superalloy well-suited to extreme temperatures. Velo3D states that it will provide its expertise in developing suitable parameter sets for Honeywell Aerospace to complete material qualification utilising the Sapphire system, in order to achieve optimal material properties. The qualification process is expected to be completed by the third quarter of 2020.

A selection of Velo3D's additively manufactured parts. These parts demonstrate how the company can produce geometries for applications such as aviation, oil & gas, aerospace and other industrial markets (Courtesy Velo3D)

"We are qualifying Velo3D's Sapphire system with the aim of printing geometries that can't be fabricated on existing 3D metal printers," stated Dr Söeren Wiener, Senior Director of Technology and Advanced Operations for Honeywell Aerospace. "Their technology will help Honeywell develop new production-part applications while also meeting our material requirements for qualification."

Wiener added, "We intend to qualify this equipment through repeatability testing in our production environment, including build and post-processing, to generate an acceptable set of material property data and qualification of flight hardware."

Benny Buller, founder and CEO of Velo3D, commented, "The geometric enablement we are able to offer customers like Honeywell Aerospace allows them to print what used to be 'impossible parts' and, yet, do it with a strong business case of improved cost and better quality. We are excited to partner with Honeywell to demonstrate that 3D metal printing is a viable production manufacturing method for a wider range of end-use applications."

www.aerospace.honeywell.com
www.velo3d.com

Sumitomo Corporation invests in Elementum 3D

Sumitomo Corporation, through Sumitomo Corporation of Americas (SCOA) headquartered in New York City, New York, USA, has invested in Elementum 3D, Inc, Erie, Colorado, USA, via its series A funding.

Elementum holds a patent for a metal powder blended with ceramics that reportedly enables faster build speeds, stronger mechanical properties and a wider usage of metal grades that have not traditionally been suitable for AM. It is believed that the investment will help expand the marketing and sales of Elementum's proprietary powder solutions.

According to SCOA, it believes Elementum's products have the potential to be utilised across several of the company's business verticals, including steel, mineral resources, aerospace and tubular. It states that it is plausible that this technology could disrupt the current supply chain altogether, seeing AM end-users working directly with Elementum rather than traditional materials manufacturers.

"This investment is an excellent complement to our growing portfolio in the Additive Manufacturing space," stated Kazuaki Tsuda, Senior Vice President and General Manager, Steel and Non-Ferrous Metal Group at Sumitomo Corporation of Americas. "Elementum is pioneering new intelligence related to the raw materials supply chain in Additive Manufacturing, and we see abundant opportunity for these applications in the near future."

Dr Jacob Nuechterlein, President at Elementum 3D, Inc., commented, "We are excited to have Sumitomo Corporation of Americas come on board as an investor. It speaks volumes that a company of this size and reach has such confidence in what we are creating. With this series A funding, we are eager to get our product further out into the marketplace and continue to grow our client base."

www.sumitomocorp.com
www.elementum3d.com

CNPC POWDER

SPECIALIZED IN POWDER MATERIALS

Low Cost Aluminum Alloy Powders

- High Quality: Low Oxygen & Nitrogen, Reliable & Consistent
- High Yield & More Efficiency: Shorter Production Cycle
- Good Spherical Shape & Flowablity

With years of experience in the industry, **CNPC POWDER** is leveraging our advanced technology to actively develop and improve our production process, which reduces the cost of powder and promotes the industrialized development of emerging industries such as 3D printing in lightweight applications.

www.cnpcpowder.com | inquiry@cnpcpowder.com | +1-902-316-0218

Angus 3D receives Scottish Enterprise funding to scale its AM services

Andy Simpson, Managing Director of Angus 3D, poses with an additively manufactured stainless steel highland bull and calf (Courtesy Angus 3D Solutions Limited)

Angus 3D Solutions Limited, an Additive Manufacturing start-up based in Brechin, Angus, UK, has received a £39,000 Regional Selective Assistance (RSA) grant from Scottish Enterprise. The funding is expected to help drive the start-up's three-year growth plan.

This funding announcement follows the start-up's growth last year, which was made possible by a grant from Zero Waste Scotland in 2018 to purchase a Markforged Metal X system. According to Andy Simpson, Managing Director of Angus 3D, this latest grant will allow a second employee to join the company, in order to increase work supporting the circular economy in North-East Scotland by enabling rapid prototyping and the remanufacture of parts to keep machines in use.

The grant will also reportedly enable the start-up to add bespoke carbon fibre manufacture and vacuum-forming services to its list of AM capabilities. Angus 3D explains that its premises at Brechin Business Centre will be expanded to incorporate its new equipment and services by expanding to a third unit.

"I've been talking about the huge opportunity the circular economy offers the manufacturing and oil and gas sectors for years now," stated Simpson. "Its ability to save on costs as well as time and materials is huge but still in the early stages of being exploited here, so it's great to have backing from Scottish Enterprise and Angus Council to pursue realising that opportunity."

Jane Martin, Managing Director of Business Services and Advice at Scottish Enterprise, commented, "Angus 3D Solutions is a great example of how entrepreneurial talent, skills and ideas can create a growing business and new jobs. With our support, Andy will be able to expand his operations and take full advantage of circular economy opportunities in the North East of Scotland."

www.angus3dsolutions.co.uk
www.scottish-enterprise.com

Farsoon expands into Thailand through partnership with Micap Machinery

Farsoon Technologies, headquartered in Changsha, Hunan, China, has expanded into the Thai market through its partnership with Micap Machinery (1986) Co., Ltd., an industrial equipment supplier based in Bangkok, Thailand. Micap will enter into the Additive Manufacturing industry by exclusively distributing Farsoon's metal and plastic AM machines throughout the country, offering Farsoon AM solutions to Thailand-based industrial users.

Vipant Chayavichitsilp, Managing Director of Micap, commented, "Micap is always looking for and working with high-quality product suppliers around the globe, and Farsoon is definitely one of the leaders in 3D printing industry. I am glad that both Micap and Farsoon have seen the same direction for the future of AM industry. With Micap's strong connections for more than thirty years in the Thai industry, we are confident that Micap and Farsoon are in a very good position in the Thailand market."

"The collaboration with Micap is very important to Farsoon, it paves the way to further expansion of our Southeast Asian layout," stated Vince Zhao, Global Channel Manager (AMEA) of Farsoon. "Being one of the most active economies in ASEAN, Thailand has a solid foundation in traditional manufacturing, including aerospace, automotive, medical, while keeping an open attitude towards advanced technology.

Zhao continued, "With over thirty years of experience in distribution of industrial equipment and technology, Micap has established an extended customer base in varies industries. Through the partnership with Farsoon, Micap will bring truly open and high-performance Additive Manufacturing systems to customers, offering quality, efficient, flexible solutions for industrial design and manufacturing."

www.farsoon.com

www.micapthailand.com

From left to right: Don Xu, Global Business Group Director of Farsoon, and Vipant Chayavichitsilp, Managing Director of Micap (Courtesy Farsoon Technologies)

Exentis Group demonstrates industrialisation of its 3D screen printing Additive Manufacturing technology

Exentis Group AG, located in Stetten, Switzerland, demonstrated its 3D Mass Customization® technology during the recent opening of its new 1,200 m² customer innovation centre. The company's industrialised Additive Manufacturing technology offers rapid series production of millions of components, in either metal or ceramic based materials, using a screen printing process followed by a final sintering stage.

Exentis' technology can be used to additively manufacture components for a wide range of applications and industrial sectors. The eco-friendly cold printing process is said to generate ultra-fine structures without reworking, with wall thicknesses and cavities down to 70 µm being possible. The process allows for complex designs with undercuts and closed cavities, without any supporting structures. Porosity can be adjusted to between 0 and 40% and surface roughnesses of Ra ≤2 µm can be achieved.

A copper sample part (left), a metallic forcep for medical applications (centre) and a casting filter for low-pressure casting of aluminium rims (right) (Courtesy Exentis Group AG)

According to the group, productivity is comparable to that of injection moulding (metal or polymer), with a major advantage being the rapid setup time thanks to the lack of need for expensive tooling which takes many weeks to produce. Exentis can provide screens within just a few days.

Customers have the option to purchase the Additive Manufacturing systems for in-house production, with guidance on the appropriate materials, development and supply of specific paste systems, screens, process technology and training provided by Exentis. Alternatively, Exentis can manufacture components for customers at its operations in Switzerland or Germany.

Exentis reports that it has already installed three inline 3D production units at customer sites, each with the capacity to produce several millions of parts.

www.exentis-group.com

Renishaw Inc. appoints Denis Zayia its president

Renishaw Inc., based in West Dundee, Illinois, USA, the US division of Renishaw, headquartered in the UK, has announced the appointment of Denis Zayia as its president. The appointment was effective January 1, 2020.

Zayia began working with Renishaw as Coordinate Measuring Machine Business Manager in 1995 and became National Sales Manager for Industrial Metrology in 2008. He previously served as Vice President Sales and Marketing, where he was responsible for Renishaw's line of Industrial Metrology and Additive Manufacturing products.

He earned a Bachelor of Science degree in Electrical and Electronics Engineering from the University of Illinois at Chicago. In the role of president, Zayia succeeds Howard Salt, who is moving to a new role as Senior Business Manager Encoder Systems.

"Renishaw has been developing industry-changing products and end-to-end solutions for over forty years," Zayia stated. "Our first product was a touch-trigger probe, which was developed to solve a manufacturing problem on Concorde engines."

"Today, we are helping manufacturers driven by the goals of Industry 4.0 with a wide range of technologies including additive, motion control, healthcare, spectroscopy, quality assurance and process control," he continued. "I am incredibly excited about the opportunity to lead the organisation through its next phase of growth."

Denis Zayia is the new president of Renishaw Inc (Courtesy Renishaw Inc)

The Renishaw Group currently has more than eighty offices in thirty-six countries, with over 5,000 employees. AM Solutions Centers are located in the USA, UK, Germany, Canada, India and China.

www.renishaw.com


FARSOON
TECHNOLOGIES
OPEN FOR INDUSTRY
FS301M
Design for Metal Production.
Enhanced User Operation.
Compact Machine Design.
> Learn more!
Gearbox Mount
Material: AlSi10Mg
Size: 275×245×191mm
Partner: Siemens
> Lightweight optimized by Siemens NX
> Fabricated on Farsoon FS301M
> Meet the required functional strength
Meet with us about our truly open AM systems.
www.farsoon.com
CONTACT US:
AMEA: globalinfo@farsoon.com
Americas: info@farsoonam.com
Europe: wehelpyou@farsoon-eu.com
AMUG
VISIT us at Booth 45 !
March 22-26, 2020
rapid + tct
VISIT us at Booth 2200 !
April 20-23, 2020

HIPER | 恒普

Full Series Debinding and Sintering Furnace

for Additive Manufacturing(AM)

- **Debinding and sintering for Metal Binder Jet and FDM**
- **Heat treatment for Laser Printing**
- **Graphite hot zone and Moly hot zone available**
- **High vacuum acceptable**




Hiper is the leading AM furnace manufacturer in the world

- Graphite/Metal hot zone debinding and sintering furnace
- Tailormade furnace acceptable

E : xiangwei.zou@hiper.cn/W: www.hiper.cn
NO.521,Haitong Road,Cixi City,Zhejiang,China

European Powder Metallurgy Association to establish new secretariat in France

The European Powder Metallurgy Association (EPMA) has announced that it will close its UK-based head office on April 30, 2020, and will establish a new secretariat team located in Chantilly, France.

The EPMA was founded in Brussels in 1989, and has had its secretariat based in Shrewsbury, UK, since 1990. A second office, established as a base for the EPMA's technical team, was opened in Chantilly, France, in 2018.

According to the EPMA, the decision has been made in order to improve overall efficiency, as well as enabling a better platform for cost optimisation. As of May 1, the French office will become the association's main administrative base and home to a new secretariat team. The EPMA's registered headquarters will remain in Brussels.

To ensure a level of continuity in the run-up to the EPMA's Euro PM2020 Congress & Exhibition, a number of key UK-based staff members will reportedly continue to work from home, with employment extended until the event.

www.epma.com

Samuel acquires remaining shares of Burloak Technologies

Samuel, Son & Co., Limited, a metals distributor and industrial products manufacturer based in Mississauga, Ontario, Canada, has acquired all remaining shares of Additive Manufacturing company Burloak Technologies, Burlington, Ontario, Canada. Samuel initially acquired a minority stake in Burloak Technologies in 2017.

The company has appointed Simon Walls, Samuel's CCO, to the position of President of Burloak Technologies, and Peter Adams, previously Burloak's President and co-founder, has been named co-founder and CIO.

"Our early belief in the transformative potential of Additive Manufacturing is paying off," stated Colin Osborne, Samuel's President and CEO. "The rapid development of this team, its relationships with many of the world's most innovative companies and the reputation it is developing as AM experts, reinforces the exciting future we see for Additive Manufacturing over the long term."

Adams commented, "We are proud of the progress we've made to rapidly scale Burloak Technologies into an industry leader in a very short time. As more companies begin to fully leverage this technology, we will see additive take off in a number of end markets. With Samuel's continued support, Burloak is uniquely positioned to remain at the forefront of that growth."

www.samuel.com | www.burloaktech.com

Particle Testing Authority launches testing service for AM powders

Particle Testing Authority (PTA), a division of Micromeritics Instrument Corporation, headquartered in Norcross, Georgia, USA, reports that it has created a comprehensive physical characterisation service for the Additive Manufacturing industry. The testing service is expected to provide fast and efficient access to the techniques routinely used to optimise process performance and the attributes of finished products.

PTA states that the relevant characteristics of AM powders (including metals, polymers and other materials) includes particle size and shape, density, porosity, bulk powder flowability, surface area and topography and environmental stability. According to PTA, it will quantify these characteristics using state-of-the-art instrumentation backed by in-depth materials characterisation knowledge. The resulting service is said to provide remarkable value for AM powder developers, manufacturers and users looking to augment, enhance or replace in-house analytical services with a more effective approach.

"We provide more comprehensive testing for AM powders than many in the industry can sustain in an in-house lab," commented Greg Thiele, General Manager of PTA. "For example, in addition to high-resolution laser diffraction particle sizing, we offer other techniques such as gravity sedimentation which can help to elucidate particle size distribution, to robustly quantify the fine and coarse fractions that can be crucial to powder performance."

"We also use the Freeman FT4 Powder Rheometer®, an instrument used by leaders in the industry to sensitively differentiate the bulk flowability of AM powders in a way that correlates directly with printing performance," Thiele added.

The properties that PTA measures in AM powders influence or quantify how they will flow, pack and respond to the thermal energy used in AM. These are the characteristics that define processability, whether a powder can be processed by AM and the throughput that can be achieved, and critical attributes of the finished product, such as resolution, strength and porosity. The resulting data support the development of new powders for specific AM systems, the effective differentiation of supplies, powder choice for a new application and the evolution of effective powder management and recycling strategies.

"Powder-based AM processes are exacting, and competing effectively relies on the application of a fairly extensive analytical toolkit," Thiele continued. "We're delighted to be able to offer access to all the instrumentation required along with the know-how required to generate relevant data of exemplary quality. Buying analytical services can be extremely cost-effective when costs are robustly assessed against the expense of maintaining a full in-house capability, or worse, not being able to reliably predict or elucidate AM powder performance."

www.particletesting.com

PostProcess Technologies partners with K.K. Irisu to reach the Asian market

PostProcess Technologies has partnered with K.K. Irisu (Courtesy PostProcess Technologies Inc.)

PostProcess Technologies Inc., Buffalo, New York, USA, a provider of automated post-production solutions for industrial Additive Manufacturing, has reported that it is expanding into the Asian market with its first distribution partner, K.K. Irisu (C. Illies & Co., Ltd.), located in Tokyo, Japan.

K.K. Irisu was founded in 1859 as the first German trading house operating in Japan. The company offers comprehensive products and services portfolio for Additive Manufacturing, including scanners, parts prototyping and production technologies. K.K. Irisu states that adding PostProcess Technologies' full-stack solutions to its portfolio will allow its customers access to sustainable, data-driven post-printing technology enabling Additive Manufacturing at scale, with local support now readily available in Japan.

PostProcess Technologies explains that its solutions automate industrial Additive Manufacturing's most common post-production processes with a software-based approach, including support, resin and powder removal, as well as surface finishing, resulting in "'customer-ready' additively manufactured parts. Its technology reportedly delivers transformative results, including decreased manual labour, reduced cycle time, improved consistency and repeatability, and lower scrap rates.

"PostProcess has been a pioneer in our market segment, leading the way with a full-stack approach to post-printing unlike any other," commented Bruno Bourguet, Managing Director, PostProcess Technologies International. "That's why we've chosen K.K. Irisu, another pioneer with an exceptional legacy, for its experience and expertise to serve our growing global customer base in Japan."

Dr Frank Oberndorff, President of K. K. Irisu, added, "K.K.Irisu's main objective is to educate the Japanese market in Additive Manufacturing and to continue to be the solution provider for the Japanese 3D manufacturing world. We feel that by adding Post-Process Technologies to our lineup, will help assist the Japanese market to compete with other countries in Additive Manufacturing as well as globally maintain the high standards of the tag 'Made in Japan'."

www.postprocess.com
www.irisu.jp

NIOSH and America Makes partner to advance research in Additive Manufacturing

The US's National Institute for Occupational Safety and Health (NIOSH), a federal institute that conducts research and makes recommendations for preventing work-related injuries, illnesses and deaths, has partnered with America Makes, Youngstown, Ohio, USA, to contribute to advancing knowledge and practice in Additive Manufacturing.

With over 220 members, America Makes is a public-private consortium working to advance and disseminate understanding in AM. NIOSH is reportedly well-positioned to contribute to the emerging knowledge and guidance around workplace safety practices, for both employers and workers.

According to NIOSH, the membership with America Makes will allow the federal institute to increase collaboration in scientific research, discovery, innovation, education, and recommendations relating to workplace environment, safety, and health. Some of NIOSH's current research is investigating potential respiratory health effects from exposure to emissions from Additive Manufacturing, including exposure to ultrafine particles, evaluating engineering controls, and providing good practise guidance to protect workers.

"We are pleased to enter into what promises to be a collaborative and creative partnership with America Makes," stated John Howard, MD, Director of NIOSH. "By working alongside industry, academia and other government partners, we can together leverage existing resources, collaborate, and co-invest to advance manufacturing innovation."

www.americamakes.us

www.cdc.gov

Unitedcoatings Group becomes Lincotek

Unitedcoatings Group, headquartered in Rubbiano, Italy, has now finalised its rebranding strategy, which sees the company renamed 'Lincotek' across all individual group brands. The group will be organised by divisions, similar to its previous structure, consisting of Lincotek Surface Solutions, Lincotek Medical, Lincotek Equipment and Lincotek Additive.

It was stated that there are no changes in the group's business relationships and services, and that ownership of the company remains with Linda and Nelso Antolotti.

Winfried Schaller, CEO of Lincotek, stated, "We are now more global than ever before and the rebranding as Lincotek signals that we are entering a new era at the start of the 2020s. Management of the new company remains exactly the same, which means there's a sense of real continuity for our existing customers."

www.lincotek.com

Fraunhofer IWS & TU Dresden develop AM rocket engine with aerospike nozzle for microlaunchers

Researchers at the Fraunhofer Institute for Material and Beam Technology (IWS) in Dresden, Germany, and aerospace experts from TU Dresden (Dresden University of Technology) have collaborated to develop an additively manufactured rocket engine with an aerospike nozzle for microlaunchers. The scaled metal prototype is expected to consume 30% less fuel than conventional engines and has been tested by researchers on the test stand of the Institute of Aerospace Engineering at TU Dresden.

According to Fraunhofer IWS, microlaunchers are an alternative to conventional launch vehicles and capable of carrying payloads of up to 350 kg. These mid-sized transport systems are designed to launch small satellites into space, and the market for them is expected to increase in the future due to movements by the UK to build a spaceport in Scotland, and the Federation of German Industries (BDI) endorsing the idea of a national spaceport.

Fraunhofer IWS states that the aerospike engine's fuel injector, combustion chamber and nozzle were additively manufactured using Laser Powder Bed Fusion (L-PBF). The design consists of a spike-like centre-body which is designed to accelerate combustion gases.

"The technology behind aerospike engines dates back to the 1960s," commented Michael Müller, Scientific Assistant at the Additive Manufacturing Center Dresden (AMCD), which is jointly operated by Fraunhofer IWS and TU Dresden. "But our ability to produce engines as efficient as this is owed to the freedom brought by Additive Manufacturing and its embedding in conventional process chains."

Mirco Riede, Group Manager of 3D Manufacturing at Fraunhofer IWS, stated, "Every gram saved is worth its weight in gold in space flight because less fuel has to be taken into orbit. The heavier the overall system, the lighter its payload has to be."

The project researchers are now looking to the injection system in a bid to further boost engine efficiency, as injectors reportedly pose major design and manufacturing challenges. This work is being undertaken as part of a collaborative project called CFDμSAT, and has been underway since January 2020 with the Ariane Group and Siemens AG as associated partners.

"Fuels first serve to cool the engine," added Müller. "They heat up and are then induced into the combustion chamber. Liquid oxygen and ethanol are added separately to be blended via an injector. The resulting gas mixture is ignited. It expands in the combustion chamber and then flows through a gap in the combustion chamber to be decompressed and accelerated by the nozzle."

The additively manufactured rocket engine prototype is expected to be featured at technology trade fair Hannover Messe 2020, which will take place in Hannover, Germany, on April 20–24, 2020.

www.iws.fraunhofer.de
www.tu-dresden.de

This prototype of the aerospike engine has already been tested by project researchers on the test stand of the Institute of Aerospace Engineering at TU Dresden (Courtesy Fraunhofer IWS)

Stelia Aerospace and Bombardier to develop wing flaps with metal AM components

Stelia Aerospace, through its two Canadian subsidiaries, Stelia Aéronautique Canada in Mirabel, Quebec, and Stelia North America in Lunenburg, Nova Scotia, has entered into a research project with Bombardier Inc., Montreal, Canada, which will see the company produce a high-lift trailing edge flap in thermoplastic composite with metal additively manufactured hinges.

The new project, titled Aile Intelligente et Légère pour l'Environnement or Intelligent and Light Wing for Environment (AILE), is part of the third phase of the mobilising project for an eco-friendly aircraft, project SA2GE-3 (Systèmes Aéronautiques d'Avant-Garde pour l'Environnement or Cutting-edge Aeronautical Systems for Environment).

Supported by the government of Québec, the project will be part of a three-year partnership and will see Stelia Aerospace produce the trailing edge flap for testing by Bombardier. Stelia Aéronautique Canada's R&T teams, supported by the France-based R&T team, will manage the project and its design and scaling phase. Manufacturing of the tooling and the scale 1 demonstrator will be managed by Stelia Aerospace North America.

Stelia Aerospace will be backed on the project by two partners: FusiA Impression 3D Metal Inc for the production and design of the metal AM hinges, and the Conseil National de Recherches du Canada – Canadian National Research Center (CNRC), already a partner of Stelia Aerospace for metal research projects.

Stelia Aerospace has already been engaged with Bombardier for three years in the context of a first collaborative R&T project aiming at reducing the cycle time necessary to the production of a metallic wing frame for business jets. Cédric Gautier, CEO of Stelia Aerospace, commented, "This new project with Bombardier highlights our wish to build strong links with our customer and will enable us to pursue our skill development strategy, while developing our footprint in Canada in terms of Research & Technology."

www.stelia-aerospace.com
www.bombardier.com

Stelia Aerospace will develop high-lift trailing edge flaps for Bombardier (Courtesy Bombardier)

Retsch Technology, Microtrac Europe and Bel Europe merge to become Microtrac MRB

Retsch Technology GmbH, Haan, Germany, Microtrac Europe GmbH, Krefeld, Germany, and Bel Europe GmbH, Krefeld, Germany, have reported that they have merged to become the new Microtrac Retsch GmbH, under the brand Microtrac MRB. This move is expected to allow users of particle characterisation in the EMEA region to access the broadest product portfolio globally from one single source.

The companies explain that under the brand name Microtrac MRB, they will provide systems for particle characterisation by laser diffraction, dynamic light scattering, dynamic & static image analysis, as well as gas adsorption measurement to determine the specific surface and pore size distributions.

Retsch Technology has been part of the Verder Group since its foundation in 1998, providing solutions for particle characterisation with dynamic image analysis by developing the dual camera technology implemented in the CAMSIZER series.

Microtrac MRB is now marketing itself as a leading manufacturer of instruments used for particle characterisation in a size range from 0.8 mm to 135 mm. Based on a variety of measurement techniques, a wide range of particle properties of dry powders and granulates, as well as suspensions and emulsions, can reportedly be analysed using the equipment provided by the company. Its product portfolio also includes gas adsorption analysers.

Gerhard Raatz, Sales Director of Microtrac Retsch, stated, "By merging our companies we can now leverage our combined capabilities, along with our business and customer relationships and profit from synergetic effects. With our comprehensive product range, we strengthen our global position as an innovative and trustworthy partner for our customers."

www.microtrac.com

Rapid Application Group expands capabilities with new Additive Manufacturing facility

Additive Manufacturing service provider Rapid Application Group (RAG), headquartered in Broken Arrow, Oklahoma, USA, recently held an opening ceremony for its new 1,394 m^2 (15,000 ft^2) AM facility, located at its headquarters as part of the company's growth strategy. The grand opening featured speeches by state and local government officials, a review of the AM industry, and the ribbon cutting for the new facility.

RAG was founded by Terry Hill, CEO, and Jason Dickman, COO, with the aim of delivering the country's best production services and solutions to customers through a wide range of AM and traditional manufacturing technologies. RAG is accredited with certifications for AS9100D, ISO 9001, ITAR, and HUBZone, and delivers mission-critical additively manufactured parts primarily in the aerospace and defence sectors, but also supports other industries.

"Rapid Application Group was founded by seasoned military veterans and Additive Manufacturing experts to meet mission-critical production work for manufacturers across all industries," stated Hill, CEO, Rapid Application Group. "This new facility enables both growth of the company and more opportunities to mentor and train military veterans in the advanced manufacturing field."

In its hiring practises, RAG aims to make 50% of its staff military veterans. The company has also established a non-profit veteran outreach effort called the RAG Friday Foundation which aims to improve the quality of life for veterans.

www.rapidapplicationgroup.com ■

Rapid Application Group co-founders and CEO Terry Hill and COO Jason Dickman in the company's new AM facility (Courtesy RAG)

Stratasys appoints Yoav Zeif as its new CEO

Stratasys Ltd, headquartered in Eden Prairie, Minnesota, USA, and Rehovot, Israel, appointed Yoav Zeif its CEO on February 18, 2020. Elchanan (Elan) Jaglom, the company's current Interim CEO, will continue in his role as Chairman.

Zeif reportedly brings global experience in industry transformation to Stratasys, having served in senior leadership roles for both public and private multi-billion-dollar corporations, leading worldwide operations across industries and professional domains. Previously, Zeif was President of the Americas Division, Head of Product Offering and Chief Commercial Officer at micro-irrigation company Netafim, from 2013 to 2018. Prior to that, he was Senior Vice President of Products and Marketing at Makhteshim (now Adama Ltd.), a global crop-protection company.

Since 2018, Zeif has been a partner in the New York office of McKinsey & Company. He obtained an Executive MBA from the Kellogg School of Management at Northwestern University and a PhD in International Economics from Bar-Ilan University.

Zeif is said to have an extensive executive management background in leading sales, product, R&D and manufacturing activity in complex competitive environments. At Netafim, he led the global development of an advanced irrigation system that leveraged Internet of Things (IoT) technology and artificial intelligence. He also restructured the organisation's go-to-market strategy and expanded its coverage through an M&A strategy. With responsibility spanning a number of global geographies and multiple lines of business, Zeif reportedly delivered growth rates significantly higher than the surrounding market.

"Stratasys has led the expansion of the 3D printing industry for more than three decades, but the potential impact of this transformative technology across all industries is just beginning," stated Jaglom. "Yoav brings the strong combination of leadership and global operational experience to fuel our next stage of growth. We are confident that as CEO he will advance our offering and further our vision to reshape the world of design, prototyping and manufacturing."

Zeif commented, "Stratasys pioneered and continues to power the Additive Manufacturing landscape, enabling companies across virtually all industries to build and improve their businesses through 3D printing technology."

"In particular, thanks to its outstanding innovations and application engineering, it is clear that Stratasys is poised not only to reshape product development and prototyping but also to transform supply chains and manufacturing through efficiency and personalisation," he stated.

www.stratasys.com

Significant weight savings in Arcimoto electric vehicle through metal Additive Manufacturing

Electric vehicle manufacturer Arcimoto, Inc., Eugene, Oregon, USA, and XponentialWorks, Ventura, California, USA, have partnered to lightweight a number of components in Arcimoto's pure electric Fun Utility Vehicle® (FUV®). Among the redesigned parts, developed using ParaMatters' software, is a metal additively manufactured steering knuckle and three cast parts built from additively manufactured patterns.

ParaMatters' design software offers artificial intelligence and computer generated design, and was used to completely redesign the components with geometries mimicking natural structures. If the new parts prove successful, it is expected that they may take the place of heavier, conventionally manufactured parts, enabling Arcimoto's electric vehicles to drive farther on a single charge, improve acceleration, and deliver better handling.

The lightweighted parts included a rear swing arm, upper control arm, brake pedal and the metal AM steering knuckle. The conventionally manufactured knuckle consisted of nine welded parts in mild steel and weighed 2.7 kg. The redesigned part was additively manufactured as a single structure in MS1 steel, and weighed 1.7 kg – a reduction of 36%. It was also reported to be three times stronger than the conventionally manufactured part.

Avi Reichental, XponentialWorks founder, stated, "We are very excited to work with Arcimoto to leverage our technological know-how to make this incredible vehicle even more outstanding. The entire redesign, from concept to parts, took only four weeks, further demonstrating how 3D printing technology is completely changing how we design and manufacture products."

"We are thrilled to open Arcimoto's ultra-efficient vehicle platform to XponentialWorks' team of lightweighting and Additive Manufacturing experts," added Mark Frohnmayer, Arcimoto CEO. "Our mission to right-size the footprint of daily mobility means a continued commitment to optimising not just the vehicle platform architecture, but all of its constituent parts as well. The speed at which the XponentialWorks team has made meaningful weight improvements to core components of the Fun Utility Vehicle is truly impressive."

"With the powerful combination of AI-generated designs and ultra-fast 3D printing processes, we are now able to create complex geometric structures which substantially lightweight vehicles, improve performance, lower production costs and save on battery power. We welcome this opportunity with Arcimoto to provide their drivers with the best possible in-vehicle experience," added Reichental.

"In this new age of Industry 4.0 manufacturing, no one company can do it all alone. This project demonstrates the power of curating relationships and building joint innovation programs that pool together resources and expertise from complementary organisations to create practical tractable products in record time," he concluded.

www.xponentialworks.com
www.arcimoto.com

The metal additively manufactured steering knuckle (left) weighed 36% less than the conventionally produced part (right) (Courtesy XponentialWorks)

A number of components in Arcimoto's electric Fun Utility Vehicle were redesigned using AM (Courtesy XponentialWorks)

GE, ORNL & PARC to accelerate AM part design of turbomachinery components

GE, in partnership with Oak Ridge National Laboratory (ORNL), and PARC, a Xerox company, have been awarded more than $1.3 million in funding from ARPA-E's DIFFERENTIATE (Design Intelligence Fostering Formidable Energy Reduction (and) Enabling Novel Totally Impactful Advanced Technology Enhancements) programme, for a project aiming to drastically reduce the time for designing and validating high-performance metal additively manufactured components for use in turbomachinery applications. The goal is to reduce the design and validation timeline by some 65%, making this stage faster than many traditional manufacturing processes and paving the way for the much broader proliferation of the technology in turbomachinery product design.

Today, the design of new components for complex power products such as jet engines, wind turbines and gas turbines involves dozens of experts in the various structural, thermal and fluid properties that apply to them. When designing a new component for AM, a wide variety of factors must be considered such as how well its material composition responds to heat and stresses, or how its design impacts airflow or aerodynamic performance. Pulling this expertise together and later validating a part can take between two and five years.

Researchers from GE, ORNL and PARC explained that they believe they can reduce the overall timeline for creating and validating new AM part designs by more than half, which would make AM faster than traditional casting. Brent Brunell, leader of GE Research's additive efforts, stated, "One of the keys to enabling the widespread use and benefits of 3D printing is the reduction of the time it takes to create and validate defect-free 3D component designs. Using multi-physics enabled tools and AI, we think we can beat the timeline for some traditional manufacturing processes by automating the entire process."

Brunell explained that the optimisation of structural characteristics has already been automated, but has not extended to a part's thermal and fluid properties. On this project, researchers from GE and PARC will seek to incorporate all three, using AI to automatically generate surrogate models from additive producibility data and seamlessly integrate it with multi-physics design optimisation techniques.

The team will use the Summit supercomputer at the Oak Ridge Leadership Computing Facility at ORNL to create these AI-based surrogates with very high precision. In addition, ORNL's High Flux Isotope Reactor will be used to analyse additively manufactured components and generate the data necessary for training and evaluating AI-based models.

"This is the type of project that leverages the unique capabilities at ORNL – experimental and computational facilities – as well as expertise in computational science and Additive Manufacturing," commented John Turner, Computational Engineering Program Director at ORNL.

The programme will culminate in the demonstration of a defect-free, high-performance additively manufactured multi-functional design capable of withstanding high temperatures and stresses with improved performance vs conventional casting. According to Saigopal Nelaturi, Manager of Computation for Automation in Systems Engineering area in the System Sciences Lab at PARC, "The combination of model-based and data-driven AI to accelerate generative design is a key innovation that will dramatically reduce the time to synthesise and fabricate quality parts.

"Surrogate models (built using machine learning) that encapsulate complex couplings between process physics and part quality will help guide the optimisation models in feasible regions of very high dimensional design spaces," Nelaturi explained. "This combination of AI techniques enables automatic multi-functional part synthesis to meet real-world application demands, for which AM can provide truly novel solutions."

www.ge.com
www.ornl.gov
www.parc.com

Researchers from GE, ORNL and PARC are collaborating to reduce the timeline to design and validate metal AM components by as much as 65% (Courtesy GE)

DMP Flex 350 DMP Factory 500

Solukon introduces automated powder removal system for large components

Solukon Maschinenbau GmbH, Augsburg, Germany, has introduced the SFM-AT1000, an automated depowdering system for large additively manufactured parts. The depowdering process is carried out by programmable pivoting of the components, including the building platform, around two spatial axes.

Solukon's SFM-AT1000 system for depowdering large additively manufactured parts (Courtesy Solukon Maschinenbau GmbH)

In order to optimise the powder flow, the powder is 'fluidised' with adjustable frequency excitation which enables the cleaning of small openings and channels. Solukon explains that due to the gentle and contamination-free process, the released powder remains unchanged and can be discharged for reuse. The process is fully automated and takes place in a protected atmosphere, thus avoiding contact with hazardous fine dust and saving valuable working time.

Solukon's portfolio currently comprises three machines, the SFM-AT800, which was introduced in 2014 is the largest machine, offering a loading volume of 800 x 400 x 550 mm and 300 kg component weight. With the release of the SFM-AT1000, the company introduces two completely new formats, with a component size of up to 460 x 460 x 1,000 mm and 500 x 280 x 1,000 mm.

The company states that the SFM-AT1000 is reportedly based on the SFM-AT800 system but features a reinforced slewing system with a novel and particularly compact design. The aim of the new design was to move the higher loads with ease but to keep the chamber volume as small as possible in order to minimise inert gas consumption. The swivel system has two endlessly rotatable servo drives, so that the component can be moved into any position.

According to Solukon, its systems meet the highest demands on functionality and are approved for safe processing of reactive and hazardous metal powders thanks to its innovative safety technology. The systems are CE-conform equipped with UL-conform components and built to meet the requirements of NFPA 29.

www.solukon.de

QuesTek co-founder Prof Greg Olson joins Massachusetts Institute of Technology

QuesTek Innovations LLC, a leading developer of metal alloys based in Evanston, Illinois, USA, has announced that Professor Greg Olson, the company's co-founder, Chief Science Officer, and a member of its Board of Directors, has joined the faculty of the Department of Materials Science and Engineering at Massachusetts Institute of Technology (MIT), as Thermo-Calc Professor of the Practice. Prior to this, Prof Olson was a full-tenured professor of Materials Science and Engineering at Northwestern University.

Called the 'father of materials design' by the American Academy of Arts and Sciences, Prof Olson and his work have led to the rapid design and development of materials through computational modelling and simulation. As co-founder and Chief Science Officer of QuesTek Innovations, his leadership and systems resulted in the development of high-performance metal alloys, used in aerospace, defence, oil and gas and high-performance automotive applications. His new affiliation with MIT is expected to expand the research assets available to QuesTek and its clients.

Prof Olson received his Doctorate in Materials Science and Engineering from MIT and has previously been honoured with election to National Academy of Engineering (NAE) and the American Academy of Arts and Sciences (AAAS), Fellowship in TMS, and the ASM International Gold Medal. QuesTek states that his approach to materials design has been highlighted in numerous technology reports, including a National Institute of Standards and Technology (NIST) / Materials Genome Initiative success story on design and deployment of Ferrium M54 steel into US Navy applications.

QuesTek explained that Dr Olson's departure from Northwestern University will not affect the company's close relationship with the university's industrial outreach programme and its Materials Science and Engineering department and facilities. "This is an exciting time for Greg," commented Dr Jason Sebastian, QuesTek President. "His role as QuesTek Chief Science Officer will be enhanced with more of his time devoted to working with the QuesTek team. In addition, in his new position at MIT, Greg will be collaborating with other top material science researchers, which benefits everyone."

www.questek.com
www.mit.edu

Project to build large-scale multi-robot metal AM machine reports results

The European Federation for Welding, Joining, and Cutting (EWF), Porto Salvo, Portugal, has reported on the results of a cooperative research project to create a multiple-robot modular metal Additive Manufacturing machine integrating both additive and subtractive manufacturing capabilities, and capable of producing large components directly from a CAD drawing. The project, titled LASIMM (Large Additive Subtractive Integrated Modular Machine), involved ten partners.

According to EWF, the end result of LASIMM is a fully functional machine that includes advanced software to manage the entirety of the complex production process, integrating Wire Arc Additive Manufacturing (WAAM) technology alongside other advanced manufacturing processes and robotics that allow it to produce metal components up to 5 m long and 3 m wide.

To assess the machine's feasibility as a production tool in real-world scenarios, the project members have tested the manufacturing of aluminium, steel and titanium components, said to bring the concept one step closer to mainstream use.

The LASIMM project has developed a fully functional prototype of a multi-robot additive and subtractive manufacturing machine (Courtesy LASIMM Project)

The modular approach of the machine's system architecture is said to enable flexible reconfiguration, making it possible to develop and assess several machine concepts. No other setup operations are believed to be required apart from those necessary to load and unload the machine at the beginning and at the end of the manufacturing/repair process.

The LASIMM project also evaluated additional features, such as cold-work, metrology and inspection, to be added into the machine. EWF explains that the possibility of integrating these extra capabilities within the machine, from rolling to peening and in-situ allowing, would enable the production of fully functional parts with superior mechanical properties that, in parallel, could lead to major cost and production time savings.

Another unique feature of the machine, reports the EWF, is its capability for parallel manufacturing, featuring either multiple deposition heads or concurrent addition and subtraction processes. This parallel manufacturing capability requires that the machine architecture is based on robotics. To ensure that the surface finish and accuracy needed for an engineering component is obtained, a parallel kinematic motion (PKM) robot are employed for the subtractive step.

It is estimated that it will take up to one year for the industrialisation of the project to take place, after which the complete hybrid cell will be ready for commercial distribution. The deliverables are said to include a modular self-contained platform with TRL (Technology Readiness Level) 6 (on a scale of 1–9, with the latter as the highest). The platform will extend the current build size of complex parts to up to 6 m in length and hundreds of kilograms in weight, in aluminium and steel, with excellent mechanical properties that match, or even surpass, equivalent forged alloys.

The ten project partners include the EWF, BAE Systems (Operations) Ltd., Foster + Partners Limited, Vestas Wind Systems A/S, Cranfield University, Global Robots Ltd., Loxin2002, S.L., Helmholtz-Zentrum, Geesthacht Zentrum fur Material – und Kustenforschung GMBH, Delcam Ltd. and Instituto Superior Técnico. This project received funding from the European Union's Horizon 2020 research and innovation programme.

www.lasimm.eu

ADDere demonstrates the benefits of Laser Wire AM for large-scale parts

ADDere, the metal Additive Manufacturing division of Midwest Engineered Systems Inc., headquartered in Waukesha, Wisconsin, USA, has reported the advantages of using Laser Wire Additive Manufacturing (LWAM) for producing large-scale, large-mass components for industries such as energy, aerospace, marine and defence.

"Currently, the AM focus has been on powder-based metal systems," stated Scott Woida, ADDere President. "That focus had a lot of potential markets stuck on the outside looking in, but those industries now see a legitimate 3D printing roadmap for their parts through what we've been doing with ADDere."

As an example of what's now possible with wire-based AM, ADDere has additively manufactured titanium and 17-4 stainless steel blocks. The titanium blocks are 15 cm x 15 cm x 30 cm and weigh 32 kg. The 17-4 blocks (also known as SAE type 630 or UNS 17400) are of the same dimension but weigh in at 55 kg. According to ADDere, the production of each of these blocks took just over six hours.

ADDere explains that, at over three times the size of most powder metal-based systems on the market, the standard ADDere AM systems feature a build area of 2 m x 1 m x 1 m and 2,000 kg capacity. The ADDere Laser Wire Additive Manufacturing system is said to specialise in producing additively manufactured large-scale, near-net shape parts in a variety of metals including titanium, stainless steel, Inconel and other superalloys, as well as most ferrous-based metals.

"We've already proven we can build things at large scales, these blocks show we can 3D print parts with substantial mass in a relatively competitive timeframe with casting," commented Pete Gratschmayr, VP of Sales & Marketing. "Now real conversations can be had about printing large, high-mass components like transmission cases, truck frames and turbine engine mounts without adding 'in the future' to the sentence. We can do it today."

www.addere.com

One of the 17-4 stainless steel blocks with machined section that ADDere produced using Laser Wire Additive Manufacturing (Courtesy ADDere)

Remembering Carl Deckard, Inventor of Selective Laser Sintering

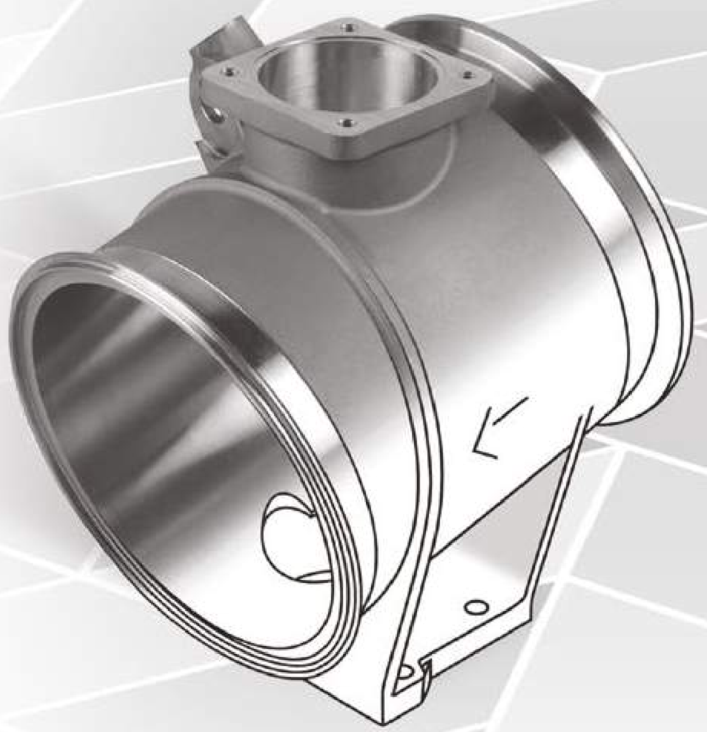

Carl Deckard, recognised as the inventor of Selective Laser Sintering, has died (Courtesy AMUG)

Carl Robert Deckard, recognised as the inventor of Selective Laser Sintering (SLS), passed away on December 23, 2019. Along with SLS, Deckard is also credited with inventing the Deckard Engine as well as a number of polymers for use in Additive Manufacturing.

With twenty-seven patents, Deckard was profiled by *Fortune* magazine as one of five modern technology pioneers, inducted into the Manufacturing Hall of Fame by *Industry Week*, and named a Master of Manufacturing by the Society of Manufacturing Engineers. Born in Houston on June 20, 1961, Deckard attended elementary school in Michigan, Ohio, and Port Arthur, Texas. After attending junior high in Clear Lake City, he moved back to Port Arthur and graduated from Thomas Jefferson High School. He attended the University of Texas at Austin (UT), where he majored in Mechanical Engineering and went on to study for a Master's degree. During a summer internship, he started to think about a new invention – a way to fabricate parts directly from drawings by using a laser to fuse together powder in the shape of the part and building up the piece, layer by layer.

He worked with Dr Joe Beaman, a young assistant professor in Mechanical Engineering, to develop the process that became known as Selective Laser Sintering, one of the earliest and most enduring forms of Additive Manufacturing. The result of his Master's project was an SLS plastic cube within another plastic cube, and with the help of a grant from the National Science Foundation, he continued working on his invention for his PhD under the direction of Dr Beaman.

Deckard's graduate work was so successful that UT agreed to license the technology in 1988, said to be the first time that UT had entered into such an agreement. This started the process of Deckard transforming his invention into a commercial product. In recent years, Carl worked with his collaborators, Jim Mikulak and Vikram Devarajan, to invent new polymers, making it possible to make better quality additively manufactured 3D parts. ■■■



Metallic3D introduces new bound metal paste Additive Manufacturing machine

Metallic3D, based in Stuart, Florida, USA, has added a new metal Additive Manufacturing machine, the M3D300. Utilising the company's bound metal paste deposition technology, the M3D300 is reported to offer a safe, easy to use system capable of manufacturing components in a wide range of metals.

The bound metal paste process is said to be suitable for any office or workshop environment, with no fumes or odours created in the M3D300 machine. Due to the use of a solvent-based binder in the feedstock, the company states that most of the binder evaporates during the build. Any residual binder is then removed during the sintering stage, rather than an additional debinding stage, which Metallic3D says makes its AM process faster from initial design to fully finished part.

"Additive Manufacturing has now for some time been the solution of choice when producing highly diverse parts," states Dan Defelici, owner of the company. "3D printing enables the emergence of radical product innovation through function-oriented design properties. Paired with the outstanding material properties of high-performance ceramics and advanced metal powders, industries and research teams can now explore entirely new areas of applications."

By building the complete system in-house, Metallic3D states it can significantly lower the barrier of entry into Additive Manufacturing. "Our new desktop printer is up to 10x less expensive than alternative metal Additive Manufacturing technologies and up to 100x less than traditional fabrication technologies like machining or casting. This gives the owner of a Metallic3D printer a higher ROI, less time making parts and fewer worries over quality," added Defelici.

www.metallic3d.com

Metallic3D's new M3D300 AM system (Courtesy Metallic3D)

A selection of parts built using Metallic3D's AM systems (Courtesy Metallic3D)

Bassetti to integrate Senvol Database in its TEEXMA for Additive solution

The Bassetti Group, headquartered in Grenoble, France, has signed an agreement with Senvol to provide the Senvol Database of industrial Additive Manufacturing machines and materials as an integrated source of data in its TEEXMA for Additive platform.

TEEXMA for Additive is an end-to-end solution supporting the complete AM product life cycle. The software offers full traceability by combining project management, materials, manufacturing, quality and knowledge management tools and processes in a single platform with a common interface.

Integrating the Senvol Database is said to provide the data necessary for companies to investigate and compare a multitude of AM material and process options. The Senvol Database is used by many industries, including automotive, aerospace and defence, oil & gas, heavy industry, medical devices, and consumer products.

Bassetti, founded in 1992 to help companies manage their technical expertise, has continued to expand globally across Europe, Asia, and North America. The company's TEEXMA platform is used by more than 400 companies and 125,000 users in various industries around the world. Solutions are modular and can be implemented individually or in combination in order to support each company's needs.

www.bassettiamericas.com
www.senvol.com/database

Dutch Aerospace Centre to install Xerion Fusion Factory Compact

The Dutch Aerospace Centre (NLR), based in Marknesse, the Netherlands, in cooperation with the Dutch Ministry of Defence, will install a Fusion Factory Compact debinding and sintering unit for use in its development of sinter-based Additive Manufacturing. This jointly undertaken research reportedly focuses on defence applications such as battle damage repair.

The Fusion Factory Compact debinding and sintering unit, which began serial production at the beginning of 2020, is built by Xerion Berlin Laboratories GmbH, Berlin, Germany. With a footprint of just 1.2 m², the unit is designed to debind and sinter parts additively manufactured with BASF Ultrafuse 316L® filament, enabling the processing of parts within twenty-four hours.

Xerion's ultra-compact Fusion Factory debinding and sintering unit (Courtesy Xerion Berlin Laboratories GmbH)

In accordance with the BASF CATAMOLD® principle, debinding is carried out by catalytic means, while the sintering furnace can reach temperatures of up to 1,450°C under protective gas conditions. Sintering under a 100% hydrogen atmosphere is also possible.

With no powder bed used in the Fused Filament Fabrication (FFF) process, and 100% of the metal powder contained in the filament, it enables the machine to be used in particularly rough or hazardous conditions, such as those found on marine vessels. The overall size of the unit, with external dimensions of 1,200 x 1,000 x 2,000 mm, further supports these application.

www.xerion.de

www.nlr.org

3D Systems President and CEO Vyomesh Joshi to retire

3D Systems, Rock Hill, South Carolina, USA, states that Vyomesh (VJ) Joshi, its President and CEO, has notified the Board of Directors of his decision to retire and that the board has initiated the search for his successor. Joshi will continue to serve in his current role until a new CEO is appointed, after which he will transition to the role of strategic advisor to the company.

Vyomesh Joshi, President and CEO of 3D Systems, is to retire (Courtesy 3D Systems)

"On behalf of the Board of Directors, I want to personally thank VJ for his accomplishments at 3D Systems. He is a pioneer and a visionary in digital manufacturing solutions and he has led this company through a vital phase," stated Charles (Chip) McClure, Chairman of the Board of Directors. "I have such great respect for him and his career. He is a man of integrity and I am grateful to have served alongside him."

Joshi joined 3D Systems in April 2016. Under his leadership, the company is said to have stabilised financially, significantly improved its product quality and reinvigorated innovation across its portfolio of AM hardware, materials, software and services to take digital manufacturing solutions from prototyping to production.

"A lot of personal reflection and discussion with the board have gone into my decision. The deciding factor was our full confidence that 3D Systems is ready for the next level," Joshi commented. "We are poised for growth and we have built a great team, a strong culture and a powerful portfolio. I am honoured to have led 3D Systems through such a pivotal stage and position the company for profitable growth in its next chapter."

3D Systems offers Additive Manufacturing machines and materials to address a wide range of applications and performance characteristics. Materials include plastic, elastomer, composite, wax, metal and number of bio-compatible options.

www.3dsystems.com

Heraeus AMLOY turns to AM for amorphous metal guitar bridge

Heraeus AMLOY, a division of Heraeus, Hanau, Germany, reports that it has successfully produced an amorphous metal guitar bridge by metal Additive Manufacturing. The guitar bridge was designed and produced in cooperation with Nik Huber Guitars, a guitar manufacturer based in Rodgau, Germany.

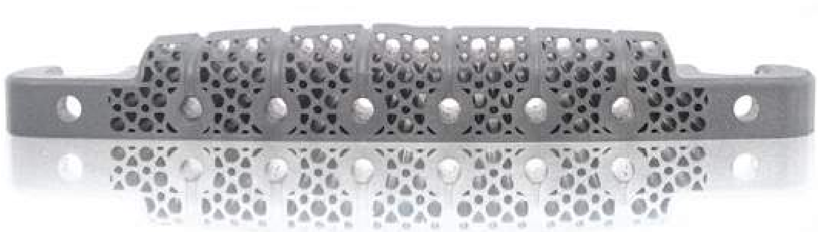
Heraeus AMLOY explained that amorphous metals offer particularly elastic properties, but are at the same time very strong. In addition to their elasticity, amorphous metals are also scratch and corrosion resistant. In contrast to conventional materials, it is expected that a guitar bridge made of amorphous metal will not wear out and will not need to be replaced. The material used is also biocompatible and therefore, unlike nickel-plated aluminium bridges, suitable for allergy sufferers.

"Since amorphous metals are significantly more elastic than crystalline materials, they transmit vibrations very well," stated Jürgen Wachter, Head of Heraeus AMLOY. "Therefore, the material is ideally suited for stringed instruments such as guitars." In addition to its aesthetic appeal, the company states that the honeycomb structure of the bridge influences its vibration period, dampening vibrations less than closed, solid structures. This changes the sound properties of the instrument.

"One could also imitate the sound of other metals by changing the structures inside the bridge," added Wachter. "A bridge made of amorphous metal would then sound like a bridge made of brass, for example. The difference is that due to its elasticity it keeps the sound longer, does not wear out and still looks like new even after years."

Nik Huber, founder and owner of Nik Huber Guitars, has been building guitars with his team for twenty-four years and reportedly enjoys testing new materials such as specialist woods or metals in guitar production. Huber commented, "3D printed amorphous metals are a promising material for guitar building due to their unique properties."

www.heraeus.com
www.nikhuber-guitars.com



The amorphous metal guitar bridge is corrosion-resistant and customisable (Courtesy Heraeus AMLOY)

BEAMIT opens agency in Japan

Italy's BEAMIT SpA has opened a commercial agency in Japan as part of its ongoing effort to bring its Additive Manufacturing services to the Japanese market. The company's Japanese representative will be Eiji Akita, a former Senior Chief Engineer of Mitsubishi Hitachi Power Systems.

BEAMIT is based in Italy and has more than twenty years of experience in metal Additive Manufacturing. It supplied advanced metal AM components to demanding industries such as aerospace, automotive, energy and racing, and holds a number of relevant quality certifications including AS 9100 for aerospace and NADCAP approval.

In 2019 Sandvik Additive Manufacturing acquired a significant stake in BEAMIT, to strengthen both companies' ability to deliver high value to their customers. Today, BEAMIT is one of the largest AM service providers in Europe, operating more than thirty Additive Manufacturing systems in its Parma facilities. The opening of a commercial agency in Japan is said to be in line with the company's strategic vision to expand its international presence in highly technological geographic areas.

www.beam-it.eu

2020 AMUG Conference: The AM community gets set to regroup in Chicago

The annual AMUG Conference is for many in the AM industry the first 'must attend' event of the new working year; a place where participants are ready once again to discover, learn, share and network.

Taking place in Chicago, Illinois, USA, from March 22–26, 2020, the thirty-second AMUG Conference will at once retain the spirit of its 'Additive Manufacturing Users Group' roots whilst continuing its evolution into an event which is fully relevant to a new generation of AM professionals – who are entering into a very different industry to that of previous decades.

With an ever-busier global AM events calendar, AMUG stands above the crowd to its regular participants as an event like no other. Crucially, attendance is restricted to those that operate or own AM technology in a professional setting. It is, therefore, a gathering of AM users, of all experience levels, who together provide and share insights and experiences to increase AM's value across industry.

Whilst this creates an immersive environment where everyone who chooses can 'contribute to the conversation', it does not mean that you'll miss the opportunity to meet with industry suppliers if you wish to. The AMUGexpo, which the organisers are always keen to stress is 'not a tradeshow', allows attendees to network with fellow participants and speak with exhibitors over dinner and drinks.

In the five years that the *Metal AM* magazine team has attended as a media partner, the AMUG Conference has not only steadily grown in numbers, but the organisers have managed to keep the event's focus 'on point' as the industry moves towards volume production. This is reflected by the growing importance of metal Additive Manufacturing within the overall programme.

The conference that never stands still...

This year's AMUG Conference again offers a range of technical sessions and hands-on workshops designed to help users get more from, and do more with, their AM systems. However, building on the success of last year's event, the 2020 conference programme will deliver even more training and hands-on experiences. The Training Lab, introduced in 2019, will again offer an engaging learning environment where AM tools are the focal point of the information exchange.

In addition to over 160 conference presentations, the sixth annual Innovators Showcase will feature an on-stage interview with 2020 Innovators Award Recipient Dr Hans J Langer, founder and former CEO of EOS GmbH and now CEO and Chairman of EOS Group. Previous recipients include Chuck Hull, co-founder of 3D Systems; Carl Deckard, creator of Selective Laser Sintering; Scott Crump, co-founder of Stratasys; Fried Vancraen, founder of Materialise; and Gideon Levy, leading developer of AM materials and technologies.

For those thinking of attending AMUG for the first time this year, some insider tips: book as early as you can, as the event is likely to be a sell-out; other than the surprise off-site party, be prepared to never have to leave the venue – from breakfast to the early hours, each day is packed with fully-catered social events and free bars; and take a lot of business cards – from 'pick a table number out of a hat' lunchtime seating to vibrant casino nights, you'll meet a lot of new faces. Hope to see you there!

www.amug.com

SLM Solutions Group reports 2019 order intake up 21%

Germany's SLM Solutions Group AG has reported that it achieved an order intake value of €67.7 million for the full year 2019, up 21% compared to 2018. In the Q4 2019, order intake of €29.5 million was recorded, which represents 100% growth year-on-year. The group states that, as announced mid 2019, its revenue and adjusted EBITDA margin for 2019 will be significantly lower than the former Executive Board team's originally forecasted group revenue of €95 million and the originally expected break-even adjusted EBITDA margin.

"As announced, we continue to work on addressing organisational gaps and positioning the company for long-term growth. Our interest is the long-term potential of SLM Solutions' technology, however, the team has worked hard and achieved great progress in the second half of 2019," stated Meddah Hadjar, CEO of SLM Solutions. "The double-digit growth in order intake in 2019 under the current market conditions demonstrates that the multi-laser technology is critical for additive adoption in all market segments. I want to thank the SLM team, our partners and our customers in believing in SLM and in the multi-laser technology."

He continued, "We still have more work to do, but with the momentum of the second half-year, we believe that we have taken the right first steps towards a long-term successful future for SLM Solutions. Sam O'Leary, who is SLM Solutions' COO since December 1, 2019, Frank Hülsmann, SLM's CFO since January 1, 2020, and the rest of the leadership staff that joined us in 2019 are working together with full dedication to position SLM Solutions as a market leader in our industry."

www.slm-solutions.com

Meggitt invests in metal AM company HiETA Technologies

Meggitt UK Ltd, a subsidiary of Meggitt PLC, which specialises in high-performance components and subsystems for the aerospace, defence and energy markets, has announced its investment in HiETA Technologies Ltd, a UK-based product design and development company specialised in the use of metal AM.

Meggitt sees the investment accelerating the development of next generation thermal systems for aerospace and energy applications. At a critical time for sustainable aviation and lower-carbon power generation solutions, it believes AM will enable new, high-performance and light-weight thermal systems to be brought to the market.

"With a 160-year track record in bringing technology to the aerospace, defence and energy markets, innovation is at the heart of everything we do," stated Hugh Clayton, Group Director of Engineering & Strategy at Meggitt. "This is an exciting collaboration with HiETA and we're proud to partner with them to push the frontiers of innovation."

Clayton added, "We look forward to a productive partnership which will shape our future: collaborating on Additive Manufacturing and thermal system technology to enable the next-generation of more sustainable aircraft propulsion systems and greener energy systems; ensuring a sustainable future for the generations to come."

Meggitt's experience in designing and manufacturing advanced heat exchanger technologies for aerospace and industrial applications complements HiETA Technologies' experience in designing and using AM to build high-performance components for aerospace, defence and motorsport applications. Mike Adams, CEO and co-founder of HiETA Technologies Ltd, commented, "This is an exciting time for HiETA, as we follow our strategy of partnering with strong industrial players in key industrial sectors. The investment enables us to bring exciting new products to new markets. It also shows the potential for Additive Manufacturing of our world-class designs, when supported by outstanding industrial knowledge, experience and capability."

www.meggitt.com
www.hieta.biz


Meggitt has invested in HiETA Technologies (Courtesy Meggitt PLC)

Renishaw and BAE Systems partner to enhance metal AM for defence and aerospace

Renishaw has signed a Memorandum of Understanding (MoU) with BAE Systems which will see the two companies partner on the development of Additive Manufacturing's capabilities for the defence and aerospace sector. The collaboration is designed to help improve performance, reduce costs and speed up manufacturing processes on the combat aircraft of the future.

The MoU was signed by Andy Schofield, Manufacturing & Materials Strategy & Technology Director for BAE Systems, and Will Lee, Chief Executive, Renishaw, during a visit to BAE's manufacturing facilities in Samlesbury, Lancashire, UK. The agreement also opens up opportunities for joint research and development.

BAE's Samlesbury site is already home to several Renishaw AM machines, which form part of a dedicated New Product Development & Process Development Centre (NPPDC), where the latest emerging technologies and processes such as AM and Virtual Reality are explored and tested for application into aircraft design and manufacture. With a particular focus on AM, investments into technologies like those provided by Renishaw are expected to help BAE Systems remain at the cutting edge of aerospace manufacturing, exploiting the latest technologies and processes to continually improve its advanced manufacturing capabilities.

BAE began researching Additive Manufacturing techniques more than two decades ago, and is currently using the technology to make production standard components for the Typhoon fighter aircraft. AM is also being applied in the rapid prototyping of new technology concepts as part of a drive to deliver the Tempest – a capable, affordable and exportable next generation future combat air system.

"Additive Manufacturing has and will continue to deliver significant benefits to our sector," stated Schofield. "Renishaw is a world leader in Additive Manufacturing and we have been impressed with the quality of parts produced on its machines. This agreement allows us to create a more open and collaborative environment to share ideas and knowledge. In an environment of fast developing technology and challenged budgets, collaboration and innovation are absolutely essential in order to retain cutting-edge capability. I'm really excited by the potential this partnership has to help us deliver that. "

"We have a great relationship already with BAE Systems, developed over many years through the application of our metrology products and have more recently worked with them on evaluating and understanding the performance envelope of our AM systems," added Lee. "We are delighted that they have been impressed with our systems, and this, together with our vision for AM development, has led to the strengthening of our collaboration. We look forward to the exciting opportunities that this strategic collaboration presents to further develop AM technologies for demanding aerospace production applications."

www.baesystems.com
www.renishaw.com

Renishaw and BAE Systems have signed an MoU to develop the capabilities of AM for defence and aerospace (Courtesy BAE Systems)

Wipro 3D launches AM adoption and acceleration programme addwize

Wipro 3D, Bengaluru, India, the Additive Manufacturing business unit of Wipro Infrastructure Engineering (WIN), has launched addwize™, an AM technology adoption and acceleration programme. The objective of the programme is to enable organisations and institutions to systematically adopt and scale the use of metal Additive Manufacturing for tangible business benefits.

According to Wipro 3D, addwize is designed to address all phases of the adoption cycle, based on learnings obtained from running a best-practice metal AM solutions business. It is said to offer a balance of competency in building content, practitioner level technical insights and experiential elements, to ramp up Additive Manufacturing adoption quickly and affordably.

The programme is designed for stakeholders at all levels and is also thought to be ideal for academia, supporting educational institutions through technology awareness sessions with Wipro 3D experts, and immersion tours offering direct insights into the operation of industry-grade metal AM workflows, supported by case studies and assignments.

Ajay Parikh, Vice President and Business Head, Wipro 3D, stated, "Wipro 3D addwize is designed and developed to support any organisation or institution who is either evaluating metal additive technology, has AM in their near-future technology roadmap or has already invested in AM, create business value using metal AM. There is no lower or upper limit to the size of the organisation who wants to evaluate AM."

www.wipro-3d.com

KEX integrates Senvol Database into its AM Knowledge Area

KEX Knowledge Exchange AG recently licensed the Senvol Database to integrate into its Additive Manufacturing Knowledge Area, a tool for near-time technology and application monitoring in the field of Additive Manufacturing for Europe. Together with research partners at RWTH Aachen University campus and elsewhere in European academia, KEX connects market and research information to identify future trends.

The Senvol Database, developed by Senvol, New York City, USA, is the first and most comprehensive database of industrial Additive Manufacturing machines and materials. The Senvol Database is free to use on Senvol's website, and the data within it is available for license and can be integrated into any type of AM software.

The integration of the Senvol Database into the KEX.net Innovation Platform is expected to extend the KEX knowledge base by the addition of a broad range of market-available machine and material information, and on the other hand to benefit the Senvol data pool by adding a broad set of application examples and exclusive research knowledge with a focus on AM processes, machines, and materials.

Patrick Wienert, Partner at KEX Knowledge Exchange, stated, "KEX.net empowers its users to connect the AM machine and material data from the Senvol Database to real application examples and exclusive research knowledge. The platform actively engages its users to generate innovative application ideas and at the same time indicates possible partners, technologies and materials for a fast implementation."

www.kex-ag.com
www.senvol.com


AM solutions
Your partner for additive manufactured components
3D printing services
3D post processing
rapid
precise
tailor-made
A brand of the Rösler Group
www.solutions-for-am.com

Open Mind Technologies introduces AM capability for its hyperMILL CAM software

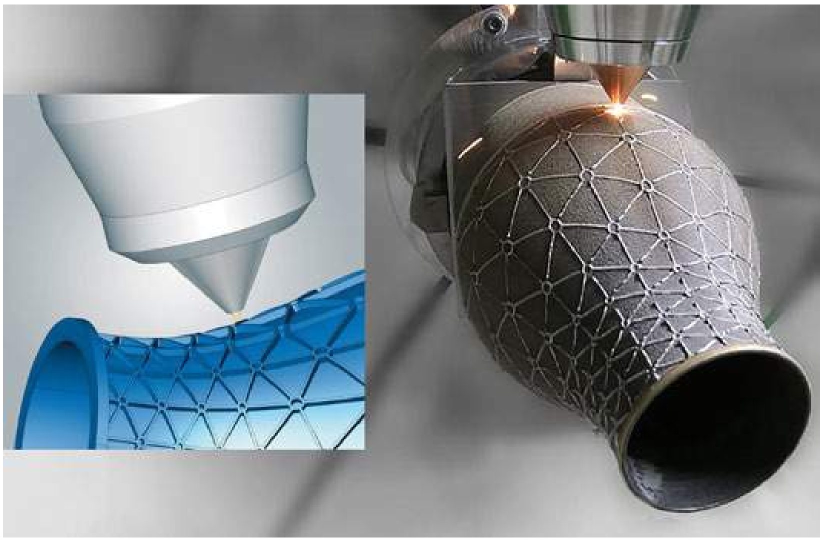
Open Mind Technologies AG, a developer of CAD/CAM software solutions head-quartered in Wessling, Germany, has introduced an Additive Manufacturing capability into its hyperMILL® CAM software to enable efficient hybrid processing, with simultaneous additive and subtractive manufacturing.

For highly complex 5-axis simultaneous processing, hyperMILL Additive Manufacturing reportedly enables an array of flexible options for Directed Energy Deposition (DED) and Wire Arc Additive Manufacturing (WAAM) processes. Both laser-based powder nozzle machining heads and WAAM energy sources can be controlled using hyperMILL AM for selective material deposition, and can be programmed and automatically simulated for collision avoidance.

Alan Levine, Managing Director of Open Mind Technologies USA, Inc., stated, "As an early adopter of driving forward the implementation of integrated process chains, Open Mind has optimised hyperMILL Additive Manufacturing technology to boost the efficiency, precision and process reliability of additive and hybrid manufacturing."

Key applications for hyperMILL Additive Manufacturing include the repair of damaged components, cladding of additional surface skins, or creation of new components from a substrate. This is also expected to create new options for combining different materials in AM, such as the addition of high-quality material layers to carrier materials.

www.openmind-tech.com



Additive Manufacturing on an aerospace nozzle, aided by Open Mind's hyper-MILL AM solution (Courtesy Open Mind Technologies AG)

NSL Analytical acquired by investment firm May River Capital

Independent commercial testing laboratory NSL Analytical Services, Inc., Cleveland, Ohio, USA, has been acquired by May River Capital, an investment firm based in Chicago, Illinois, USA. The company carries out a range of analytical testing services, which include quality control, failure analysis, product performance, and material selection and characterisation

NSL Analytical was established in 1945 and, under the recent leadership of company president Larry Somrack, the company has expanded to seventy-five employees serving over 1,700 customers globally from two locations in Warrensville Heights, Ohio, USA. Somrack will reportedly continue with NSL Analytical as President Emeritus, lending his experience to the next stages of the company's development. The leadership team will also include Ron Wesel as Chief Executive, Carey Lewis in growth and development and Andy Housley in finance and administration. Somrack stated, "I am excited to work with Ron, Carey and Andy to drive innovation for our customers and build upon the accomplishments and strengths of our talented team."

"The board and I carefully evaluated the next phase of development for NSL, our employees and our customers. We are pleased to be partnering with a group in May River that is like-minded and aligned with us on both the cultural values and the strategic path necessary to meet our collective goals," he concluded.

Wesel commented, "Thanks to Larry's decades of leadership, NSL's expert team, and the value they provide customers around the world, NSL has experienced consistent and impressive growth. We are excited to preserve and build upon that legacy, and to support the kind of continued investment in innovation, scientific capabilities and talent that will drive NSL Analytical forward in the future."

www.nslanalytical.com
www.mayrivercapital.com

Additive Industries to open new Process and Application facility in the UK

Additive Industries, Eindhoven, the Netherlands, will open a new Process and Application Centre at Filton Aerospace Park, Bristol, UK. The centre is part of a global network of Additive Industries Competence Centres, in Eindhoven, Los Angeles, USA, and Singapore, which have their own specialism in different aspects of industrial Additive Manufacturing. The new facility will focus primarily on new materials and process development.

The new Additive Industries Process and Application Centre is located at Filton Aerospace Park, Bristol, UK (Courtesy Additive Industries)

Additive Industries explains that the location of the new centre was chosen due to the growing Additive Manufacturing hub at Filton Aerospace Park,and its proximity with Filton Airfield. The area is already the established home for a number of world-class aerospace, advanced engineering and manufacturing businesses including Airbus, Rolls-Royce and GKN.

Russ Dunn, CTO of GKN Aerospace; Dr Mark Beard, Additive Industries' Global Director Process & Application Development and General Manager of the Centre; and Daan Kersten, CEO of Additive Industries will open the centre in an official ceremony on March 12. The event will include a presentation by Paul Perera, VP Technology at GKN Aerospace, about the GKN Global Technology Centre, also in Filton, of which Additive Industries is a partner.

www.additiveindustries.com
www.gknaerospace.com

The Virtual Foundry names Sapphire3D its first certified sintering partner


Sintered FFF parts (Courtesy Sapphire3D)

The Virtual Foundry, LLC, Stoughton, Wisconsin, USA, has announced that Sapphire3D, Inc., a metal and ceramic Additive Manufacturing and sintering company based in Chicago, Illinois, USA, will be the first certified sintering partner for its plastic-infused metal filaments, which can be used in Fused Filament Fabrication (FFF) Additive Manufacturing.

Sapphire3D states that it has developed expertise in the heat treating 'green' parts made from The Virtual Foundry's open-architecture plastic-infused metal Filamets™ to produce high-quality, high-purity finished metal parts. According to the company, it has maintained a database of every sintering cycle it has performed with The Virtual Foundry's metal Filamets™, which has reportedly enabled Sapphire3D to achieve 100% success with copper and bronze.

Tricia Suess, President of The Virtual Foundry, stated, "In addition to their proficiency with our materials, the team at Sapphire3D also shares our vision, which is to make metal 3D printing attainable to everyone. Most manufacturers today are investigating metal Additive Manufacturing, but they're wary of the investment it requires. For many companies, using a sintering partner like Sapphire3D is a very economical way to start."

"They can help you work through a variety of part design, printing and sintering issues to ensure that you can create the highest-quality metal parts," she continued. "As you become more knowledgeable about designing for Additive Manufacturing with metal and its unique post-production requirements, you can always invest in your own sintering equipment later."

David Lawson, founder of Sapphire3D, stated, "Successfully sintering a metal part involves some trial and error. The decisions you make during part design and printing affect the outcome of the sintering process. That's why my partner Joe Divizio and I will often work directly with our clients to help them optimise those first two steps."

www.thevirtualfoundry.com
www.sapphire3d.com


DIGITAL
METAL

QuesTek collaborates with German Aerospace Center on new Al alloy for AM

QuesTek Innovations LLC, Evanston, Illinois, USA, is collaborating with the German Aerospace Center (Deutsches Zentrum für Luft-und Raumfahrt – DLR), Cologne, Germany, to explore the full potential of its new aluminium alloy, which was developed for Additive Manufacturing. Questek states that this alloy is capable of high-strength performance at elevated temperatures (200–300°C) in its as-built condition. It is believed to be the first powdered aluminium material to meet those requirements without the need for subsequent heat treatment.

The new high-temperature Al alloy for AM is one of a series which the company is developing under multiple US Navy-funded Small Business Innovation Research awards. It is expected to enable the Additive Manufacturing of lighter-weight precision components not currently producible using traditional manufacturing methods. Because of the high-temperature strength of components additively manufactured using QuesTek's new alloy, the new material is also expected to make it possible to reduce weight in parts that must currently be made from titanium.

The new alloy was developed using QuesTek's Integrated Computational Materials Engineering (ICME) technologies and Materials by Design® approach, which combines the company's computational technology with an exclusive stage-gate design and development process. In an effort to explore the full potential of the company's new Al alloy, QuesTek will partner with the DLR to additively manufacture demonstration components for aeronautics and space applications and prepare a performance brief for European aerospace manufacturers.

Greg Olson, QuesTek's Chief Science officer, stated, "The accelerated design and development of a printable aluminium alloy capable of meeting so many current needs is especially exciting, as it will enable concurrent design of material composition and component geometry. Based on our internal test results, we see broad application of this material in manufacturing components for aerospace, satellite, automotive and high-performance racing."

"We are particularly pleased to be collaborating with the DLR," he continued. "Their unrivalled reputation, expertise and close relationship with industry needs will bring an important new scope to our efforts."

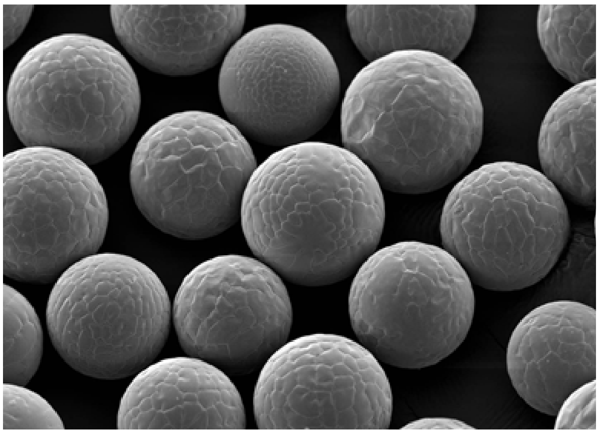
Heinz Voggenreiter, Director of the Institute of Materials Research for the DLR, commented, "For Additive Manufacturing to become a production technology with the capacity to produce components capable of performing in high-temperature, high-stress applications, new extraordinary printable alloys will be needed. The German Aerospace Center, with its decades of experience in the development of materials and structures for space and aeronautics, is an ideal cooperation partner for QuesTek to explore intended applications."

www.questek.com | www.dlr.de

Equispheres receives $8 million in cleantech funding to scale metal powder production

Equispheres, a materials science company based in Ottawa, Canada, has received $8 million of funding from Sustainable Development Technology Canada (SDTC) to facilitate scaling its metal powder production capacity over the next two years. SDTC is a government foundation that helps Canadian entrepreneurs accelerate the development and deployment of globally competitive 'cleantech' solutions.

As automotive and aerospace manufacturers seek to reduce the carbon footprint of their products, vehicle weight optimisation is a top priority. Equispheres states that its metal powder is designed specifically for Additive Manufacturing and has been optimised for the automotive and aerospace industries. As such, this powder is said to allow parts to be manufactured faster, and up to 30% stronger and lighter than parts produced with traditional AM powders.



Equispheres has received $8 million from Sustainable Development Technology Canada to scale its metal powder production capacity (Courtesy Equispheres)

According to Equispheres, although Additive Manufacturing is not new to the automotive and aerospace industries, it was previously not feasible for use as a mass production tool using aluminium alloy powders. Since aluminium alloys account for a significant amount of material demand in these industries, a powder that allows for faster, more efficient production of stronger and lighter parts has significant implications.

The results the company has achieved reportedly impact not only production efficiency but also part performance as related to carbon footprint. In the automotive industry alone, it's anticipated that Equispheres' powder could improve fuel efficiency by over 10%. Additionally, Equispheres reports that its powder outperformed in aerospace-ready quality tests and has "proven exceptional" in tests performed by McGill University.

"We are excited to receive this funding award from the SDTC Foundation," stated Kevin Nicholds, CEO of Equispheres. "This support from SDTC speaks to the importance of our powder technology as a key to achieving significant emissions reductions in the automotive sector. The funding from SDTC will help Equispheres to continue to accelerate our production capacity and support this important work by our automotive partners."

Leah Lawrence, President and CEO, Sustainable Development Technology Canada, commented, "Canadian cleantech entrepreneurs are tackling problems across Canada and in every sector. I have never been more positive about the future. Equispheres has developed a metal powder that acts as ink for 3D printing and enables automotive and aerospace manufacturers to reduce the weight of their products. With Equispheres' powder set to remove 100–200 kg of mass from an automobile, this would be the equivalent to removing seventy-five million cars off the road!"

www.equispheres.com
www.sdtc.ca

Nordmetall adds Gefertec arc403 system for AM of high-strength steel parts

Nordmetall logo additively manufactured on the Gefertec arc 403 system. (Courtesy Gefertec GmbH/Nordmetall GmbH)

Nordmetall GmbH, a materials testing specialist located in Neukirchen, Germany, has acquired an arc403 system for wire-arc metal Additive Manufacturing from Gefertec GmbH, Berlin, Germany. The addition of the new machine is expected to improve its process technologies as it undertakes R&D projects aimed at advancing technologies for the production of components from high-strength steels.

Gefertec's arc403 uses the company's 3DMP® process, a wire-fed arc welding technology. The advantages of wire-arc metal AM include the build speeds available, the ease of handling wire feedstock as opposed to loose powder, and the feedstock's comparative affordability. The arc403 enables 3-axis production of metal components to a maximum mass of 800 kg.

"We work on many customer projects that include components made from high-strength steels – and build-up welding is one of our standard manufacturing techniques," stated Dr Norman Herzig, Nordmetall CEO. "Now, with our new arc403, we can automate this process instead of relying on manual operations. This Additive Manufacturing technique has great potential for reducing the time required to produce components made from high-strength steels – and lowering costs at the same time!"

www.gefertec.de

www.nordmetall.net

BEAMIT acquires stake in AM post-processing start-up PRES-X

BEAMIT SpA, Fornovo di Taro, Italy, has acquired a stake in PRES-X, a start-up specialising in post-processing for Additive Manufacturing, in particular in the field of surface finishing and advanced thermal treatments. According to BEAMIT, PRES-X is the first European company that has made it possible to perform high-pressure heat treatments on additively manufactured production parts.

In partnership with leading high pressure technology company Quintus Technologies, PRES-X has acquired a HIQ60 system, said to be designed specifically for the high-pressure heat treatment of AM parts. The HIQ60 system is able to perform heat treatments at high pressure, and incorporates specific features for complete thermal cycle control, allowing users to perform Hot Isostatic Pressing (HIP) and heat treatment at the same time. This service goes alongside the innovative services already provided by PRES-X on surface finish solutions. BEAMIT states that its investment in PRES-X is in line with its strategic vision to broaden its knowledge and special process offering, strengthening its position as an Additive Manufacturing service provider for the most demanding industries.

Michele Antolotti, Chief Executive Officer of BEAMIT, stated, "We are extremely pleased to announce this deal and partnership with PRES-X, which aims to leverage synergies and further strengthen both companies' position in the metal AM market. We see the need to simplify the AM supply chain, to make it more efficient, including highly advanced special processes. We are convinced that this will further enhance the value we offer to our customers."

Andrea Scanavini, President of PRES-X, says "We are extremely pleased about our strategic partnership with BEAMIT, since we share the same vision regarding what will be the key drivers for the AM market in order to achieve excellence in all areas. Our collaboration with a leading AM service provider like BEAMIT is a strategic booster for our new and innovative services, which allows us to create a competence and production centre that can play a key role on the worldwide market for metal Additive Manufacturing."

www.beam-it.eu


ASME SETTING THE STANDARD
ASME L&D LEARNING & DEVELOPMENT
FAST TRACK YOUR CAREER WITH DESIGN FOR ADDITIVE MANUFACTURING WITH METALS ELEARNING COURSE
BE THE NEXT GENERATION OF
ADDITIVE MANUFACTURING
ENGINEERS
GO.ASME.ORG/DFAM
SPECIAL INTRODUCTORY OFFER
USE THE CODE DFAM595 AT CHECKOUT AND PAY JUST $595
(REGULAR PRICE $2,495)
Offer ends June 2020
ASME's Design for Additive Manufacturing with Metals eLearning Course will teach you how to:
• Evaluate design decisions from a Business, Part and Process perspective
• Validate design considerations with the Advanced Manufacturing Flight Check™ protocol
• Determine the best use case of AM for your organization by using the ASME Replicate, Adapt, Optimize™ Framework.
Register today @ go.asme.org/dfam
The American Society of Mechanical Engineers® ASME®
ASME® SETTING THE STANDARD

Ford develops unique metal AM locking wheel nut designs based on driver's voice

Ford Motor Company, headquartered in Dearborn, Michigan, USA, has partnered with EOS GmbH, Krailling, Germany, to develop a unique anti-theft locking wheel nut for its vehicles. The design concept uses the customers voice pattern to define the physical shape of the lock.

According to the automotive manufacturer, as car security systems become increasingly more sophisticated, thieves are targeting car parts instead, including alloy wheels. While current locking nuts can be used to deter theft by requiring a key to loosen them, they are not invulnerable.

Ford's new locking wheel nut concept is designed using a recording of the driver's voice, speaking for a minimum of one second. The recording is then converted into a physical pattern based on the soundwave, which is used as the design for the locking nut's indentation and key.

The nut and key are metal additively manufactured as one piece in stainless steel on an EOS machine. When complete, the two parts are separated, with a small amount of grinding being required to ready them for use. The design also includes second level security features, which help to prevent the nut from being cloned or copied. Because the design features unevenly spaced ribs inside the nut and indentations that widen the deeper they go, a thief would be unable to make a wax imprint of the pattern as the wax would break when pulled from the nut.

Ford stated that design options for the metal AM nuts and keys are not limited to the soundwave pattern. Other designs could include the driver's initials, or patterns inspired by the driver's interests, such as the outline of a famous racetrack.

Raphael Koch, Research Engineer, Advanced Materials and Processes, Ford of Europe, stated, "It's one of the worst experiences for a driver, to find their car up on blocks with all four wheels gone. Some alloy wheels can cost thousands to replace, but these unique rim nuts will stop thieves in their tracks. Making wheels more secure and offering more product personalisation are further proof that 3D printing is a game-changer for car production."

www.ford.com
www.eos.info


The anti-theft wheel nut is additively manufactured on an EOS machine (Courtesy EOS GmbH)

MAPP 2nd International Conference to take place in June

Following on from the success of its 2018 event, MAPP (Manufacturing using Advanced Powder Processes), the EPSRC Future Manufacturing Hub led by the University of Sheffield, will hold its second international conference at Milton Hill House, Abingdon, Oxford, UK, on June 1–2, 2020.

The conference will bring together key international decision-makers from across the powder design, processing and manufacturing sector, as well as early-career academics comprising 180 senior academics, researchers and industry professionals. Attendees are welcome from sectors including suppliers to the fields of materials science, automatic control and systems engineering and mechanical engineering, with a particular focus on powder materials, advanced in-situ process monitoring and characterisation, or new approaches in modelling and control.

The two-day event will focus on three key themes including:

- Right first time manufacturing and future manufacturing technologies
- From in-process monitoring and control to in-service prediction and performance
- Tailored properties for enhanced product performance

In addition to the conference sessions and social events, there will be a drinks reception sponsored by *Metal AM* magazine prior to the conference dinner.

www.mapp.ac.uk

NCAME researchers awarded grant for additive nanomanufacturing of multifunctional materials

Two researchers from Auburn University's National Center for Additive Manufacturing Excellence (NCAME), Auburn, Alabama, USA, have been awarded a $400,000 National Science Foundation (NSF) grant to advance the science of additive nanomanufacturing of multifunctional materials and hybrid structures.

The project is led by Masoud Mahjouri-Samani, Assistant Professor of Electrical And Computer Engineering, and Nima Shamsaei, Director of NCAME. The grant will support research to develop an additive nanomanufacturing platform capable of producing multifunctional nanoparticles on-demand to produce durable hybrid structures.

The researchers explain that the Additive Manufacturing of nano-scale multifunctional materials is challenging because of minimal source materials and inadequate fabrication systems. As project leader, Mahjouri-Samani plans to generate a stream of multifunctional materials, sinter them on a submicroscopic scale using laser technology and study their behaviours on various additively manufactured-surfaces.

According to the researchers, one of the challenges of the project will be to ensure the robustness and long-term functionality of these materials. Shamsaei will reportedly lend his expertise by evaluating the durability and structural integrity of the additively manufactured hybrid structures.

"Today, Additive Manufacturing is mainly focused on metallic and structural components, which are not functional materials," stated Mahjouri-Samani. "What we proposed here is to combine our knowledge of Additive Manufacturing with a variety of multifunctional materials and, for the first time, create multifunctional devices that can be printed on any conformal surface. We are hoping this technique can revolutionise the way we are printing multifunctional and electronic devices."

Shamsaei commented, "We are definitely excited about having this technology and research at Auburn. At our Additive Manufacturing centre, most of our capabilities lie in fabricating metallic materials with micro-level accuracy. This research will be a new addition not only to our centre but also to the field of Additive Manufacturing."

www.eng.auburn.edu/research/centers/additive

Knust-Godwin adds Velo3D Sapphire metal AM system

Knust-Godwin, a precision-tool and component manufacturer headquartered in Katy, Texas, USA, has purchased a new metal Additive Manufacturing machine from Velo3D, Campbell, California, USA, the Sapphire® System. The metal AM system will be installed alongside Knust-Godwin's existing fleet of seven metal Additive Manufacturing machines in the first quarter of 2020 at its site in Texas.

The company has recently achieved AS9100 certification and is now said to be expanding its capabilities to address the needs of the aerospace industry. Oil and gas and aerospace share requirements for intense thermal management of extreme temperatures and complex geometries, as well as expectations of cost-control and rapid delivery of parts. Knust-Godwin stated that the addition of SupportFree capabilities will enable it to expand its total addressable market and enable it to be more competitive across a wider range of industrial applications.

Michael Corliss, VP of Technology for Knust–Godwin, stated, "We see so many parts that have been manufactured with traditional methods that could take advantage of the benefits from AM. Our new Sapphire system provides the accuracy and low-print-angle capabilities that enable recreation of those parts via AM without having to go through a complicated redesign process. We can finally print parts as-is, offering valuable cost-savings to our customers and improved turnaround time for delivery."

"The oil and gas industry is one of the largest emerging market segments to adopt metal AM, and I'm thrilled to partner with oilfield leaders like Knust-Godwin for direct-part production," commented Benny Buller, Founder and CEO of Velo3D. "Their extensive background of over fifty years in precision machining, combined with their additive production experience, means that they understand what it takes to close the gap between prototyping and serial manufacturing."

www.kgsbo.com

www.velo3d.com

Knust-Godwin has added Velo3D's Sapphire System for metal Additive Manufacturing to its range of AM machines (Courtesy Velo3D)

Canadian FabLab installs Rapidia metal Additive Manufacturing system

KAST's MIDAS Lab has installed the Rapidia metal AM system (Courtesy KAST/MIDAS Lab)

The Kootenay Association for Science and Technology (KAST) based in Trail, British Columbia, Canada, has installed a Rapidia metal Additive Manufacturing system, at its MIDAS Lab. The Metallurgical Industrial Development Acceleration and Studies – or MIDAS Lab – is reported to be the first rurally located FabLab (fabrication laboratory) in Canada to install a metal AM system.

The MIDAS Lab provides access to the equipment needed for digital fabrication and rapid prototyping, as well as project work areas, a research and development lab, a metal shop, a woodshop, a computer lab and a training centre.

"Metal printing is a game-changer for fabricating parts and prototypes," stated Cam Whitehead, Executive Director of KAST. "Lower costs and increased speed to produce prototypes means faster innovation and more competitiveness. This all means more jobs and wealth for the region. Our services are available to commercial members, unlike most universities - these machines are so new and expensive that previous focus has been on research and not necessarily business needs."

"MIDAS Lab is unique in Canada and has been since it opened its doors in 2016," added Whitehead. "We're thrilled that it's received countrywide recognition and we're using some of the lessons learned to help other start-up fabrication labs and innovation centres across B.C."

The Rapidia system uses a water-based metal paste which eliminates the debinding step, enabling the two-stage Rapidia process to produce most parts in under twenty-four hours. The system is also believed to cut Additive Manufacturing time further by avoiding the need to produce a metal base plate or most metal supports. It is capable of building a range of materials including stainless steel, Inconel, tool steel, ceramics and titanium.

"While there are printers that can do what the Rapidia can do, we chose this one because of its safe operation, the speed at which you can operate and create the designs and parts that our industry partners and Selkirk College needs," explained Jason Taylor, Instructor & Applied Researcher at Selkirk College.

KAST partner, Selkirk College plans to launch Digital Fabrication & Design, a two-year diploma programme that trains graduates for advanced manufacturing, in September 2020. Daryl Jolly, School of the Arts chair, stated that the Rapidia system will be an exciting new educational tool students will be able to utilise. "As we launch this new programme, it's exciting to again see that Selkirk College students will be trained on and have access to world-class equipment. We expect our graduates will be well-positioned to support continued economic growth in our region, bringing value to industry and innovation," he commented.

www.kast.com
www.midaslab.ca
www.rapidia.com

The Rapidia system builds parts using water-based metal paste technology (Courtesy Rapidia)

Titomic partners with Thales to develop next-generation military components for Australian soldiers

Titomic Limited, Melbourne, Australia, has signed an agreement with global technology company Thales, headquartered in Sydney, Australia, to develop advanced Additive Manufacturing methods to support Thales's development of next-generation soldier weapons systems for the Australian Defence Force.

The company states that as part of the agreement, it will use its Titomic Kinetic Fusion® (TKF) AM process to manufacture lighter, stronger and better-performing soldier system components. That Titomic's extensive R&D for soldier systems is now being commercialised with defence primes such as Thales is thought to validate the unique capabilities of TKF and the potential value chain of titanium from Australian resources. The company added that its vision is in line with the Australian government, which aims for the country to be one of the top ten defence exporters globally.

"We are proud to be partnering with Thales, a global technology leader, in the critical design and manufacture of military products for Australian and UK Defence Forces," stated Jeff Lang, Titomic's Managing Director. "This next generation of soldier system products will ensure our armed forces have the latest cutting-edge equipment that is lighter, stronger and higher performing, enabling them to deliver mission success in demanding and dangerous environments."

Graham Evenden, Director of Soldier Weapons Systems, Thales, commented, "Partnering with Titomic to industrialise research outcomes in the development and manufacture of lighter and stronger soldier systems equipment continues to demonstrate Thales's commitment to deliver capability advantage to the Australian soldier. While developing a resilient Australian Sovereign Industrial Capability that will pave the way for future export opportunities."

The Hon Melissa Price MP, Australia's Minister for Defence Industry, reported, "It's great to see Australian businesses like Titomic making the most of the opportunities created through our record investment in the defence industry. It proves we are developing world-leading capability right here in Australia – which has tremendous export potential in global markets."

www.titomic.com
www.thalesgroup.com

Titomic will use its Titomic Kinetic Fusion AM process to produce next-generation soldier weapons systems (Courtesy Titomic Limited)

Smiths HP and Burloak Technologies to supply additively manufactured parts to Formula 1

Smiths High Performance (Smiths HP), a supplier of advanced engineering materials to the global motorsport sector, based in Bedfordshire, UK, and Additive Manufacturing specialist Burloak Technologies, Ontario, Canada, have signed an agreement to supply additively manufactured metal and polymer components to the worldwide Formula 1 motor racing market.

"We are excited to partner with Burloak Technologies, a world leader in Additive Manufacturing," stated Rob Kitchen, General Manager, Smiths HP. "They will enable us to provide unique value to our customers through Additive Manufacturing. We look forward to working with Burloak to develop parts and applications that will be at the forefront of Formula 1 racing for many years to come."

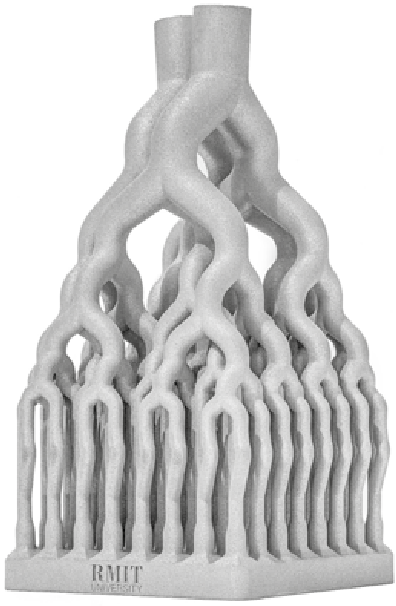
The companies state that they will work together to apply design for Additive Manufacturing principles to the complex challenges of making lighter, stronger and optimally designed parts that improve overall performance. Additive Manufacturing will allow design flexibility and modifications that are not available through traditional manufacturing processes.

Peter Adams, President and co-founder of Burloak Technologies, commented, "We are pleased to have signed this agreement with Smiths High Performance, we believe this is the best channel to leverage and extend our leading capabilities in Additive Manufacturing into the world of Formula 1 racing. With their reputation and position in the market, we are looking forward to the opportunity to apply Additive Manufacturing in innovative ways to solve real-time needs."

www.smithshp.com
www.burloaktech.com

Smiths High Performance and Burloak Technologies are working together to supply AM components to the Formula 1 sector (Courtesy Smiths HP)

Optimisation of flow distributor and mixer designs



Additively manufactured Ti-6Al-4V dual fluid flow distributor and mixer comprising of 64 mixed outlets (Courtesy RMIT University)

Researchers at Australia's RMIT University, Melbourne, and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Clayton, have utilised metal Additive Manufacturing to develop flow distributor and mixer designs which enable the uniform distribution and mixing of fluids, a common functional requirement in a range of fluid handling applications.

Flow distributors are needed in a number of industries, for fuel burners, heat exchangers, spray manifolds, bubble columns and spargers, and catalytic converters. In many applications, system performance is directly dependent on the uniformity of flow distribution. For example, in chemical reactors utilising catalytically coated monoliths comprising many parallel channels, variation in the flow distribution across channels results in non-uniformity of catalyst utilisation. Similarly, in large-area gas burners, maldistribution of fuel and oxidisers and non-uniform mixing can result in uneven temperature distribution and combustion inefficiencies.

A range of flow distributor designs have been used in practice, however the ability of these to achieve high flow uniformity over multiple outlet channels and flow conditions has been limited by design constraints due to manufacturing by machining or casting. Applications requiring uniform flow distribution and fluid mixing further complicate the required geometry and challenge conventional manufacturing processes. However, according to the research team, the maturing of metal Additive Manufacturing processes has significantly increased the range of possible geometries, enabling the construction of high-performance flow distribution devices which were not previously feasible.

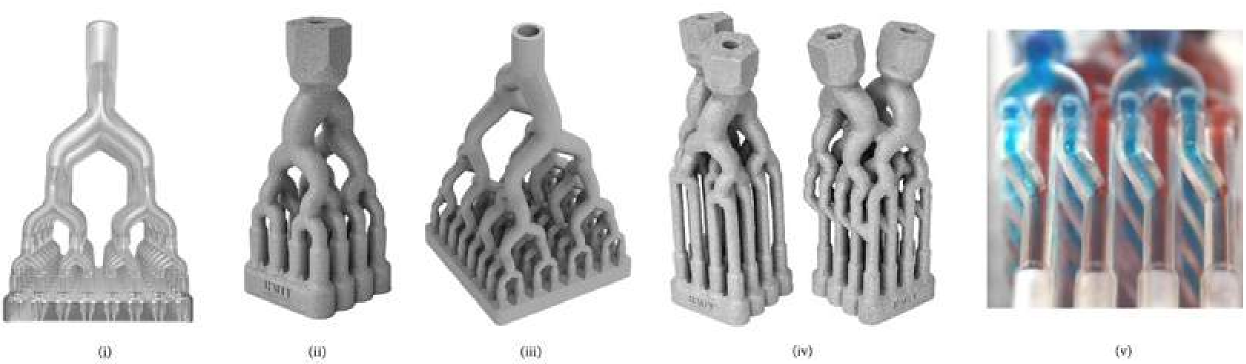
To exploit this opportunity, the researchers have developed flow distributor and mixer designs based on a recursively self-similar flow bifurcation scheme, which achieves very high outlet flow uniformity and packing density. Studying systems encountered in nature, such as in plants, blood vessels and lung bronchial trees, the researchers observed that these achieve good performance due to generally symmetric and repeating flow paths. By using this symmetrical approach, tailored for Additive Manufacturing, the designs have achieved high flow uniformity across a broad range of channel diameters, number of outlet channels and flow conditions.

The flow distributor designs can be manufactured efficiently due to the use of an inherently self-supporting geometry, with no support structures required and complete internal void powder recovery. A range of devices have been manufactured by L-PBF from titanium and nickel alloys, with varying design configurations. Experimental testing is said to confirm the predicted high flow uniformity, and the resulting patented flow distribution system has the potential to improve performance across many industrial applications, particularly in chemical process applications such as milli/microchannel reactors, contactors and static mixers.

The team's research was published in *Science Direct*, Volume 143. For further information, contact Dr Maciej Mazur (maciej.mazur@rmit.edu.au).

www.rmit.edu.au

www.csiro.au



Flow distributor and mixer devices (i) Six-stage polymer flow distributor (64 outlets) (ii) Four-stage Inconel 625 flow distributor (16 outlets) (iii) Six-stage Inconel 625 flow distributor (64 outlets) (iv) Four-stage Inconel 625 dual fluid flow distributor and mixer (16 outlets) and (v) Four-stage dual fluid flow distributor and mixer in operation (Courtesy RMIT)

Bloodhound LSR, featuring metal additively manufactured parts, reaches 628 mph in speed testing

The Bloodhound LSR, a supersonic car incorporating a metal additively manufactured titanium nose tip and steering wheel produced by Renishaw, achieved a speed of 1,011 km/h (628 mph) during high-speed testing at the Hakskeen Pan track in South Africa. The team behind the Bloodhound LSR, formerly Bloodhound SSC, are working towards breaking the world land speed record, set over twenty years ago.

Renishaw began working with the Bloodhound project in 2013 when it became a sponsor, and has since provided its Additive Manufacturing expertise to design and manufacture parts for the supersonic car.

The titanium steering wheel is designed specifically to fit the hands of Andy Green, assisting him when driving the car. The Bloodhound's nose tip, again manufactured from titanium powder, is a strong, lightweight component, capable of dealing with the extreme loadings that occur when the car is at high speeds.

"Reaching 628 mph in South Africa was an incredible achievement for Bloodhound and it was exciting to see Renishaw's technology being a part of it," commented Chris Pockett, Head of Communications at Renishaw. "Additive Manufacturing gave us the freedom to design the nose cone and steering wheel specifically to undergo the extreme forces involved in the land speed attempt, which would've been difficult with traditional manufacturing methods."

The Bloodhound team is now working through its plan of high-speed testing, followed by its attempt to set a new world land speed record in 2020/21. The current land speed record of 1,227.985 km/h (763.035 mph) was set in 1997 by the Thrust SSC car, also driven by Andy Green.

www.renishaw.com
www.bloodhoundlsr.com



Renishaw additively manufactured a titanium steering wheel (top left) and nose tip (top right) for the Bloodhound LSR (Courtesy Renishaw/Bloodhound LSR)

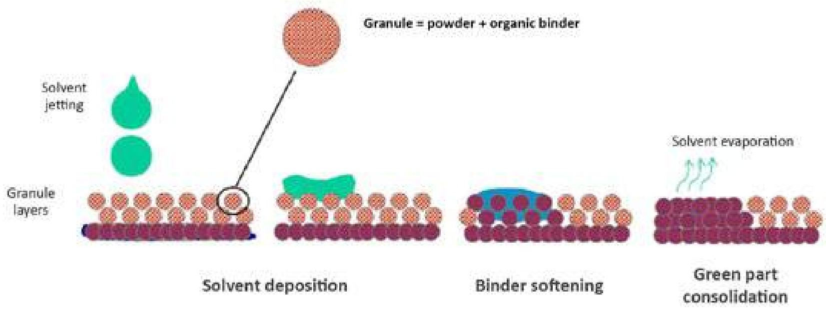
Fraunhofer IFAM short courses on Powder Handling and Flow for AM

Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM), Bremen, Germany, is set to deliver two short courses on Powder Handling and Flow for Additive Manufacturing in 2020. The first is being held at its headquarters in Bremen, Germany, April 22–23, and the second will be held at Carpenter Additive's facility in Widnes, Cheshire, UK, on July 15–16. The courses, organised in cooperation with Wolfson Centre for Bulk Solids Handling Technology, University of Greenwich, Kent, UK, will be presented across two days and include the following topics:

- Recycling and quality issues
- Standards for AM Powders
- Hoppers for storage and discharge
- Flow patterns, principles of reliable flow
- Powder flow properties
- Description and control of powder properties
- Powder flow measurements
- Density measurements and particle morphology
- Basic overview of powder evolution and quality loss
- Control of flow properties
- Segregation in processes
- Particle aggregation
- Powder electrostatics
- Particle degradation

www.ifam.fraunhofer.de
www.gre.ac.uk
www.carpenteradditive.com

Discover the future for sinter-based Ti parts in *PIM International*



Efraín Carreño-Morelli presented a binder-based AM technology

The PM Titanium conference series is a key international event for those involved in the powder metallurgical processing of titanium and its alloys. In September last year, PMTi2019 was held at the University of Utah, Salt Lake City, USA.

In the December 2019 issue of *PIM International* (Vol. 13 No. 4), Dr Thomas Ebel reviewed a selection of conference papers from PMTi2019 that suggest that progress on the sinter-based processing of titanium and titanium alloys continues to mature, with cost reduction a major focus of research. While the number of presentations focusing specifically on Metal Injection Moulding (MIM) was lower than in previous years, Ebel notes a trend toward presentations on 'MIM-like' AM technologies such as Binder Jetting (BJT) and Fused Filament Fabrication (FFF).

These technologies enable the production of single parts or small series of parts without the need for a mould or tooling. Binder Jetting is currently being developed into a production technology, with the aim to facilitate the manufacturing of large numbers of parts; these efforts have been widely publicised, and complete production systems including an AM machine, debinding and sintering furnace are now available to purchase.

It is clear from these widely-publicised developments that sintering and the use of feedstocks comprised of metal powder and binder remain very attractive manufacturing technologies. In addition, some, such as FFF, are comparatively cheap to set up and run, making them an attractive entry-level technology for companies new to metal Additive Manufacturing.

However, not all of these technologies were originally developed for the processing of titanium, the sintering of which remains comparatively difficult. To reliably sinter this material and its alloys, specialist equipment and processing considerations may be required to achieve results equivalent to those attainable by non-powder-based technologies.

The papers reviewed by Ebel showed promising progress toward addressing these considerations, and reinforced the position of sinter-based AM again as one of the most important areas of research in titanium processing. The key application areas highlighted, such as aerospace and medical devices, offer a promising potential market for these technologies if the challenges of titanium sintering can be addressed.

The full article is available to read for free online in the digital edition of *PIM International*.

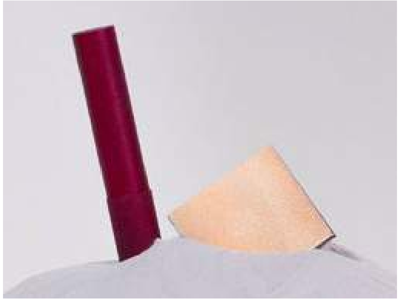
www.pim-international.com

Fehrmann's AlMgty brings colour to metal AM parts

Fehrmann Alloys GmbH & Co KG, Hamburg, Germany, has reported that its silicon-free aluminium alloy AlMgty has the ability to be anodised in a variety of colours, bringing the option to its metal additively manufactured parts for the first time.

Components made of the standard alloy AlSi10Mg cannot be anodised well due to its silicon content of 9 to 11%, resulting in grey-brown coloured parts. The company states that AlMgty does not require silicon and as a result, components which are additively manufactured with AlMgty can be anodised in various colours as corrosion protection and for decorative purposes.

The company explains that the two components shown in the image above were produced using AlMgty by Andreas Wiesner, former head of R&D at SLM Solutions and now owner of the firm AM & Research, on a standard SLM Solutions SLM 280 HL system. The test parts comprised a converted and half turned tension rod and a small plate which were then anodised in dark red or gold. The anodised layer was approximately 25 µm thick and the platelet was then polished.



The two AM test parts anodised in red and gold (Courtesy Fehrmann Alloys)

www.alloys.tech

EWIE Group launches Additive Manufacturing brand Azoth 3D

The EWIE Group of Companies (EGC), a family of manufacturing brands headquartered in Ann Abor, Michigan, USA, recently launched a new brand focused on the provision of Additive Manufacturing services to its group companies and customers. Azoth 3D offers both metal and polymer Additive Manufacturing, as well as associated services such as design and prototyping, and 3D scanning and reverse engineering.

East West Industrial Engineering Company, the founding brand of EGC, was founded in the 1980s and has since focused on using technology to reduce its customers' operating costs and improve production efficiencies. The group's companies now service 300+ facilities in twelve countries.

Explaining the decision to enter the Additive Manufacturing market, EGC stated that, understanding the shifting landscape of manufacturing as part of Industry 4.0, the need to diversify became clear. One of the largest subcategories of items that its brands are often asked to source are machine spare parts, with most production facilities stocking rooms full of brackets, gripper fingers, fixtures, motors, and automation components in order to minimise the impact of machine downtime.

In many cases, when a machine part fails, it is too old to locate an original manufacturer to source a replacement. This is further complicated when submitting a one-off emergency order to a local machine shop, where lead times are long and prices are high. This, EGC saw, offered the perfect opportunity to take advantage of Additive Manufacturing's unique capabilities.

"The EGC's success, and consistent growth, can be attributed to three things," explained Joey Mullick, Vice President, Azoth 3D. "First, identifying the best technology for a plant operation. Second, consolidating the vendor base by identifying manufacturers who provide world-class products and global support. Lastly, benchmarking best practices and replicating them throughout a customer's manufacturing facilities. Azoth is leveraging these same principles in the world of additive."

Azoth 3D's Center of Excellence, also located in Ann Arbor, is said to have grown from an empty warehouse into an impressive lab of the industry's highest-performing technology in less than two years. The team stated that it envisions being able to support the bulk of orders from this HQ, focusing primarily on Binder Jetting for its metal AM offering.

To support its metal AM capabilities, the company has so far built partnerships with Digital Metal and its parent company Höganäs, Höganäs, Sweden; Desktop Metal, Burlington, Massachusetts; and Elnik Systems, LLC, and its sister company DSH Technologies, Cedar Grove, New Jersey, USA. "Just as a traditional manufacturing facility could not procure all its tools from one toolmaker; Azoth is diverse in its partnerships and holistic in its services," stated Mullick. "The team has built up a network that includes shops that offer technologies they do not, machine distributors, and partners with deep additive expertise. They are also providing reverse engineering and DFA services."

ECG reports that its vision for Azoth is to transform the physical inventory of a plant into a digital one, thereby reducing the costs of its customers. To this end, the company has coined a new phrase: 'Take One Make One' or 'TOMO'. "The problem Azoth seeks to solve was ever-present in EGC's existing customer base, and early adoption of their business model has been significant," explained Mullick.

"Since the issues surrounding spare parts are common to all manufacturing facilities, Azoth has been able to grow beyond the group's common customer architype," he continued. "New customers choose Azoth because of their ability to manufacture precision parts to blueprints, their vast knowledge of the additive tools available in the market, and the ability to implement digital inventory on demand. Customers that choose to work with Azoth get more than a 3D printed part. They get a team focused on generating solutions, with access to the latest technology in AM, and EGC's manufacturing history."

www.azoth3d.com
www.ewie.com

Cody Cochran, Azoth 3D's Key Account Manager, with an installed machine from Elnik Systems, LLC (Courtesy Azoth 3D)

McLaren MP4-12C performance improved with customised metal AM powertrain components

In a project to boost the performance of a McLaren 2014 MP4-12C supercar, a team of engineers have used metal Additive Manufacturing to build a number of customised powertrain components. Keselowski Advanced Manufacturing (KAM), a specialist in hybrid manufacturing based in Statesville, North Carolina, USA, was recently approached by ACME Hi-Performance Laboratories, a custom design and engineering business developing components for automotive, aviation and military applications, to assist in its project to improve the powertrain efficiency of the vehicle.

According to KAM, the project began when ACME Hi-Performance lead engineer Safa Yousef and his partners approached the company having recently analysed a McLaren 2014 MP4-12C and found inefficiencies in the powertrain that it believed it could improve upon. The team developed its own new powertrain designs, but encountered challenges in that, while the motor and transmission for the vehicle would stay in place, many other elements including the intercoolers, the intake manifold, and more, would have to be dramatically redesigned.

Because shaping the individual parts 'by hand' using conventional manufacturing methods would be both time consuming and cost-prohibitive, Yousef was advised to contact KAM for advanced manufacturing support. Yousef stated that, prior to this, he had not considered using AM to produce automotive parts; however, given the complex nature of the project at hand, AM was the ideal solution.

Additively manufactured intake manifold for the McLaren MP4-12C, built at KAM for ACME Hi-Performance Laboratories (Courtesy KAM)

Over a number of meetings, Yousef and the KAM design team reevaluating his designs to ensure the final CAD designs would be optimised for Additive Manufacturing. Inconel 625 and Aluminum 6061 were selected as the materials to be used, and the metal powders were analysed using KAM's in-house lab prior to Additive Manufacturing to ensure they met the required specifications.

Following the production of the parts by metal Additive Manufacturing on a Laser Powder Bed Fusion (L-PBF) machine, Yousef stated, "We were able to create these super complex shapes and pieces into actual solid parts. They'll perform the way we need them to perform. The exterior shape that we needed to achieve was possible with 3D printing, but we could also optimise the interior shape, so the inside shape can be completely different than the outside shape. So that was also another great advantage of the 3D printing. Complexities are absolutely free."

Each of the parts was then analysed using KAM's on-site CT scanning machines to inspect their quality. Those parts which required it were also machined using KAM's 3-7 axis Mazak CNC machines. "Even if you just want to go into KAM with just an idea for a part design," Yousef commented. "They can take it from a sketch off of a napkin and go to full-blown finished production, a final produced part. And that's what's great about working with these guys."

Yousef added that the additively manufactured parts performed better than he had expected. "It's just a complete overhaul and revamp of the entire powertrain," he stated. In the coming months, the company will conduct additional testing of the McLaren parts in the field, including road courses and standing mile and two-mile testing at the Kennedy Space Center.

www.kamsolutions.com
www.acmehpl.com

Swansea University opens £35 million materials and engineering research facility

Swansea University, Wales, UK, has opened the Institute for Innovative Materials, Processing and Numerical Technologies (IMPACT), a £35 million materials and engineering research facility, at the College of Engineering on Swansea University's Bay Campus, reports Materials World magazine. The new facility is intended to cater for collaborative research projects between industry and academia. It will reportedly target five core research areas including future manufacturing, next-generation material property measurement, advanced structural materials, thin films and coatings, and data-centric engineering.

The facility has 1,600 m^2 of open plan laboratories and is fitted with cutting-edge equipment set to serve projects in innovative materials, modelling and manufacturing, and advanced engineering to support both theoretical and applied research projects. The centre also features robotics, cobots and Additive Manufacturing capabilities, as well as a £1.2 million wind tunnel for testing airflow movements around solid objects.

www.swansea.ac.uk

The Barnes Group Advisors reports on potential economic benefits of Neighborhood 91

The Barnes Groups Advisors (TBGA), headquartered in Pittsburgh, Pennsylvania, USA, has released an impact study revealing the overall economic benefits of an Additive Manufacturing production campus for the Pittsburgh International Airport, currently in development and known as Neighborhood 91.

According to TBGA, its report substantiates that a cluster concept like Neighborhood 91 can act as a catalyst for AM industrialisation and innovation with the creation of a cost-efficient ecosystem. Multiple numerical data models with relevant industry data were reportedly complemented by economic theory to analyse the impact. The following five key impact areas were identified:

- Reduction in production costs – 25% for parts and 30% for powder
- Simplified supply chain with 80% reduction in manufacturing lead time and 80+% reduction in transportation cost and miles for powder to part production
- Workforce development and R&D boost productivity and innovation
- Agglomeration economies and labour market pooling for reductions in learning curves and under-utilised equipment
- Reduced energy consumption and emissions

Laura Ely, TBGA ADDvisor Services Leader and the report's co-author, commented, "The current AM production supply chain is fragmented. This study validates that Neighborhood 91's centralised campus will significantly reduce cost and the need to manage parts across a dispersed supply chain."

John Barnes, TBGA Founder and Managing Director, stated, "A cluster does two key things: It enables process owners to focus on developing and optimising their core process, and it creates a skilled regional labour pool."

The full economic impact report is available via the Neighbourhood 91 website.

www.neighborhood91.com
www.thebarnes.group

Submitting news..

Submitting news to *Metal AM* is free of charge.

For more information contact Paul Whittaker:
paul@inovar-communications.com

U.S. marines in Okinawa install Metal X system for AM of vehicle or weapon parts

The socket on the right was made with the unit's new Markforged Metal X (Courtesy M M Burke/Stars and Stripes)

Members of the III Marine Expeditionary Force (III MEF), stationed at the U.S. armed forces base Camp Kinser, Okinawa, Japan, have installed a Markforged Metal X Additive Manufacturing system to produce vehicle or weapon parts in the Indo-Pacific region, reports *Stars and Stripes*.

The Metal X system is located at the 3rd Maintenance Battalion shop at Camp Kinser and became operational in December 2019. The III MEF is reportedly the first expeditionary force to receive one of the $150,000 machines.

Staff Sgt Quincy Reynolds, Shop Foreman, explained that the shop has twelve marines who are responsible for repairing components for vehicles and weapon systems, which can mean milling new parts out of blocks of metal, a wasteful and time-consuming process.

The Metal X system is capable of additively manufacturing multiple pieces at the same time, so that once a marine ensures the build's base layers are correct, it can be left unmanned, freeing up the marine for other tasks.

Reynolds added that with the Metal X, marines can now take on as many as four projects at a time. The battalion's goal is to be able to produce any metal part required. Currently, it has made gauges for .50-caliber machine guns, sockets for wrenches and a piece to test weapon optics at the armoury.

www.iiimef.marines.mil

www.markforged.com

AM start-up focuses on production of titanium orthopaedic implants with Arcam EBM

Amplify Additive manufactures titanium orthopaedic implants using three Arcam EBM Q10plus machines (Courtesy Amplify Additive)

Amplify Additive, Scarborough, Maine, USA, a metal Additive Manufacturing start-up which specialises in orthopaedic implants, is producing a range of titanium implants using GE Additive Arcam's Electron Beam Melting (EBM) technology. The company operates three Arcam EBM Q10plus machines at its facility in Scarborough.

The Arcam EBM Q10plus is designed for the industrial production of orthopaedic implants, and operates under vacuum at elevated temperatures to provide material properties that exceed industry standards.

Brian McLaughlin, President, CEO, and Founder of Amplify Additive, stated, "By 3D printing titanium with this Electron Beam Melting technology, we can produce implants that not only have never been able to be designed and manufactured before but provide a better quality of care for patients."

McLaughlin added, "Because we have experience on all sides of the industry – design & manufacturing with one of the largest orthopaedic suppliers, clinical experience as an orthopaedic implant distributor, unique and specific experience helping commercialise the 3rd generation Arcam platform, and having had an opportunity to provide guidance to the FDA on Additive Manufacturing – we fully understand what it takes to bring an additive product through the FDA and out to the market. This complete experience is what separates us from other suppliers."

www.amplifyadditive.com

www.ge.com

Ellen Brooke named as CEO of ImphyTek Powders

Following the formation of the new jointly-established company, ImphyTek Powders™ SAS in November 2019, Aperam S.A., Luxembourg, and Tekna, a subsidiary of Arendals Fossekompani ASA, headquartered in Sherbrooke, Canada, have nominated Ellen Brooke as CEO of the new company.

Brooke has worked in senior roles at Aperam since 2002 and the companies state that she has demonstrated strong capabilities in achieving revenue and business growth objectives within multiple environments, both in Europe and South America. Brooke has extensive experience in sales and manufacturing, with a deep understanding of critical business drivers in multiple markets and industries, and holds a Bachelor of Law from Hull University, UK.

According to Aperam and Tekna, after pre-notification discussions and short-form CO filing, the companies are in the process of obtaining European Commission clearance to create a full-function joint venture combining their expertise in nickel and speciality alloy spherical powders for advanced Additive Manufacturing technologies.

Upon EU Commission clearance, ImphyTek Powders™ SAS will be based in France and will market the companies' jointly-developed high-quality spherical metal powders to meet the growing needs of Additive Manufacturing and Metal Injection Moulding (MIM) in all industrial segments.

Ellen Brook has been nominated as CEO for Aperam and Tekna's jointly established company, ImphyTek Powders (Courtesy Aperam/Tekna)

www.aperam.com
www.tekna.com

Arcast begins year installing multiple gas atomisers in USA and Europe

Arcast Inc., Oxford, Maine, USA, has announced it shipped and installed several new gas atomisers in January 2020. The company, a producer of advanced melting and metal powder atomisation systems, has supplied atomisers to the Center for Manufacturing Research of Tennessee Tech, USA; CEIT, San Sebastián, Spain; South Dakota School of Mines and Technology, USA; and North Carolina State University, USA.

Arcast's large-scale gas atomiser in action at CEIT (Courtesy Arcast Inc.)

"The increase in metal powder research for Powder Metallurgy and AM applications is significant in the USA at the moment," stated Arcast. "We currently have seven inert gas atomisers being supplied within the USA. It is good to see the USA investing in this growing market. This is a big change from just a few years ago when most of the growth in this area was in Europe."

Tennessee Tech has received a VersaMelt multi-mode inert gas atomiser. Due to its wide range of melting and processing options, this atomiser is expected to give the research group the ability to cleanly melt and atomise a large number of diverse materials, including titanium, copper, iron, cobalt, hafnium, tantalum, tungsten and other metal alloys.

An Arc 200 arc melting furnace, with gas atomising option, has been installed at the South Dakota School of Mines and Technology's Materials and Metallurgical Engineering department. The system will enable the research team to work with industrial partners and government agencies to develop new materials and applications.

At North Carolina State University, the Center for Additive Manufacturing and Logistics (CAMAL) will use a VersaMelt gas atomiser for powder production to support its AM hub. The atomiser is expected to allow the centre team, led by Tim Horn, to produce the source material for its Additive Manufacturing projects, eliminating long lead times for externally sourced powders.

Outside of the US, a large-scale inert gas atomiser has been shipped to Spain's Centro de Estudios e Investigaciones Técnicas de Gipuzkoa (CEIT), for installation at its new powder development centre in San Sebastián. CEIT's metal powder research includes the atomisation of metal powders for use in Additive Manufacturing, magnetic materials and the automotive aeronautic sectors; the development of Powder Metallurgy steels; the manufacture of hard and soft magnetic materials using PM routes; the design of metal powders specifically for AM, and more.

www.arcastinc.com

ASTM International developing new Additive Manufacturing standard

ASTM International's Additive Manufacturing Technologies Committee (F42) is developing a standard that could help to quickly assess the quality of additively manufactured parts, as well as the performance of Laser Powder Bed Fusion (L-PBF) machines.

The F42 committee is comprised of 725 members and eight technical subcommittees, and all standards it develops are published in the *Annual Book of ASTM Standards*. The committee welcomes representatives of industries, universities, and research facilities, that work in AM technology, to participate in the upcoming round-robin experiments to assess the robustness of the proposed standard (WK71395).

The high demand for reliable AM parts requires the Additive Manufacturing process to be repeatable and with minimal deviation in order to confidently fabricate parts that meet specific quality standards. There are procedures implemented to qualify a metallurgical process (QMPs), such as MSFC-SPEC-3717, but these are time consuming and can potentially increase downtime during the evaluation period. Additionally, there is little guidance on how to monitor and understand build health during the intervals between QMPs.

The proposed standard aims to use off-the-shelf tools to quickly generate qualitative data related to dimensional accuracy and material strength, both of which serve as indicators of the health of the machine and the part.

"We are successfully working to capture variations in the Laser Powder Bed Fusion process. Now we need to determine the sensitivity of these variations and assess repeatability across various users, materials, and systems," stated Nima Shamsaei, a founding member of ASTM International's Additive Manufacturing Center of Excellence, a professor in the Mechanical Engineering department at Auburn University and the Director of the National Center for Additive Manufacturing Excellence (NCAME).

The technical point of contact for this standard's development, Jonathan Pegues, of Sandia National Laboratories, explained that the standard could ultimately assist manufacturers, laboratories, government agencies and other stakeholders that produce L-PBF parts for structural applications. It is believed that the applicability of this method could potentially be extended to other Additive Manufacturing systems.

www.astm.org

Osseus introduces additively manufactured titanium transforaminal lumbar interbody fusion device

Osseus Fusion Systems, Dallas, Texas, USA, a medical device company specialising in advanced technology products for minimally invasive surgery, has launched Aries™-TS, an additively manufactured transforaminal lumbar interbody fusion device.

The company explains that its range of Aries devices are constructed from highly porous titanium, which is optimised for bone fusion and biological fixation using Osseus' Additive Manufacturing technology, PL3XUS. This titanium technology utilises Powder Bed Fusion, specifically Laser Powder Bed Fusion (L-PBF), to create 80% porous implants with increased bone graft packability and lower stiffness compared to competitive devices on the market.

According to Osseus, the Aries family of lumbar interbody fusion devices features a proprietary mesh lattice structure, which helps reduce the stiffness of the cage and maximise bone graft packability. The distinctive mesh structure is optimised to create a superior environment for bone cell fixation and proliferation.

The Aries-TS system is intended for intervertebral body fusion procedures in skeletally mature patients with degenerative disc disease (DDD) of the lumbar spine at one or two contiguous levels from L2 to S1. It also offers aid to Grade 1 spondylolisthesis or retrolisthesis at the involved level(s). The company states that its next interbody to be released will the Aries™-TC Transforaminal Curved Interbody.

Osseus Fusion Systems has launched the Aries™-TS, an additively manufactured titanium spine implant (Courtesy Osseus Fusion Systems)

"In January, we celebrated the one-year anniversary of the first implantation of the Aries-L lateral lumbar interbody fusion device so we are very excited to follow it up with the launch of the Aries-TS," stated Robert Pace, CEO of Osseus Fusion Systems. "As a company committed to helping those in need of relief from chronic lumbar pain, we are confident that the Aries™ family of lumbar interbodies is a positive step toward that goal."

www.osseus.com

Grain structure control during metal Additive Manufacturing by high-intensity ultrasound

The Additive Manufacturing of metals typically leads to the formation of columnar grain structures along the build direction in most as-built metals and alloys. These long columnar grains can cause property anisotropy, which is usually detrimental to component qualification or targeted applications.

In a recent article in *Nature Communications* ((2020) 11:142), an Australian research team led by Professor Ma Qian and comprising colleagues at the Centre for Additive Manufacturing, RMIT University, Melbourne, and the Centre for Advanced Materials Processing and Manufacturing, University of Queensland, reported on the development of an AM solidification-control solution for metallic alloys with an equiaxed grain structure and improved mechanical properties, which does not change alloy chemistry.

Using the titanium alloy Ti-6Al-4V as a model alloy, the team employed high-intensity ultrasound to achieve full transition from columnar grains to fine (~100 μm) equiaxed grains in AM Ti-6Al-4V samples produced by laser-based Directed Energy Deposition (DED).

The application of high-intensity ultrasound to crystallisation from liquid to solid can noticeably affect the properties of the crystalline material. Ultrasonic irradiation of liquids can cause acoustic cavitation. Acoustic cavitation during solidification of metal systems agitates the melt to activate nuclei naturally present in the alloy, proving useful in promoting fine equiaxed grains in welding and traditional casting processes.

During the study, Ti-6Al-4V samples with and without high-intensity ultrasound were prepared. The ultrasound was introduced into the melt by directly depositing the alloy on the working surface of a Ti-6Al-4V sonotrode vibrated at 20 kHz (Fig. 1).

Microstructural analysis revealed a substantial difference between the AM-fabricated Ti-6Al-4V samples with and without ultrasound (Fig. 2). The sample without ultrasound exhibited columnar prior-β grains several millimetres in length and ~0.5 mm in width traversing multiple deposited layers (Fig. 2a, c). In contrast, the sample with ultrasound showed fine (~100 μm), equiaxed prior-β grains (Fig. 2b, d).

The prior-β grain number density was increased from 3.3 mm^{-2} to 65 mm^{-2} by ultrasound, confirming that ultrasound enhances nucleation

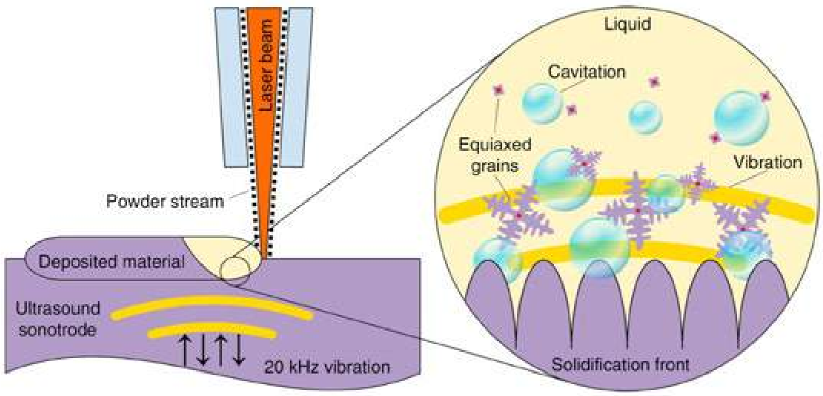


Fig. 1 Cross-sectional schematic showing metal AM by laser-based DED onto an ultrasound sonotrode vibrated at 20 kHz. The formation of acoustic cavitation and streaming in the liquid metal by high-intensity ultrasound can vigorously agitate the melt during solidification, thereby promoting significant structural modification or refinement

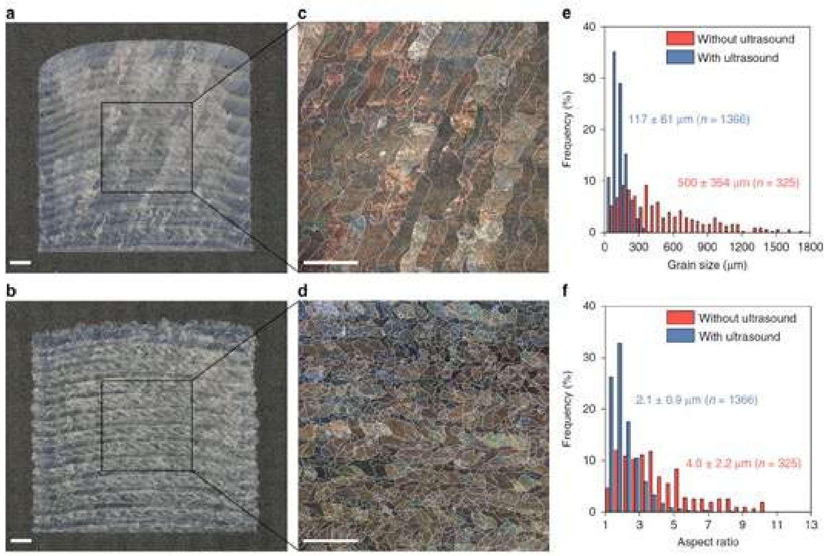


Fig. 2 Left; Optical microscopy images of the samples a) without b) with ultrasound. Centre; polarised light microscopy images showing c) large columnar grains and d) fine equiaxed grains. Right; Histograms of e) the prior-β grain size and f) prior-β grain aspect ratio for the samples with and without ultrasound. Measured from traced prior-β grain images. The prior-β grain boundaries in c and d are traced in white. Scale bars, 1 mm

during solidification. The distribution of both the prior-β grain size and prior-β grain aspect ratio were changed dramatically by ultrasound (Fig. 2e, f), reflecting the much-improved prior-β grain structure homogeneity.

Tensile engineering stress-strain curves (Fig. 3) showed that the yield stress and tensile strength of the as-built Ti-6Al-4V were both increased by around 12% by ultrasound (e.g., from 980 ± 13 MPa to 1094 ± 18 MPa for yield stress). Both groups of samples showed a strain-to-failure value of around 5%, which is said to be typical of as-built DED processed Ti-6Al-4V.

To put the strength improvement by ultrasound into context, the change in yield stress of AM-fabricated Ti-6Al-4V by ultrasound vs that achieved by chemical approaches is plotted in Fig. 3b. Deploying ultrasound, without modifying alloy composition, results in a greater increase in yield stress than alloying with B, LaB6 and C.

Fig. 3c plots literature data and data from this study on the yield stress of AM-fabricated α–β Ti-6Al-4V vs the inverse square root of the prior-β grain size (d). An approximate Hall–Petch relationship is observed. This implies that the resulting equiaxed prior-β grain size has played a major role in improving the yield stress (~7% out of the total 12% increase).

To test the generality of this developed approach, high-intensity ultrasound has been similarly applied to the AM of Inconel 625, using a custom-made stainless-steel 4140 sonotrode. The sample fabricated without ultrasound exhibited columnar primary γ grains of 500 µm in length and 150 µm in width with a strong <001> texture. In contrast, the application of ultrasound produced predominantly equiaxed primary γ grains of only a few microns in size (much finer than for Ti- 6Al-4V) with a near-random crystallographic texture. This confirms the generality of the ultrasonic approach for AM of different metallic materials.

To further showcase the capability of this approach for solidification control during Additive Manufacturing, a microstructurally graded Inconel 625 sample was fabricated that exhibited an alternating columnar/equiaxed/columnar grain structure along its build height. This was achieved by simply turning on and off the high-intensity ultrasound during AM. The approach thus also offers an alternative means of fabricating graded grain structures during AM.

Although the reported work was restricted to Directed Energy Deposition for ultrasonic grain refinement during Additive Manufacturing, previous studies have shown that stimulating solidification control during wire-fed welding processes is possible by ultrasonically vibrating the weld pool. Since both wire-fed welding and wire-fed AM deposition processes share similar fundamental principles, the authors anticipate that the method can be extended to wire-fed AM processes.

However, the vibrating sonotrode may risk disrupting the powder layers after recoating in a powder bed fusion AM system. In this context, an inoculation path for grain refinement may be more applicable to metal AM by powder bed fusion processes.

Greater detail on this study is available from Professor Qian, the paper's corresponding author.
ma.qian@rmit.edu.au

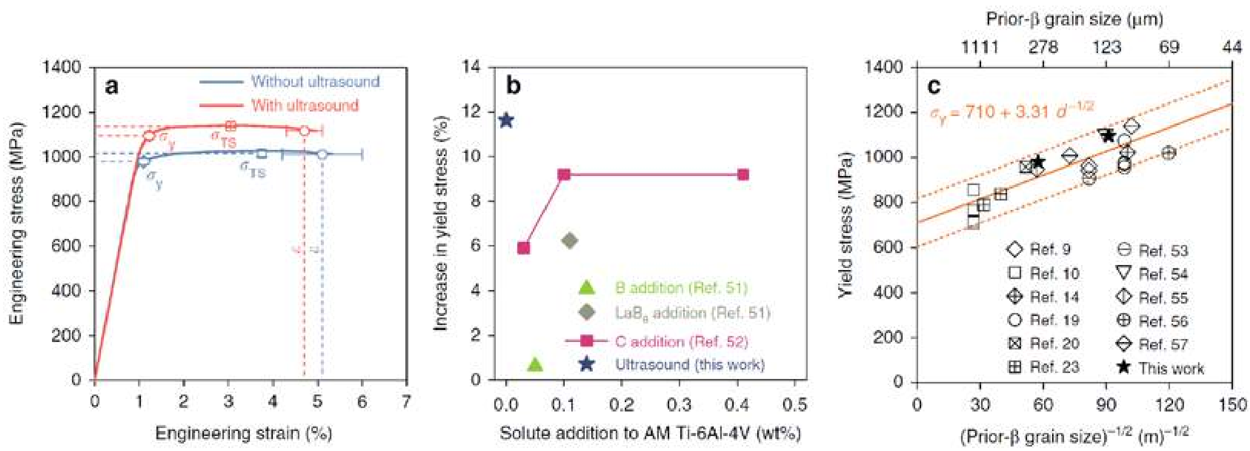


Fig. 3 a) Engineering stress-strain curves of the as-built samples with and without ultrasound. The error bars represent one standard deviation of three tests. b) Change in yield stress of AM-fabricated Ti-6Al-4V by chemical addition compared with ultrasound in this work. c) Tensile yield stress vs the inverse of square root of prior-β grain size from the literature and this work. The solid line in c represents the Hall-Petch line (σy = σ0 + kd-1/2, σ0: friction stress; k: material constant; d: grain size) of best fit, while the dashed lines define ±0.15σ0 (where σ0 = 710 MPa) along the linear fit

Aurora Labs agrees certification services framework with DNV GL

Aurora Labs, Bibra Lake, Australia, has has entered into a Framework Agreement with DNV GL, a global quality assurance and risk management company headquartered in Oslo, Norway. As part of the agreement, DNV GL will provide certification services for Aurora's metal Additive Manufacturing machines.

According to Aurora, the companies will work towards developing processes in which parts or objects which are additively manufactured by Aurora can be independently qualified or certified using the external qualification or certification services provided by DNV GL.

DNV GL will provide certification services for parts built on Aurora's metal Additive Manufacturing machines (Courtesy Aurora Labs)

"The use of an independent certification process for parts manufactured by our printers will strengthen the competitive position of our technology in parts manufacturing markets," stated David Budge, Managing Director of Aurora Labs. "Certification gives confidence to original equipment manufacturers and consumers of parts that our printing technology is able to meet the high industry standards of performance, quality, and reliability."

Budge added, "We are very excited about the opportunity to work with DNV GL, being major players in the certification, ship registry and 3D printing certification space. Their certification services will help to fast track the adoption of Aurora's technology in our core industries and beyond."

The Framework Agreement reportedly sets out a general scope of certification and audit services that may be provided by DNV GL to Aurora, and the terms and conditions of delivery of these services. Aurora announced in December 2017, that it had signed a non-binding term sheet with DNV GL for the creation of an independent certification process. The companies state that they will explore opportunities with current and potential partners to utilise DNV GL's certification procedures.

Brice Le Gallo, Regional Manager for South East Asia & Australia, DNV GL – Oil & Gas, commented, "3D printing has the potential to save the industrial sector cost and time worth billions of dollars and increase the sustainability of supply chains. While it is currently in its infancy, the efficiency gains of shorter lead times for sourcing parts, and reduced need for storing stock, as well as the new design opportunities provide a convincing argument that demand will develop rapidly."

"Issues of trust are key to 3D printing gaining acceptance. I'm delighted that DNV GL will be partnering with Aurora to implement systematic qualification and certification processes that provide industrial supply chains with assurance that Aurora's metal printers meet high standards of quality and integrity," Le Gallo continued.

www.auroralabs3d.com
www.dnvgl.com

Dates announced for Additive International Summit 2020

Dates have been confirmed for the Additive International Summit, formerly the International Conference on Additive Manufacturing and 3D Printing, which will take place across three days from July 14–16, 2020. The first day will feature the pre-summit event located at the University of Nottingham, Advanced Manufacturing Building, Nottingham, UK, with the main event based at Trent Bridge Cricket Ground, Nottingham.

Organised by Added Scientific Ltd, the Additive International Summit regularly attracts over 250 delegates from more than 170 institutions with interests in all the newest technological developments for the AM industry. The event is targeted at academic and industrial leaders in Additive Manufacturing and, since 2006, has showcased next-generation technology and the latest thinking. It provides a forum for practitioners to build networks and drive innovation.

To accommodate the growth of the event, the Additive International Summit will be held for the first time at the Trent Bridge Cricket Ground, which is close to Nottingham City Centre, offering excellent transport links for visitors.

Additive International will take place at Nottingham's famous Trent Bridge cricket ground (Courtesy NCCC)

The programme and speakers for the 2020 Additive International Summit are yet to be announced. Further information and registration details are available via the event website.

www.additiveinternational.com

SUPREME Project Workshop

Want to learn about innovative ways of improving the sustainability of powder metallurgy processes?

The SUPREME project aims at optimising powder metallurgy processes throughout the value chain, focusing on a combination of fast growing industrial production routes and advanced ferrous and non-ferrous metals. Join the intensive one-day workshop to learn about its main achievements!

The SUPREME experts' workshop will cover a vast range of subjects including:

- Production processes
- 3D manufacturing
- Real time monitoring of energy and resource efficency
- Use-cases & impact demonstration
- Life cycle assesment & eco-innovation

© GKN Sinter Metals Engineering GmbH

Event Date: 09 July 2020

Location: Senlis, France

Standard Registration: €50

Registration Deadline: 15 June 2020

Find out more and book your place at:

www.supreme-project.com

This project has received funding from the European Union Horizon 2020 Programme (H2020) under grant agreement no. 768612

Guhring UK reports 75% cost savings on AM tool steel milling cutter

Guhring Ltd, Birmingham, UK, a subsidiary of cutting tool manufacturer Guhring Group, has put into production an H13 tool steel milling cutter additively manufactured on the Metal X Additive Manufacturing system, developed by Markforged, Watertown, Massachusetts, USA. The new milling cutter features a uniquely designed infill for increased efficiency, and is said to be 60% lighter and 75% cheaper to produce than its conventionally-manufactured predecessor, allowing for faster tool changes in cycles and a reduction in cycle times.

Guhring UK specialises in the supply of made-to-order carbide and polycrystalline diamond (PCD) cutting tools for leading companies like BMW, Jaguar Land Rover, Airbus, and BAE Systems. The company made its initial move into Additive Manufacturing using a Markforged carbon fibre AM machine to produce custom sample parts and replacement parts for its plant. Now, using Markforged's Metal X, the company is supplying a range of production-grade cutting tool bodies for milling and special-purpose applications.

The Metal X system produces parts using a process Markforged refers to as Atomic Diffusion Additive Manufacturing (ADAM), in which metal powder bound in plastic is deposited a layer at a time to form the part geometry, then debound and sintered. Alan Pearce, PCD Production Supervisor at Guhring UK, commented on using system, "Within five days, we had printed and sintered a fully functional metal cutter body/ Using Markforged 3D printers just speeds up everything."

"Guhring UK is doing something truly remarkable — they're using additive to make subtractive processes better," commented Michael Papish, Vice President of Marketing at Markforged. "This is the first time a company in our space has had a foothold in the specialised and early-stage production tooling market. And instead of just replacing their traditional cutting tool, Guhring has used our additive technology to optimise the weight and interior geometry of the part, thereby creating more efficient tools faster and cheaper."

"The Metal X removes the traditional design constraints of conventional tool manufacturing while providing the best that additive has to offer," he added. "The ability to reduce the weight of the part as well as introduce completely new interior features ensures Guhring UK will stay at the cutting edge of tool design."

www.guhring.co.uk
www.markforged.com

The additively manufactured H13 tool steel milling cutter was produced using a Markforged Metal X system (Courtesy Markforged)

AMRC appoints Steve Foxley Executive Director

The Advanced Manufacturing Research Centre (AMRC), University of Sheffield, South Yorkshire, UK, has appointed Steve Foxley, former Managing Director of Siemens, as its new Executive Director. Foxley will join the AMRC on January 20, 2020.

As part of his new role, Foxley will lead the centre's Management Board to develop and strengthen relationships with new and existing industrial partners; engage with government to identify opportunities for further strategic development of the AMRC, and establish relationships with key stakeholders to ensure the continued development and investment in the City Region and Advanced Manufacturing Innovation District.

Foxley takes on the role as Executive Director of the AMRC as it expands its footprint across the Midlands and the North, with new R&D facilities in Broughton, Preston and Derby, supporting the government in achieving its goal of raising R&D spend in the UK to 2.4% of GDP.

Professor Koen Lamberts, President and Vice-Chancellor of the University of Sheffield, stated, "We are delighted that Steve is joining us at this pivotal time for the AMRC and the North. At the AMRC we have an ecosystem for the university to work with government and industry to address productivity, processes and skills in a range of sectors – including aerospace, energy, construction and all types of manufacturing."

On his appointment, Foxley commented, "It is a privilege to be appointed as Executive Director of the AMRC. Coming from a company that has a long history of research collaboration with the University of Sheffield and an even longer history of involvement in innovation in the city, I have long admired the truly innovative work being done here."

www.amrc.co.uk
www.sheffield.ac.uk

Isostatic Toll Services opens new HIP facility in Spain


The new facility will be officially opened this month (Courtesy ITS Bilbao)

Isostatic Toll Services Bilbao SL, opened its new Hot Isostatic Pressing facility on 29th January, 2020, in Abanto Zierbena, Biscay, Spain. With a total investment of €14 million ($15.5 million), the new plant reportedly offers the largest available HIP systems in southern Europe.

Already installed and operational at the Bilbao facility is an AIP52 HIP unit, with a second identical system due to be installed in December 2020. With a hot zone diameter of 1100 and depth of 2500 mm at 103 MPa, the AIP52 is capable of processing large components, such as engine blades, vanes and integral rings used in the aviation industry. In addition to supporting the high-tech aerospace sector, the facility is expected to serve the region's growing medical implant manufacturing industry.

The new facility has been granted EN 9100 approval by Bureau Veritas and has been successfully audited and approved by Rolls Royce and Pratt & Whitney. Safran approval is currently underway, with Nadcap approval planned for mid 2020.

In addition to providing toll services, staff at ITS Bilbao will support a new AIP European Competence Centre, established to serve the EMEA region with installation, commissioning, maintenance, inspection and repair of AIP's range of presses and systems.

www.isostatictollservices.com
www.aiphip.com

Cheaper powders, faster build speeds and no thermal stresses? How AM is going supersonic at SPEE3D

In recent years, Australia's SPEE3D has made waves in the AM industry with its Cold Spray-based metal Additive Manufacturing systems. Following successful projects with the US and Australian military, and multiple installations at one of Europe's most experienced metal AM parts manufacturers, the world is starting to take note. Alex Kingsbury visited the company at its Melbourne base for *Metal AM* magazine and spoke with its founders and newly expanded management team about its technology and international expansion.

SPEE3D co-founders Byron Kennedy and Steven Camilleri are no strangers to commercialising deep tech innovations. It was during their time working together on the Charles Darwin University World Solar Car Challenge team that they developed a revolutionary high-efficiency motor for their car, the 'Desert Rose'. The Desert Rose was awarded the world speed record for solar cars in 2000; and in 2001, Kennedy and Camilleri established In Motion Technologies to commercialise their electric motor. A successful sale of the company in 2006 to NYSE-listed manufacturer Regal Beloit made the motor technology one of the most successful spin-offs from solar car racing, and the motors are now widely used in many commonplace applications such as pool pumps and air conditioners.

The sale to Regal gave the co-founders the opportunity to oversee commercial production of their electric motors around the world, and the pair embraced the new knowledge and learning that came with commercial production. "We're electrical engineers that come from research backgrounds," explains SPEE3D CTO and co-founder Steven Camilleri. "Regal helped us understand how manufacturing worked. You don't normally have academic people that worry about cost, lead time, or customer experience." Through exposure to international metal supply chains and products, the pair found sourcing quality metal components to be a very painful experience.

In 2010, they began investigating alternative manufacturing methods and were excited by the promise of Additive Manufacturing, but the excitement faded quickly when confronted with the price tag. Calling on their manufacturing training, they knew this was due to the slow speed of the machines. "We set our minds to solve the scaling issue that Laser

Fig. 1 Byron Kennedy, CEO, and Steven Camilleri, CTO, co-founders of SPEE3D

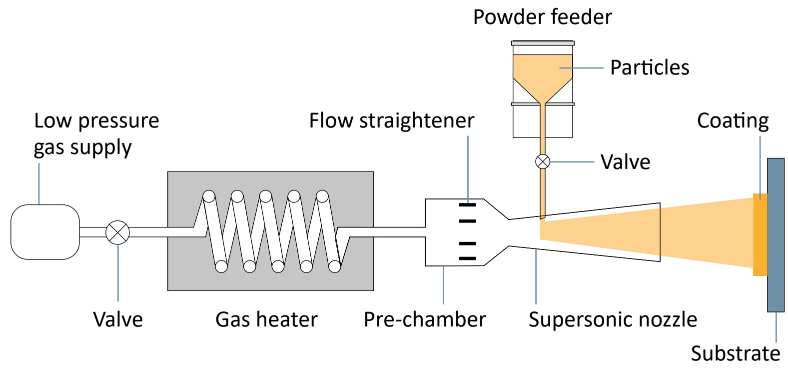


Fig. 2 Operating principle of low-pressure Cold Spray [1]

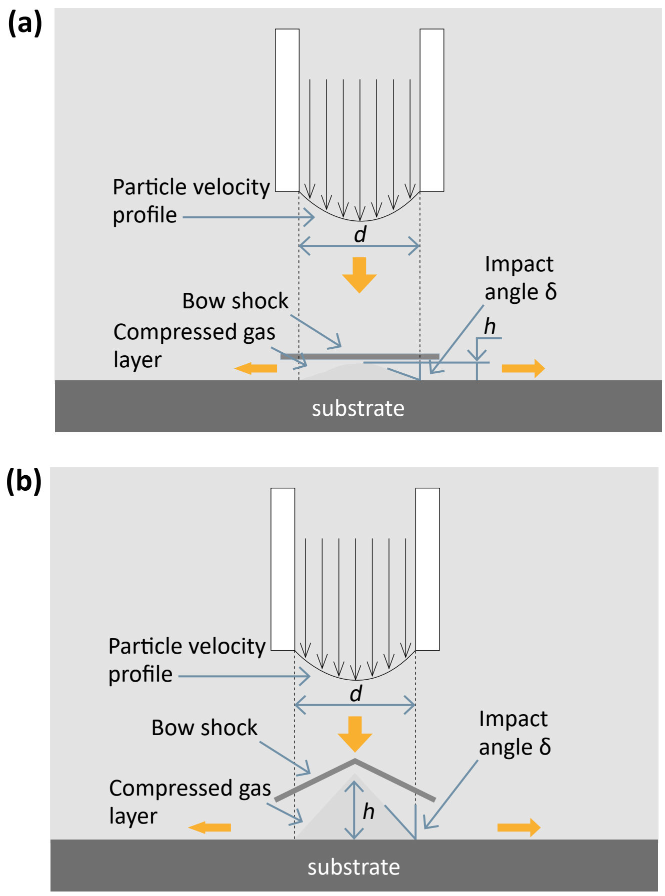


Fig. 3 Impact angle between gas-particle jet and surface and position of bow shock in case of Cold Spray deposition of single tracks with low (a) and high (b) thickness [2]

Powder Bed Fusion (L-PBF) faces, but ultimately we realised that there was no way forward due to the laws of physics," says Camilleri. Knowing heat was the limiting factor, they looked at technologies that could densify material without heat. During a visit to the CSIRO laboratories (the Commonwealth Scientific and Industrial Research Organisation), they witnessed Cold Spray technology and saw the potential immediately. In 2015, Kennedy and Camilleri decided to pursue commercialisation of this technology full time, and SPEE3D was born.

What is Cold Spray?

In the Cold Spray process, metal powder of a 5–45 μm size range is deposited onto a substrate by accelerating the particles to supersonic speeds via a carrier gas. This kinetic energy plastically deforms the particles upon impact, forming a 'particle splat' on the substrate. The plastic deformation of the particle is shown in a change of shape in the particle and substrate. Some mechanical interlocking occurs, and a small amount of heat is produced; however, the heat is not significant enough to change the microstructure of the particles. In fact, the particles largely retain their original microstructure, with the exception of some peening or cold working effects. Unlike many other AM processes, Cold Spray can process a wide range of particle shapes; spherical, irregular or dendritic morphologies are all cold-sprayable by adjusting spraying parameters.

Like many innovations, Cold Spray's discovery was one hundred years too early; true commercialisation has only occurred in the last thirty years. The key innovation in the technology is the use of a de Laval nozzle, a convergent-divergent nozzle that allows metal powder to reach supersonic speeds; this method was first patented in the 1960s. In the 1980s, scientists at the Russian Academy of Science experimenting with metal powders in a wind tunnel were able to achieve coatings of a thickness and density that signalled that the technology had potential for commercial use (Fig. 2) [1]. Since the 1990s, it has been successfully used as a coating technology, but its use as an AM technology to create near-net shape structures has only developed in recent years.

What is key to understanding this technology is an awareness is that bonding between materials and particles does not require a thermal source, i.e. there is no melting and cooling cycle; it is a solid-state process. The cold sprayed deposit is therefore very low in oxides and has little thermally-induced residual stress. Unlike thermally processed parts that are built in tensile stress, cold sprayed parts are built in compressive stress, which increases the fatigue properties of built parts. The absence of heat in the process makes it ideal for use with reactive materials such as titanium, aluminium and magnesium. Solid-state processing enables thick coatings to be applied without compromising the dimensional tolerance or underlying metallurgy of a parent part, making Cold Spray ideal for reclamation and repair processes. Cold Spray has, for example, been widely used for the repair of magnesium helicopter gearboxes.

The ductility of the sprayed material is an important consideration; less ductile materials undergo less plastic deformation and the built part can exhibit a brittleness not seen in thermally processed parts. Thermal post-processing such as Hot Isostatic Pressing (HIP) can negate these effects. More ductile materials such as aluminium and copper are less prone to embrittlement and, depending on the end use, do not always require a thermal treatment.

Cold Spray is a 'line of sight' technology similar to Directed Energy Deposition (DED) processes and, as such, the Cold Spray nozzle must be perpendicular to the sprayed surface. For this reason, intelligent toolpath strategies need to be employed to create shapes with overhangs, internal, or complex features. In general, the spot size of the nozzle limits the fidelity that Cold Spray can attain, and highly complex features, sharp corners or smooth surfaces are only achievable with post-machining.

Despite these challenges, the most exciting characteristic of Cold Spray is the speed with which it can deposit material. At rates of up to 6 kg per hour for small-scale Cold Spray systems, it is clear that Cold Spray can deposit material an order of magnitude faster than L-PBF systems, which was what drew Kennedy and Camilleri to the technology in the first place.

Fig. 4 To most Cold Spray users, the SPEE3D machine design appears counter-intuitive. The nozzle is fixed at the base of the machine and a six-axis robot controls, rotates and orientates the build platform

Cold Spray AM in SPEE3D systems

Kennedy and Camilleri's biggest task was to create a product that could leverage the advantages of Cold Spray while addressing the challenges of taking the technology into the AM realm. The evolution of Cold Spray from coating technology to Additive Manufacturing seems simple, but it is not straightforward. Camilleri explains, "One of the problems with Cold Spray is that shapes saturate; you build a cone and then you cannot continue to build as the cone starts deflecting particles away, so you have to be able to reorient the nozzle." (Fig. 3) [2].

To most Cold Spray users, the SPEE3D machine design appears counter-intuitive. The nozzle is fixed at the base of the machine and a six-axis robot controls, rotates and orientates the build platform (Fig. 4). In fact, a moveable build platform means that the Cold Spray machinery is stationary within the machine, reducing operational complexity. With this key piece of architecture confirmed, Kennedy and Camilleri then commenced the arduous task of developing the Cold Spray Additive Manufacturing (CSAM) design rules and build strategies that underpin SPEE3D's TwinSPEE3D software and, ultimately, the key value proposition of their offering.

The LightSPEE3D was the company's first machine release; with a build volume of 350 mm diameter by 300 mm, this is the company's smallest format machine. The larger WarpSPEE3D was released in 2019 and has a build volume of 1 m diam-

Fig. 5 The WarpSPEE3D system, released in 2019, has a build volume of 1 m diameter by 0.7 m and was designed with robustness on a manufacturing floor in mind

eter by 0.7 m. Both machines have a similar design and layout, and were built with a view to the robustness of a manufacturing floor. "Our mission was always to make manufacturing easier, it informs everything we do at SPEE3D," explains Kennedy. "We are solving the issues that we faced when commercialising our electric motor." The company's latest offering, the SPEE3Dcell, was also designed with this mission in mind. The 'cell' integrates Cold Spray, heat treatment and machining operations in one product offering. "We have cut out the supply chain headaches. We aren't going for the fun stuff, we are doing the hard work to attack the volume market," stated Kennedy. To that end, SPEE3D's machines are capable of additively manufacturing thirty tonnes of copper per year.

"Where traditional Cold Spray utilises inert gases such as argon or the even more costly helium, SPEE3D systems use only compressed air. Likewise, rather than focus on exotic materials, SPEE3D's focus has been on the larger markets of aluminium and copper."

This manufacturing mindset, combined with a strong commercialisation track record and deep foundations in innovation and R&D, makes Kennedy and Camilleri a rare and formidable combination. From the outset, they have had a razor-sharp focus on their value proposition. Where traditional Cold Spray utilises inert gases such as argon or the even more costly helium, SPEE3D systems use only compressed air. Likewise, rather than focus on exotic materials, SPEE3D's focus has been on the larger markets of aluminium and copper. Furthermore, metal powder from conventional Powder Metallurgy supply chains can be used with Cold Spray, dramatically lowering the material cost when compared with L-PBF technologies. Kennedy and Camilleri have always seen casting as their competitor technology and, throughout their product development, have continued to benchmark against more conventional manufacturing technologies to ensure cost-competitiveness.

A business model that works for mid-size firms

SPEE3D's key markets are defence, transport, and marine, and it has so far placed systems in the key geographic markets of the US and Germany. The company's business model has recently moved to a subscription basis, allowing customers the ability to access equipment and services for a monthly rate. Kennedy explains, "We are selling capacity. People don't want printers; they want to be able to build parts easily." As the customers that SPEE3D is targeting are primarily mid-size manufacturing businesses, the subscription model is proving to be a popular option.

Indeed, with the groundwork having been done on the robust hardware, software with algorithmic design rules, and intuitive user-interface, SPEE3D machines are designed to be run by an apprentice with minimal training. The robust equipment design means that most of the support and upgrades come via the software. As Kennedy explains, "Fortunately the hardware is very robust; most of the support requirement is for the software, which we can do from anywhere." This suits the Australian-headquartered business well. The machines themselves have an envelope which makes it possible for them to fit into a small shipping container or Conex box, allowing for ease of deployability in and out of locations.

Fig. 6 Rather than focus on exotic materials, SPEE3D's focus has been on the larger markets such as aluminium and copper. This aluminium bronze propeller is corrosion resistant in sea water and naturally anti-fouling, making it ideal for marine applications. The part weighs 1.4 kg and took sixteen minutes to build

Success in the defence sector

Deployability is something that the defence sector prizes highly, and SPEE3D's technology has attracted interest from defence forces in Australia at the highest level. In late 2019, an AU$1.5 million investment in a two year pilot for the Royal Australian Navy was announced. For Captain Chris Eggleton, Patrol Boat System Program Office Director, the opportunity to trial building parts on demand using SPEE3D technology provided unparalleled operational flexibility and accessibility. "We extend the lives of our boats for as long as we can," he stated, "and when spare parts are no longer stocked or hard to source, that affects the availability of our fleet."

While the ability to reverse engineer spare parts provides operational flexibility at base, the ultimate aim is to have Additive Manufacturing capability at sea. Having a machine in the field and an inventory of digital files has been a long-held dream of the AM industry and, with SPEE3D technology, this may prove viable in the very near future. The savings to an operation at sea are immense: "It saves logistics headaches, inventory management issues, and very costly delays," says Eggleton. The robust design of SPEE3D's systems makes them potentially perfect for expeditionary use – that is, use on the front line.

To that end, researchers in the US have found that battlefield scrap, when reclaimed and atomised via a 'mobile foundry', can be success-

Fig. 7 This aluminium part is a replacement drive wheel for an air compressor. This was an early demonstration of SPEE3D's capability to produce critical replacement components on-demand. It weighs 200 g and took less than eight minutes to produce

Fig. 8 These aluminium door handles weigh 130 g each and took under five minutes to produce

fully cold sprayed to repair parts, or build spare parts at a forward operating base [3]. For Eggleton and the Australian Navy, the vision is to have Cold Spray capability at an 'organisational' level. This means deploying a SPEE3D machine onto a large platform, such as a landing helicopter deck, to support a task group operational deployment at sea.

New appointments support international expansion

While success on home soil provides some validation, Kennedy is clear that the key markets for SPEE3D are the US and Europe. Being Australian-based and located at some distance from these markets requires a level of flexibility in business structure. Subsidiaries have been established in both the US and Germany, and key appointments have been made in each region. "We need feet on the ground to support customers in those regions," says Kennedy. "We are confident that we have hired the best people and now we need to build their teams up so we have a full complement of service and support in both regions."

The first appointment was Bruce Colter, who officially joined the team in June 2019 as Vice-President of the North American operation. Having come from a background in growing and building technology companies, the attraction to SPEE3D was the challenge of establishing a new AM technology in an unproven market. Colter was also drawn to working for SPEE3D by its strong management team, solid financial backing, and clear strategy, but what particularly impressed him was that SPEE3D had a differentiated and very competitive technology. "I wanted a Moore's Law for AM and I saw that Byron and Steve were really bending the cost curve," explains Colter. "With our build speeds we can compete with traditional manufacturing and have the advantage of being able to easily do multiple product iterations." As someone with an eye on software, it is SPEE3D's digital offering that he believes really differentiates the company from other providers in the marketplace. As to the culture of the company, Colter says the team at SPEE3D are "the smartest and hardest working team I've worked with, but without the ego, which is really refreshing."

The defence market in the US is the focus for Colter; a market that has been made more accessible through SPEE3D's alliance with Phillips Corporation, Federal Division, a machine supplier to US federal government departments. Phillips Corporation's new $1.5 million Additive Manufacturing centre in Baltimore, Maryland, will feature SPEE3D equipment and can supply to defence forces such as the Army, Navy, Marines, Air Force, and Coast Guard. A recent workshop with the US Army uncovered battery

Fig. 9 Left to right, Byron Kennedy, Stefan Ritt, Bruce Colter, Stefan Beyer, Simone Baxter, Prof Raoul Mortley, Steven Camilleri, Grant Anderson and Phil Bowles

terminals as a perfect application for Cold Spray technology, as terminals corrode easily and require frequent replacement in the field. Together with Larry Holmes at the University of Delaware, the team manufactured fit-for-purpose battery terminals in ten minutes. Successful testing demonstrated just how useful Cold Spray technology can be on the frontline.

To support US sales, Colter will be establishing a SPEE3D applications centre where customer benchmarking can be performed and spare parts stocked. "The US has a high level of service expectation; it's important that we can meet those needs," says Colter. As such, the US team will be growing by two-to-three people in 2020, with the expectation it will double again the following year.

The next key appointment was Stefan Ritt, who joined the team in January this year as Vice-President of Europe, the Middle East and Africa. Ritt has spent over twenty years working in the AM industry at a global scale and has been instrumental in establishing metal AM technology in new geographical markets. It was the potential for AM to become an everyday, industrial manufacturing tool that drew Ritt to SPEE3D. "The reason AM is not picking up exponentially as was predicted is because it's not fast enough, cheap enough, or simple enough yet," says Ritt. "SPEE3D's technology integrates well into existing supply chains. We use known alloys, have more flexibility in the powder feedstock, and integrate well with known post-processing technologies." Past roles within the AM industry have made Ritt a regular visitor to Australia, and he is excited to finally work for an Australian company. "I am honoured that SPEE3D are entrusting me to be their representative in Germany," explains Ritt. "This was a business relationship that grew from a friendship".

"SPEE3D's technology integrates well into existing supply chains. We use known alloys, have more flexibility in the powder feedstock, and integrate well with known post-processing technologies."

Fig. 10 Left: An industrial copper cable clamp weighing 970 g, which took under twenty-five minutes to produce. Right: A pure copper rocket nozzle cover, 265 mm x 300 mm high, weighing 17.9 kg. The typical lead time for producing these parts is about six months, but WarpSPEE3D manufactured this part in less than three and a half hours

SPEE3D has something of a head start in the European market, having sold a LightSPEE3D machine to FIT Additive Manufacturing Group in 2018. Since that time, the German service bureau has been working to understand the capabilities of Cold Spray and now offers the technology as part of its AM portfolio. In 2019, FIT AG upgraded to the larger WarpSPEE3D. The ability to additively manufacture large-sized copper parts is the biggest selling point for FIT AG and its customers.

Ritt believes that the automotive and industrial markets will be a major focus for SPEE3D's technology in Europe. The ability to process copper is a boon for electric vehicle manufacture, and the ability to build multi-material components has many applications in the electronics industry. To showcase just how Cold Spray can be used in electric vehicles, Camilleri recently cold sprayed copper water cooling channels directly onto a battery pack busbar for an electric vehicle. Using Cold Spray eliminated the need for a separate, complex water-cooling system, while improving cooling performance and reducing weight. The part was built in twelve minutes and was less expensive than the currently used system.

Similar to its efforts in the US, the initial focus for SPEE3D in Europe will be on educating the market on Cold Spray's capabilities and building trust in the technology. Demonstration parts such as the busbar and battery terminals are important for conveying the end-use applications where Cold Spray technology makes sense. The team will be generating more case studies as part of its increased focus on market outreach.

Governance: Putting together an experienced board

In addition to building out the team internationally, SPEE3D has also made two significant board appointments. As of early 2020, Grant Anderson and Stefan Beyer have joined Chairman Raoul Mortley to form the full board complement. These appointments were strategic additions for SPEE3D and each brings valuable skill sets that will assist the company to scale.

Anderson was previously CEO of ANCA, an Australian-based Tier 1 supplier of CNC tool and cutter grinders. ANCA has successfully achieved exceptional business growth, with 98% of its revenue being export derived. As Kennedy explains, "We are mirroring ourselves on ANCA; they are a machine tool company that successfully scaled their business

Fig. 11 At Formnext 2019 the SPEE3D team additively manufactured sparkless copper hammer heads in six minutes apiece, to showcase the scalable capabilities of the SPEE3DCell

from an Australian base." Accessing Anderson's experience will be key to SPEE3D's growth in international markets. "Grant brings an approach to business that we need to scale our operations. He will help guide us to put adequate processes and systems in place," says Kennedy.

Industry veteran Stephan Beyer is co-founder and former CEO of BigRep, a provider of large-scale polymer AM machines. Kennedy and Camilleri had always admired Beyers' achievements at BigRep, both in marketing an AM product to a broad audience and also in his significant success in fundraising for BigRep. A focus for the team in 2020 will be to increase the market awareness of Cold Spray technology, and to turn SPEE3D into a global brand. "Stephan is crafting our outreach strategy," says Kennedy. "We will be focusing more on promoting high-profile user case studies." Like Anderson, Beyer has also overseen the expansion of a business into international territories, having established a BigRep presence in the US and Singapore.

It is clear from these appointments, both at the board and senior management level, that SPEE3D's focus into the future is on strong business growth via expansion. Certainly, there is a quiet optimism and confidence that abounds in the SPEE3D Melbourne offices, and anticipation is building for a very promising few years.

Future plans

SPEE3D has already made a few waves in the media, with its latest efforts at Formnext in November 2019 catching the attention of many show goers. The team was keen to impress upon the audience the speed and functionality of Cold Spray technology. This was done by holding a live demonstration in which the SPEE3Dcell was used to produce a 1.012 kg copper sledgehammer in just ten minutes and two seconds, breaking the world record for the fastest 'live print' of a metal part. In a great display of showmanship and spectacle, the hammer head was then attached to a handle and a Thor look-alike smashed a record, literally. For the duration of the show, the team additively manufactured sparkless copper hammer heads in just over six minutes apiece, to showcase the scalable capabilities of the SPEE3DCell.

"We printed hundreds of kilos of copper at Formnext. No other exhibitors could say the same for any material," says Kennedy. SPEE3D will continue to exhibit at AM shows such as Formnext and RAPID, but will also look to move into larger manufacturing shows such as EMO and IMTS

Fig. 12 A multi-material heat sink created by depositing copper powder onto aluminium fins to create a heat sink that is high performance, low weight and inexpensive to produce. This 200 g part weight took two minutes to produce

in 2020, to access more conventional industry businesses.

While sales and marketing efforts will be ramping up at breakneck pace, that doesn't mean the company won't continue to push technical boundaries with its technology. The team is busy working through a programme of getting stainless steel ready for release to SPEE3D customers, adding to its materials suite of aluminium and copper. Customers are driving many other materials development programmes such as an aluminium bronze, and differing high-performance copper alloys. Applications will also drive powder sourcing. "We will be offering a range of powders with varying qualities for different applications," explains Kennedy. "For example, we will offer a copper material for thermal and electrical applications, and another copper material for mechanical applications."

Given the importance of the defence and aerospace markets, SPEE3D will also work with customers and suppliers to ensure full traceability through supply chains. It will continue to make its machines as easy to operate as possible, increasing robustness and continuing to remove the manual handling touch points of the operation. With increased digital capability comes the need for data storage and analysis, aiding the traceability that is critical for many customers.

Wrapping up

The foundations for SPEE3D are now truly in place. With solid governance and an experienced and knowledge-able team situated in strategic locations around the globe, 2020 presents a clear runway for business growth. The task ahead is not being underestimated by anyone, least of all Kennedy and Camilleri; however, the duo remain undaunted by the task ahead. The co-founders are confident that their product solves problems that they faced as manufacturers and that many others continue to experience on a daily basis. Their solution may have roots in a hundred-year-old technology, but if anyone can navigate that valley of death, it's the SPEE3D co-founders, serial entrepreneurs and innovators, Byron Kennedy and Steve Camilleri.

Author

Alex Kingsbury
alex.kingsbury@rmit.edu.au
www.rmit.edu.au

Contact

SPEE3D
5 Wayne Court
Dandenong
Melbourne, Victoria 3175
Australia

contact@spee3d.com
Tel: +61 (03) 8759 1464
www.spee3d.com

References

[1] Singh, Harminder & Sidhu, T.S. & Kalsi, Sukhminderbir & Karthikeyan, J.. (2013). Development of Cold Spray from innovation to emerging future coating technology. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*. 35. 10.1007/s40430-013-0030-1.

[2] Kotoban, D, Grigoriev, S, Okunkova A, Sova, A. (2016). Influence of a shape of single track on deposition efficiency of 316L stainless steel powder in Cold Spray. *Surface & Coatings Technology* 309 (2017) 951–958

[3] Pepi, M, Zander, N, Gillan, M. (2017). Enabling Expeditionary Battle-field Manufacturing Using Recycled, Reclaimed, and/or Indigenous Mate-rials. RAPID + TCT 2017 Proceedings; 2017 May 8–11; Pittsburgh, PA. p. 1–23.

Current perspectives on metal AM: Hype, volume manufacturing and the geographies of production

Metal AM exists in a potentially confusing place between the world of 3D printing and its 'maker' movement, and Industry 4.0, with its drive towards new economic models. Here, Dr Jennifer Johns, Reader in International Business at the University of Bristol, UK, contextualises metal AM within broader narratives around technological change and economic development, Industry 4.0 and the Factory of the Future to give us a better understanding of what the outside world expects. Drawing on recent empirical research, different and often contradictory viewpoints are presented on the key issues facing the move to volume manufacturing and the geographies of production.

Recent years have seen consistent media and industry interest in Additive Manufacturing, fuelled by reports of high growth rates and publicity around exciting new case studies. The 'hype' surrounding AM has increased the external profile of the industry but has also resulted in some damaging consequences. One such consequence is the lack of realistic approaches to understanding the sector and the degree to which it can ever be as transformative as pundits would lead the general public to believe. This article does two things. Firstly, it contextualises metal AM within broader narratives around technological change and economic development, 'Industry 4.0' and the 'Factory of the Future', to give us a better understanding of what the outside world is expecting of the technology. Secondly, it pays close attention to two of the most significant areas of projected change – the volume and geographies of production – and draws on recent empirical research to present different, often contradictory viewpoints. This will offer insight into how well metal AM industry insiders feel it is able to meet external demands. The focus of this article is predominately on Laser/Electron Beam Powder Bed Fusion (L-/EB-PBF), as these are the most mature metal AM processes and currently offer the highest level of technological readiness. Other technologies, such as metal Binder Jetting, are highlighted where interviewees raised them as presenting a potential deviation from the development trajectories of L-/EB-PBF. The article will conclude with some reflections on the evolution of metal AM and on the possible outcomes of the dialogue between those inside the industry and those outside it.

For many external to the metal AM sector, it is included under the non-specific umbrella of '3D printing', and as such is more strongly associated with the 'Maker Movement' and 'Makerspaces' and their ubiquitous plastic chess sets and 3DBenchies.

Fig. 1 For many outside of metal AM, it is included within the wider field of 3D printing, itself more commonly associated in the public imagination with the hobbyist plastic 3D printing of toys such as the pictured '3DBenchy'

Fig. 2 3D printing forms part of the vaguely understood and much hyped 'Industry 4.0'. The current rhetoric around Industry 4.0 and the Factory of the Future is driving many national government strategies around manufacturing technology

The diversity of different technologies, materials and applications that make up the world of Additive Manufacturing, and metal AM specifically, is not widely acknowledged. Nor is the scope of metal AM in industry (either as a prototyping or a production tool) widely understood. Instead, in the public – and often policy-making – imagination, 3D printing forms part of the vaguely understood Industry 4.0, as a tool of the 'Factory of the Future'.

As a consequence, the value and future trajectory of metal AM is bound up with the narrative of a wide number of different kinds of technological progress, including AI and big data. For those within the metal AM industry, who certainly view AM as having a significant role in the Factory of the Future, this can obscure the identification of the change dynamics and particular industry and policy demands of the sector.

The current rhetoric around Industry 4.0 is driving many national government strategies around technology in manufacturing and the move towards full automation of production lines and factories. In 2019, the World Economic Forum met in Davos, Switzerland, to discuss 'Globalisation 4.0: Shaping a Global Architecture in the Age of the Fourth Industrial Revolution'. The agenda considered how countries can respond to, and shape, changes in how goods are produced, distributed and consumed. This is based on the idea that the world is entering a fourth industrial revolution, where a wave of technological progress will launch us into a new era of globalisation. The world's leaders are pinning their hopes for economic growth on technological leaps, of which AM is expected to be one. These global discussions are mirrored by national initiatives such as the widely-mimicked German Industry 4.0 strategy, the UK's Industrial Strategy and Chinese action plans around technology development.

Pressure and expectation are weighing on the AM sector as a whole to make progress in machine capacity and speed, integration with other technologies and processes such as robotics, AI and big data, and to transform supply chains to increase speed of delivery, often through localised distributive manufacturing. Unpicking the role of *metal* AM is unclear, as '3D printing machines' are perceived as multi-material (plastics, metals and electronics) and multi-functional in this narrative. With global economic growth continuing to falter and no easy solutions apparent, the weight of expectation is likely to increase, not decrease, and delivery is expected to be in terms of years, not decades. Much is being asked of AM.

These expectations are amplified by academic work on AM. While engineering and material sciences focus on technological advances, social science has begun to focus on what it still calls 3D printing. Sociologists, economists, management scientists, geographers and political scientists have been musing over the societal impacts of 3D printing, focusing on predictions of a narrowing of the gap between producer and consumer as individuals design and print their own consumer goods. This work has offered valuable insights into how 3D printing could transform production and consumption. Supply chain management has begun to model scenarios around the length of supply chains based on known variables related to different configurations of machines, their capacity and proximity to suppliers and customers. One of the most significant papers written in my field of international business makes a series of predictions about the impact of AM in manufacturing and suggests which sectors will be most likely to experience transformative change. It is, unfortunately, based on several misconceptions of the sector, the result of information sourced from secondary industry and media reports, and fails even to distinguish between technologies and materials.

In consequence, I secured funding from the British Academy to spend time talking to the AM sector, interviewing owners and senior management in AM firms and their OEM users in the UK, US and Germany. Between 2017 and 2019 I interviewed fifty-two individuals from across the supply chain about their operations and business strategies, and what they saw as the current and future directions for AM evolution. Around half of the interviewees worked in, or in roles connected to, metal AM (e.g. metal powder suppliers), and all interviewees spoke to the whole AM sector. I attended the global industry conference at Formnext, Frankfurt, Germany, in 2017 and 2018, and presented my initial research findings at the Additive Manufacturing User Group (AMUG) Conference in Chicago in 2019, where I will present again in March 2020. The rich interview dataset available to me reveals many interesting findings related to the changes within this sector, including common challenges and barriers, underlying business models, regulation and standards, policy-making and innovation rates, as well as a wealth of historical information on the evolution of the AM industry. This article will focus on two current and topical debates. First, that of volume Additive Manufacturing and second, the reshoring of production.

Fig. 3 There was a consensus that current build speeds are no longer a significant barrier to process adoption, with multi-laser machines offering dramatic increases in productivity. This image shows the difference in productivity within a fixed build time using 1, 2 and 4 lasers on a RenAM500Q machine (Courtesy Renishaw plc)

Metal AM: From prototyping to volume manufacturing?

For several decades, AM has been used primarily for prototyping, across all industry sectors. "We had technologies that were OK for prototyping parts but not for functional parts," stated one of my interviewees. A common source of commentary and debate within the sector – demonstrated by my research and also the programme content of conferences such as Formnext and AMUG – is the issue of how the industry can increase its production of functional parts and achieve manufacturing in larger volumes. A source of intense debate is how close AM is to high-volume, functional part production. This discussion will focus on some general trends and specific issues related to metal AM and place the debate within the context of Industry 4.0 and the Factory of the Future.

From prototyping to manufacturing

The process of moving to parts for end-use applications is not straightforward, and the sector's long association with prototyping has created some challenges. "The prototyping applications of technology have a very long background. They've got excellent diffusion in the manufacturing industry; everyone's aware of it, everyone uses it for that, and that's fine," explained one interviewee. "Proposing this for manufacturing, the story changes a little bit, and in many companies who use it for prototyping, they wouldn't even consider using it for manufacturing, simply because of the associated experience with the technology." Despite the hype around AM, within industry there remains a perception barrier to overcome. This is due to the increased demands being placed on the technology. "There have been some stories out there with folks who have struggled for way too long simply because they didn't get the proper training or the decisions with choice of materials versus process. It is taxing to get to the application you are looking to. Going to production puts a spin on that because our expectations are much higher than with prototyping. You can make a prototype that is pretty strong, but if you make a production part it has to work," they added.

Speed

Among my sources, opinions diverged on the importance of speed in Additive Manufacturing, with a consensus that current build speeds are no longer a significant barrier to adoption. Laser/Electron Beam Powder Bed Fusion parts often have long build times, but other factors such as functionality were considered relatively more important, along with total product development time. "We'd always take more speed. It does, however, also have to perform. So, if it is a trade-off against functionality, then no, we wouldn't take it. No, we wouldn't take it ever. Whatever it is doing, it has to perform," one source commented. Build speeds have to be considered as part of the whole production process. "When you include the set-up time, 3D printing can be much, much faster than other methods. So speed is something that all of the 3D printer vendors are working to improve, but even so, 3D printing has its place when you talk about speed." A broader perspective, then, needs to be adopted when making manufacturing decisions.

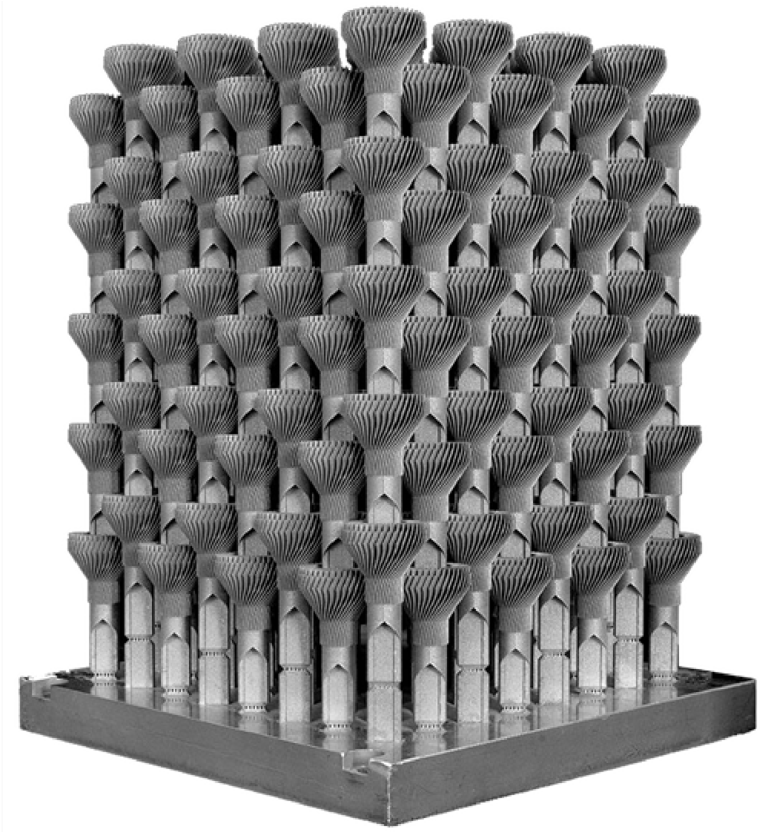


Fig. 4 The move to higher production volumes is challenging for the industry, but opportunities exist. This optimised build enabled 384 automotive LED heatsinks to be stacked on the same build plate. Coupled with a number of parameter optimisations, the build time of each part was reduced from 1 hour to under 5 minutes (Courtesy Betatype)

Production volumes

Recently, the focus has been on whether metal AM can meet the demands of industrial production. There is some disagreement about whether this is happening now, is a short- to medium-term possibility, or remains a future goal. "To happen on an industrial scale, we need to see serial manufacture. One part may be made at volumes of say 10,000 a year. This is becoming a possibility," one source stated. However, there are sectoral differences, and it is currently easier to 'sell' the business model for smaller parts. "A lot of our repeat production customers are producing relatively small things in quite high numbers."

Several interviewees expressed confusion around what the industry meant by 'volume'; i.e hundreds, thousands or millions. Aerospace and Formula 1 are heralded as leading the adoption of AM, due to their comparatively low volumes but real-world use of the technology. The leap to industrial-scale manufacturing in other sectors familiar with AM prototyping will be harder. "The automotive industry is a high cost pressure industry, so they need low unit costs and high volumes, and it's not really a thing that additive is good at, at least at the moment," one source noted.

Indeed, many felt that the industry needed to be more conservative about both its claims for current and future capacities. "We're not at high volume," stated one interviewee. "It can be a few hundred a year or it can be several thousand. I think the highest volume we will see is about 75,000 a year, but a lot of things will just be thousands, not tens of thousands." The race to high volumes also risks overlooking potential areas for growth. "We're getting there in the transformation from small volume to high volume, but I think the small-volume market is one of the markets that's underestimated. So everyone is looking at the high-volume application, for example, the eyewear or shoe sole industry where you get millions of parts a year, but actually what makes the biggest amount when you look at our revenue or the revenue that our customers do, it's more serious, and that's 50 to 500 parts or something, and there are many applications out there."

Metal AM technologies

Conversations about the type of metal AM process that will achieve industrial scale manufacturing highlighted the fact that there isn't a single trajectory of development. "The most advanced technologies in the industrial context are powder bed with their selective laser sintering processes," stated one interviewee, reflecting the wider global focus on L-PBF AM. However, sources repeatedly acknowledged that there are alternative technologies becoming more viable. One global OEM stated that it has been holding back on investing heavily in a single technology, instead preferring to observe competitors and wait for alternative technologies to mature. "They [competitor OEMs] have invested in powder bed laser fusion equipment and been playing on it for some years. It is all very good as learning, but the probability is that it won't be powder bed laser fusion techniques that drive the price point down to a point at which our industry can seriously look at making metal laser fused end-use components."

Binder Jetting processes are viewed as having significant potential in moving metal AM towards industrial production. "There are opportunities with some of these new binder jet processes coming out. As the metals industry leverages the Metal Injection Moulding industry, I think there will be opportunities to

Fig. 5 Binder Jetting processes are viewed as having significant potential in moving metal AM towards industrial production, as can be seen at Indo-MIM's metal Binder Jetting operation in San Antonio, Texas (Courtesy Indo-MIM Inc)

leverage metal parts at a much lower cost and maybe a higher throughput," one stated. However, the suitability of these new technologies varies depending on function. "The main issue in the Powder Bed Fusion process is the internal stresses. So it will have its uses whether you build multiple components or whether you start using different hybrid processes, [Binder Jetting could be the] perfect technology for particular types of components, not for us, not for very complex thin walls, thin wall heat exchangers, but for other components I see it as a way forward, because of the build rate and the post-production. At the moment the Powder Bed Fusion process helps us realise our design. The design is the driver rather than the technology."

Business models

Progress is being made in AM in relation to the break-even point in comparison to traditional manufacturing methods. As one source reflected, "Clearly 3D printing is more attractive for smaller runs of parts in terms of number of units, and other methods are more attractive to larger volumes. So the question is where the break-even between those two happens, and that's a matter of some debate. The break-even is very different, depending on what exactly it is that you're fabricating." Speed is not therefore independent of other variables. Significantly, though, there are several indicators that a wider perspective needs to be taken on the value of metal AM rather than cost per part. The potential time savings, as suggested above, due to process and/or reduced logistics and also a wider concept of value. This includes consideration of the whole lifetime of the part as considerable cost savings may be made through the use of AM. The use of metal AM in building functional parts for aircraft due to weight savings is an obvious example. Greater strength and durability of products may also be a significant

"Clearly 3D printing is more attractive for smaller runs of parts in terms of number of units, and other methods are more attractive to larger volumes. So the question is where the break-even between those two happens, and that's a matter of some debate."

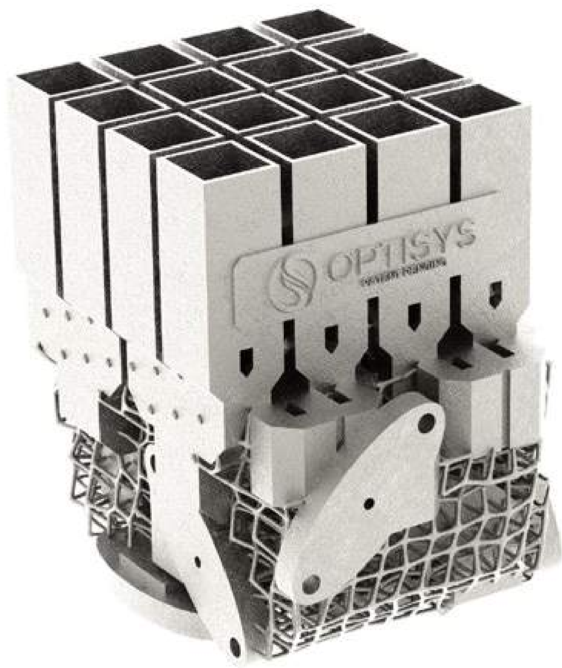


Fig. 6 This RF antenna system, designed and manufactured by AM as a single product, replaces and outperforms a previous 100-piece design. By viewing an antenna assembly as an integrated structure in which all the parts are combined into a single functional one, lead times could be reduced from months to weeks, size and weight cut dramatically and costs reduced (Courtesy Optisys LLC)

factor due to sustainability agendas. Vertical integration can allow the whole production chain to be viewed in full. "The value chain can be optimised and costs manipulated. The discrete bits of tech all add up. You can then drive the economics of it. You can get costs down and quality up which means that serial manufacture comes onto the agenda. This helps to overcome the overriding perception of AM as low volume and for prototyping."

Many discussions of industrial manufacturing noted the shift of focus from polymer AM to an acknowledgement of the potential of metal AM at the industrial scale. "There is a much greater history of people using additive on the polymer side so what we are seeing is an increase in metal additive both in the volume and in the criticality of the parts that are being pursued," stated one interviewee on the topic. Awareness that 'there are critical parts flying now' is leading to renewed confidence in the capacity of metal AM in industrial production.

'Selling' the business model

The sector is keen to emphasis the potential of AM and to publicise the advantages that AM offers. As one source put it: "Higher productivity, better economics, lower waste. It's really hard to see anything wrong with it; it basically delivers on all fronts." Part of this process, which relates back to the race to high volume, contexualised within conventional understandings of how products should be designed and manufactured, is emphasising that more systemic change needs to happen. "Which I think is the crucial difference with AM, isn't it?" they stated. "That's what the selling point is, it's actually we're not saying we can do existing things better, we're saying we can do totally different things. And proving that there's a business model underlying it."

Two things need to happen in relation to how the metal AM business model is understood within the industry and externally. First, there needs to be greater transparency around existing business models. Many expressed extreme frustration at business models that were marketed as successful but which were increasingly questioned as unfeasible and pushed to drive market growth and the profile of particular AM firms. Second, the tendency to view metal AM (and AM in general) as a unique and special technology may be alienating potential users and limiting application. "We think the A-list celebrity status of AM needs to be normalised," one company stated. Part of my research examined the rhetoric around the replacement of conventional technologies by AM. This is not voiced at all within the industry, where there is instead widespread acknowledgement that metal AM is one tool among many, sitting in complement to established production processes.

Barriers to higher volume manufacturing

There are numerous issues for metal AM to tackle with regard to the shift away from prototyping. Table 1 outlines the four key factors. A firmly-voiced concern of several OEM users was on the current capacity of metal AM machines. "Many of the machines around us are not really production capable. They are good for prototyping, they can be improved for niche applications, but as volume manufacturing equipment they aren't there. What we need are lower cost, faster, scalable platforms that can work with a variety of materials," stated one OEM. Others had a different vision of how machines could be configured to produce the required outputs: "I believe the future is not necessarily a large machine that is very expensive; as long as you can print a part in a given build volume it's better for companies to consider multiple machines so they can have true flexible manufacturing and scale."

To summarise, there are divergent opinions on how far metal AM has come in the shift from prototyping to volume manufacturing, from extreme scepticism of the claims that volume production is occurring through to enthusiastic certainty. Much insight can be gained by stepping back from our examination of the technology and price-per-part to consider the broader rationale for using AM. A key necessity is greater transparency around the business models underpinning higher volume AM production. Currently, publicised examples are treated with a level of distrust by industry, and this results in a more uncertain and confusing environment for potential adopters.

Factor	Problem	Solution
Equipment	Uncertainty around capacity to build in volume	Greater evidence from those claiming high volumes and/or improvements in machine throughput Advances in different Metal AM technologies Automation of post-processing Standard production matrices
Materials	Too few materials compared to traditional technologies	Increase materials available or justify why current range is sufficient
Adoption	Potential users unsure of shift from prototyping	Education and knowledge sharing of concrete examples and transparent business models
Product quality	Issues around the quality, accuracy and reliability of parts, meeting standards	Machine manufacturers need to deliver controlled processes to reduce variability

Table 1 Problems and solutions to AM volume manufacturing

Geographies of production

In addition to the focus on production methods, AM is expected by the general public, policy-makers and many in academia to not only transform how products are made, but also where they are made. The technology has the potential to radically change the geographies of where products are designed, prototyped, produced and distributed by radically reducing supply chain length and delivery times.

Reshoring is the process of bringing offshore operations back to their originating country. It is viewed as a contemporary counter-balance to the new international division of labour caused by the acceleration of globalisation since the 1970s. This caused a wholesale shift in manufacturing to low-labour-cost economies in the Far East. More recently, the rising cost of labour in developing countries (including China), peaks in oil prices, increased transport costs and supply chain vulnerabilities have resulted in some evidence of a shift back to advanced economies such as the US and Europe. Firms are also driven toward reshoring by the economic downturn, sustainability agendas, customer demands for flexibility and pressure to improve cost performance to consider where to undertake all parts of their production process.

The phenomenon of reshoring has gained greater prominence due to political engagement with the topic. In the US, it became a campaign issue during the last presidential election, with Donald Trump stating that he wants to see more manufacturing on American soil. In the UK, it has been cited as a possible solution to the negative economic and trade consequences of Brexit. *The Economist* recently cited the Chartered Institute of Procurement and Supply (CIPS) as their survey suggested that almost a third of British businesses that use EU-based suppliers were seeking British replacements.

AM is intimately tied up in this narrative, as the technology appears to offer a high-tech solution to the problem of severed international supply chains caused by political actions and/or firm-based strategies. During my conversations with those in the industry, the vast majority expressed scepticism about the degree of contemporary evidence of geographical shifts in production. However, a few anecdotal references were made to the return of some forms of prototyping and some injection moulding (both due to speed and quality issues) from China to the US, Germany and UK. Many in the industry also articulated strong opinions around how they envisioned the future of production and metal AM, positing several different inter-related factors as outlined below.

Dominance of traditional production methods

Rather than seeing AM as a factor in reshoring, several interviewees cited change in existing conventional supply chains as being due to concerns around quality and delivery times. "I already have some customers that are bringing it back from China because of problems they had with the supply chain around delivery uncertainty and poor quality," stated one. Other more strategic reasons were also cited. "A lot of it is to do with the tax laws. A big corporation relocated here [to the US] to take advantage of tax loops. They are playing that game in Ireland too."

These interviewees saw little or no role for AM in the short-term in driving geographical changes in supply chains. This was due in part to the dominance of existing supply chains by conventional production

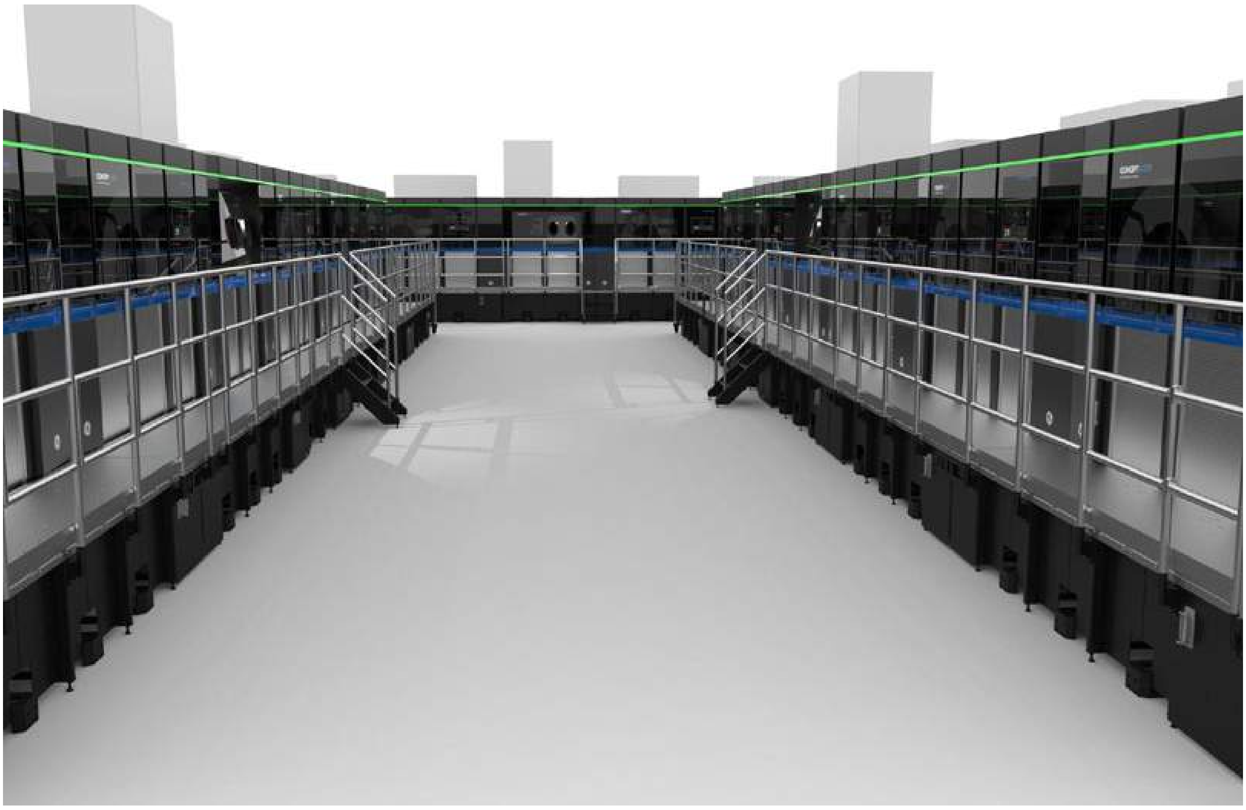


Fig. 7 Metal AM technology suppliers are evolving their model AM factory concepts, in which full automation increases productivity and reduces manual labour. Such scenarios, of course, depend on the ability to automate post-processing (Courtesy GE Additive)

processes; metal AM has insufficient power to drive those changes while it is dwarfed by other technologies. "Even in a single site, never mind multiple sites, doing diagnostics of the processes because I am using additive, I still at the moment have to use traditional supply chains for most parts," one interviewee explained. "The ability to change a design within a few moments and then make a part within hours is significant. You can't do that sourcing from Asia." This was also due to the fact that metal AM parts often form only a small part of a final product, again diminishing the capacity for change.

Design for AM

The transformative potential of metal AM is being curtailed by contemporary limitations on designing for AM. "The transition for designing for additive hasn't really been established. Once parts are optimised for additive then location for manufacturing is almost meaningless," stated one company's CEO. This interviewee saw potential for significant change, but this is predicated on systemic shifts in how production parts are designed and manufactured. The decision to use metal AM parts needs to happen at the design stage to maximise the benefits of using AM. This too can influence where the actual production takes place. As labour costs rise in developing countries, decision-making around which parts of the production chain drive location decisions may alter. "The cost of manufacturing, the cost of an AM machine is the same in China as it is in the UK, to cost the material is the same in China as in the UK, so in that respect it levels the playing field," they stated. "So if that means that the design holder, the person that's commissioning that work, is based in the UK, then yes, it is more likely to come over to the UK." This adds significant complexity in a still largely vertically disintegrated industry around the locational demands of the various parts of the production process, from design through to distribution.

Labour costs

The majority of interviewees understood the location of production based on the analysis of costs, with the primary factor being labour costs. There was, however, tension between opinions on the impact of increased automation resulting in reduced labour costs. Many in the industry aligned themselves with the political discourses around AM leading to reshoring to advanced economies, arguing that reduced labour costs would make production more feasible in 'home' markets. This argument is based on the understanding that more advanced, high-tech technologies do tend to stay closer to their home markets, or lead firms. The vast majority of global firms retain their core research and development facilities in their home markets, often close to their headquarters. There are good strategic reasons for this related to the protection of IP, recruitment of skilled labour and inter-firm interaction, which are eased through greater geographical proximity.

Relatedly, the home markets are those that seek, and are prepared to pay for, cutting-edge technologies. "In the Far East, the demand isn't necessarily for the expensive multi-laser, process monitoring machines, it is much more for the cheap machine and of course there are a number of Chinese manufacturers who have copied machines or invented their own machines. The latest technology tends to be consumed in the advanced economies," stated a source. Similarly, metal AM machines are still far from being 'plug and play', demanding trained operators and maintenance which are all presently easier to access in advanced economies.

However, two counterpoints were offered to this position regarding labour costs. The first is the present-day limitation regarding the relatively high degree of manual labour involved in metal AM, including post-processing. This is a barrier to full automation and sufficient reduction of manual labour to trigger the recalculation of costs in different geographical locations. "As long as there is a lot of assembly needed, which is labour intensive, then it will basically stay in the countries where they stay. Once you remove the manual assembly work, then for sure the production can go where the parts are needed or where the products are sold."

The second is that, over time, labour costs will again become more significant, creating subsequent drivers towards lower cost locations. "At the moment, the throughput and cost-per-part and the technology is such that the labour cost isn't really the issue," a source noted. "However, as we increase the throughput and as we bring down the cost-per-part, then I am sure the labour rates will become more of an issue and then the machines will probably be taken up more widely in those markets where you get that advantage." This is predicated on significant advances

Fig. 8 Adidas' decentralised digital 'Speedfactories' were located in Germany and the US before being moved to two suppliers in Asia (Courtesy Adidas)

in the metal AM machines, and on support infrastructure. Therefore, this is likely to first occur within OEM organisational structures, i.e metal AM production sent to subsidiaries in developing countries rather than through outsourcing agreements.

Sectoral and volume variation

Interviewees felt that small, low-volume series of production are the most likely to reshore and suggested that the current limitations around the scale of production, as discussed above, are limiting the potential for a significant shift in global supply chains. As one interviewee explained, "In terms of high-volume production, we haven't seen any evidence so far where someone is taking high-volume production from China, moving it to the US or Europe, and saying 'because we can do this with 3D printing, now we're moving it back,' because high-volume manufacturing in China is increasingly automated itself and so the difference in what you can achieve in terms of labour costs between China and the US is shrinking. So I don't see 3D printing just completely transforming the economics of manufacturing high-volume products overseas."

There is a high degree of sectoral variation. Aerospace firms in the US pointed out that they have been prevented from offshoring by government regulations. There are, however, some widely-cited sectors in which we can observe some reshoring. "AM has the potential to change where things are manufactured, and maybe it depends on the applications... for sure, all our eyewear customers produce in Europe. None of them produces the glasses in China or Asia. Would they have done in the past? They have done in the past, but only the low-quality frames," stated a source. Similarly, the relocalisation of dental implant and related production has seen significant shifts over recent years, with dentists able to build implants in their own dental surgeries rather than subcontracting production to centralised labs. If they

Reshoring factors	Current role of AM	Points of debate	Future scenarios
Labour costs	Manual costs still too high for majority of activities to reshore	Automation will bring decreased labour costs	Significant reshoring of manufacturing to advance economies
		Increased machine speed and throughput could increase significance of labour costs	Manufacturing does not reshore or we see a return to offshoring to low-cost economies
Proximity to high-level firm functions (HQ, R&D)	Tendency for innovative and most costly AM to occur in home markets	How much longer advanced economies (Germany, UK, US, etc) will dominate AM technological development	Continued dominance driven by greater demand for AM services in advanced economies. Or rise in expertise in low-cost economies like China, which means firms can locate R&D functions outside home market more easily
	AM development and operation still concentrated within key centres of OEMs	Degree to which OEMs with AM capacity will continue to concentrate AM in core centres	Large OEMs will distribute AM throughout their geographical footprint if the cost-benefit analysis is positive
Proximity to user/clients operations	AM firms and service centres locate near to users /clients in advanced economies	Degree to which AM will follow users/clients throughout their global distribution	If users/clients reshore activities, AM is likely to remain concentrated in advanced economies: if not it will follow its users/clients
	AM still concentrated within a relatively small market of users and clients	Degree to which AM will have a much larger share of the manufacturing market	If AM increases its position vis-à-vis traditional production methods it may have greater impact on design, production and logistics decision making. This will likely force production closer to the consumer
	AM still relatively autonomous and vertically disintegrated	Industry evolution and trajectory will likely increase vertical integration through merger and acquisition	Vertical integration will decrease the clustering of firms in advanced economies, opening up the potential for different functions to be located based on cost. Or it will concentrate activities in a smaller number of geographical locations
Access to resources such as highly skilled labour and materials	AM firm location decisions driven by accessing increasingly scarce highly skilled labour	Degree to which the necessary skilled labour will be present in advanced or low-cost economies	AM continues to be concentrated in areas where skilled labour is located due to inter-industry and outside industry interventions in advanced economies to boost the supply of labour. Or low-cost economies increase their supply of highly skilled labour, raising the amount of higher level AM functions outside advanced economies
	AM production predicated on access to materials	Degree to which the supply chains for materials will keep pace with AM demand	Decentralisation of AM reduced by vulnerable material supply chains limited by extensive global material supply chains. Or supply levels and supply chains match or outstrip demand, which may be facilitated by increased vertical integration with AM and/or OEMs
Faster time to market	AM still currently services the majority of users/clients in advanced economies	Degree to which AM remains within traditional production and logistic supply chains	Larger shares of manufacturing output could drive more significant, possibly decentralised production chains in which production and consumption are geographically closer
Government intervention	AM considered part of reshoring initiatives. These policies vary by nation	This is not a current point of debate within AM but there are questions about the degree to which AM will be impacted by reshoring initiatives	Advanced economy initiatives may clause reshoring of manufacturing in advanced economies, which will increase opportunities for AM in home markets. Or the initiatives will be unsuccessful due to budgetary restrictions during economic downturn and little changes. And/or low-cost economies introduce their own incentives to prevent manufacturing reshoring which will maintain status quo

Table 2 Reshoring scenarios and AM

do subcontract, it is more likely to be to an AM service bureau, although it should be noted that dental implants never tended to be sourced using geographically extensive supply chains due to time demands.

To summarise, there is currently scarce evidence that AM is impacting the geographies of production. There are anecdotal examples of some prototyping and injection moulding work returning from China, but at present, any reshoring that is occurring appears to be caused by broader shifts in the cost-base of manufacturing rather than by AM technologies. We are therefore in a period of anticipation in which there are several directions of change. Table 2 charts the key factors involved in reshoring, applying these to AM and outlining the possible future scenarios. The degree to which metal AM could transform existing geographies of production is dependent on machine speed and throughput, material supply and access to skilled labour, labour costs and the composition of the AM sector as a whole. In the short term, it appears likely that the status quo will remain. Longer-term, it is likely that existing production will remain dominated by traditional organisational geographies but that newer products that are designed for AM will be able to be produced closer to the consumer – be that in advanced or low-cost economies - using the (projected) expanded global networks of AM firms and OEMs.

As one interviewee sought to remind us: "Money controls everything and unless there is an economic financial reason to change something, it doesn't change." It is most likely that a global transformation in the location of manufacturing will be precipitated by larger global crises, such as peak oil and/or climate change significantly increasing the cost and vulnerability of long distance supply chains. Here we would see a shift to more regionalised or localised production, in which AM would play a significant role. We can therefore suggest that AM may not cause geographical changes, but it will likely play a crucial role in solving the problems that will emerge, with a particularly significant role for metal AM.

Metal AM, Industry 4.0 and the Factory of the Future

The metal AM industry is evolving rapidly. Some aspects of that change are clear and relatively uncontested, such as the diversification of applications from prototyping to functional parts. Others are more hotly debated, including where improvements need to be made (equipment, materials, supply chains, or all of these), where the greatest growth potential lies (sectoral and geographical) and how the industry should be most efficiently organised in the future. Given the huge pressure of expectation being exerted on AM – and metal AM in particular – by policymakers, this article will conclude with some reflections on how metal AM may be part of this almost universally adopted vision of our manufacturing future.

Surprisingly, some members of the community still felt that the notion of AM machines being integrated on the factory floor was in the distant future. "I've never seen it. The cost of the machines is a barrier to this," stated one. Others felt that changes were already happening as part of the process of moving toward the Factory of the Future: "AM is a big part of the factory of the future. As new [products] are developed we see production changing – the production line for each generation of [our product] has changed. Robotics, automation will feature. AM is also used in supporting [our product] i.e. printer at maintenance site. We can send the design standard for printing on site."

Overall, metal AM is preparing itself in numerous ways for the future, anticipating that several aspects of contemporary methods and processes will have to change. "We are rapidly heading towards AM's role in the factory of the future with automation and robotics. I think the whole transformation of the digital factory, where we can go all the way from design to really looking at modelling and simulation to manufacture, to inspect, I really think the next frontier is going to be software," stated another source. In terms of timescale, the automated factory of the future, understood as a lights-out factory containing AM machines combined with post-processing equipment, was estimated to be at least five to ten years away. This is later than policymakers are anticipating. For several interviewees, reflecting on their own corporate and industry-wide strategies emphasised the need for long-term continuous improvements to alloys, powder quality, powder management and management systems to ensure process stability and control.

At present, the metal AM industry is offering a compelling case for increased public and policy interest and support. It combines technological innovation and is evolving quickly to develop the systems and standards that are needed to appeal to a wider user-base. Benefits may be gained from interaction with the 'other kind of scientist' (social scientists), who can offer a broader perspective on the industry; how it is changing, competing and helping to redress the imbalance created by all the hype around Additive Manufacturing.

Author

Dr Jennifer Johns
Reader in International Business
Department of Management
University of Bristol
Howard House
Queen's Avenue
Bristol
BS8 1SD

jennifer.johns@bristol.ac.uk

The author acknowledges the contribution of the British Academy (award number SG162550) and the contributions of the research participants.

AM Ventures: An insider's perspective on venture capital for start-ups in Additive Manufacturing

In an industry driven by innovation, start-ups play a vital role in creating the next generation of AM technologies, applications, software solutions and materials. However, only a small percentage of these start-ups will survive, and even fewer will thrive. Arno Held, Chief Venture Officer at AM Ventures Holding GmbH, presents a statistical analysis of start-ups across the AM sector, including success rates, geographic distribution and key areas of focus, and offers his insight into venture capital as it relates to the Additive Manufacturing industry.

When my long-time mentor Johann Oberhofer and I started AM Ventures, with great support from the Langer family, just five years ago in January 2015, we knew very little of what the world of AM start-ups looked like. I still remember my first day at the desk, in an oversized office on EOS's Krailling campus, very well. The story of AM Ventures, however, actually began about six months before.

After meeting an inspiring team of young entrepreneurs at a 3D Printing Cluster meet-up in Munich and convincing them to bring some colour to our industry by founding what is today the huge success story of DyeMansion, I realised exactly what I wanted to do with my network, and the technical experience I had built up at EOS over almost seven years: I wanted to found a start-up that helps other start-ups to start up. I pitched the idea to Dr Hans Langer and Johann Oberhofer, who quite liked it, and the rest, as they say, is more or less history.

So, six months later, there I was. Alone in a big office. A desk, a chair and me. And what does a typical representative of Generation Y do when they have to start with a blank sheet of paper? They research the next steps on Google.

I think I spent more than three months doing almost nothing else but researching every start-up that was developing or using Additive Manufacturing technology. I created an archive, collected data and started to compare. I found reports, went to conferences, got introduced to very helpful contacts and eventually found the next start-up to invest in, and then the next, and then the next.

Today, almost exactly five years after we began to build AM Ventures, I am very proud to have built a team of eight highly passionate AM experts

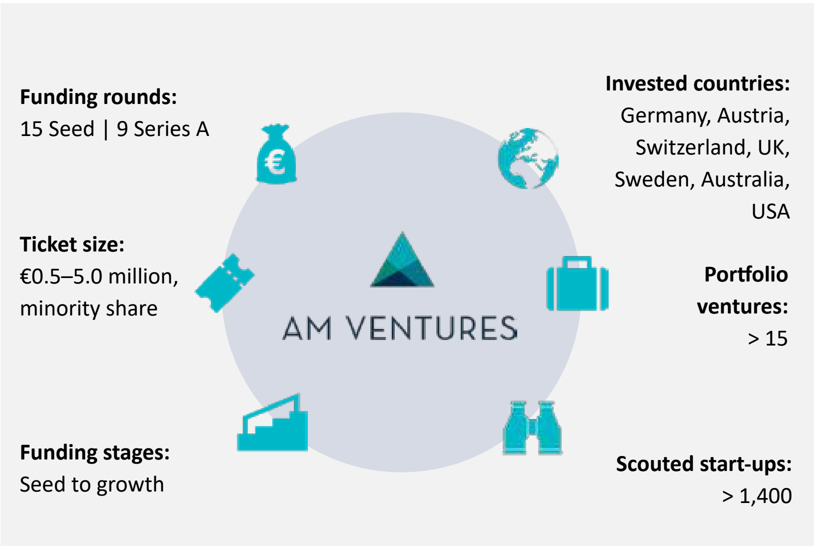


Fig. 1 Overview of the investment activities of AM Ventures

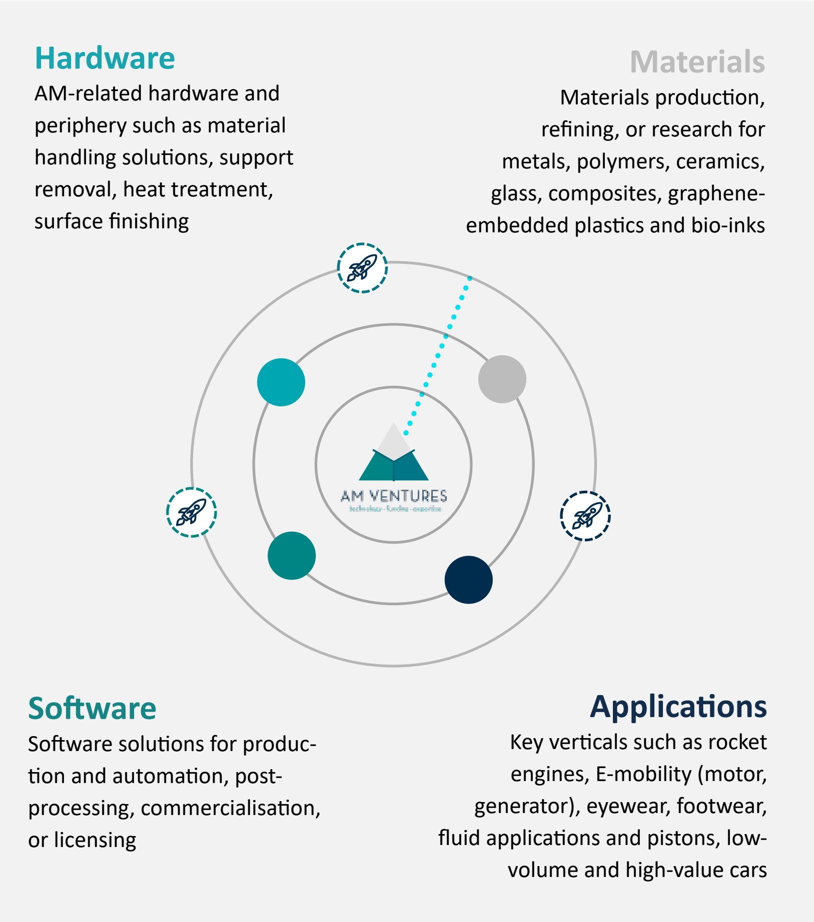


Fig. 2 AM Ventures' general investment focus lies in the industrial side of AM, namely hardware, software, materials and applications

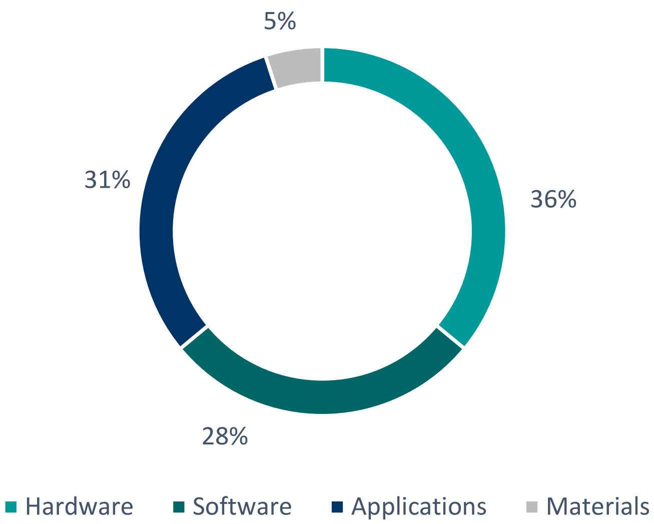


Fig. 3 Global distribution of start-ups across all AM areas, showing that three of the main categories are similarly sized: hardware, software and applications

that have conducted more than two dozen funding rounds and now manage a portfolio of seventeen start-ups in seven countries. We have always had the feeling that we were building great knowledge with every start-up that was added to the portfolio, but it was only once we decided to build our own database, from which we could extract structured data and customised views, that we truly appreciated what we had created since early 2015.

Today, we know quite a lot about the world of AM start-ups. Our database currently contains information on more than 1,400 of them. In 2019 alone, we added more than 220 companies, and I cannot imagine that there is another team in our industry that has gathered a comparable amount of data spanning the entire planet. Since we are an investor that is very clearly focused on a specific technology, we are not limited geographically in our areas of engagement. Our current portfolio is distributed across the world, from Austria to Australia, and just one year ago, AM Ventures opened its first branch office in Busan, South Korea, in order to scout the Asian continent.

AM Ventures' general investment focus lies in the industrial side of Additive Manufacturing technology. More specifically, we are looking for start-up teams which are dealing with AM hardware, software, materials and applications. Particularly with regards to relevant materials, we are by no means limited to polymers and metals – even if this is by far the largest field of engagement.

What follows are insights into our operations, along with data on the sometimes hard reality of being a technology start-up in the AM world.

Distribution of start-ups across all AM areas

Looking at the distribution of start-ups across our four main AM technology categories, it is nice to see that three of the main categories are similarly sized: hardware, software and applications (Fig. 3).

For us, as Additive Manufacturing enthusiasts and participants in this industry, it is particularly encouraging to see quite a large number of applications in development. This means that our industry as a whole is reaching a level of maturity, that investment in AM-education is finally paying off, and that the technology is finally starting to change the way future products are conceived of, developed and – in the end – manufactured.

The fact that only very few start-ups are dealing with the development of new materials is not very surprising, as this domain is still heavily dominated by machine vendors and – particularly in the polymers business – occupied by very large chemical companies. These two facts alone represent very high entry barriers.

Survival rates and global distribution

When one looks at a technological segment from a Venture capital perspective, it is always interesting to know what the overall likelihood is for a start-up to succeed. In our world, we define survival as the ability to establish a company and keep it alive at least until a business angel invests, or a so-called 'seed-round' of financing can be undertaken. A really successful start-up is defined as one which progresses to raising series A funding with a professional VC investor, or even conducting a so-called 'exit' by selling the company to another entity or taking the company public through an IPO.

Our research has shown that, across all countries and technical categories over the past five years, AM start-ups had a mere 23% likelihood of survival (Fig. 4, top left). This number might be quite interesting information for a general first contact. However, it only starts to become valuable once one starts looking into the more specific

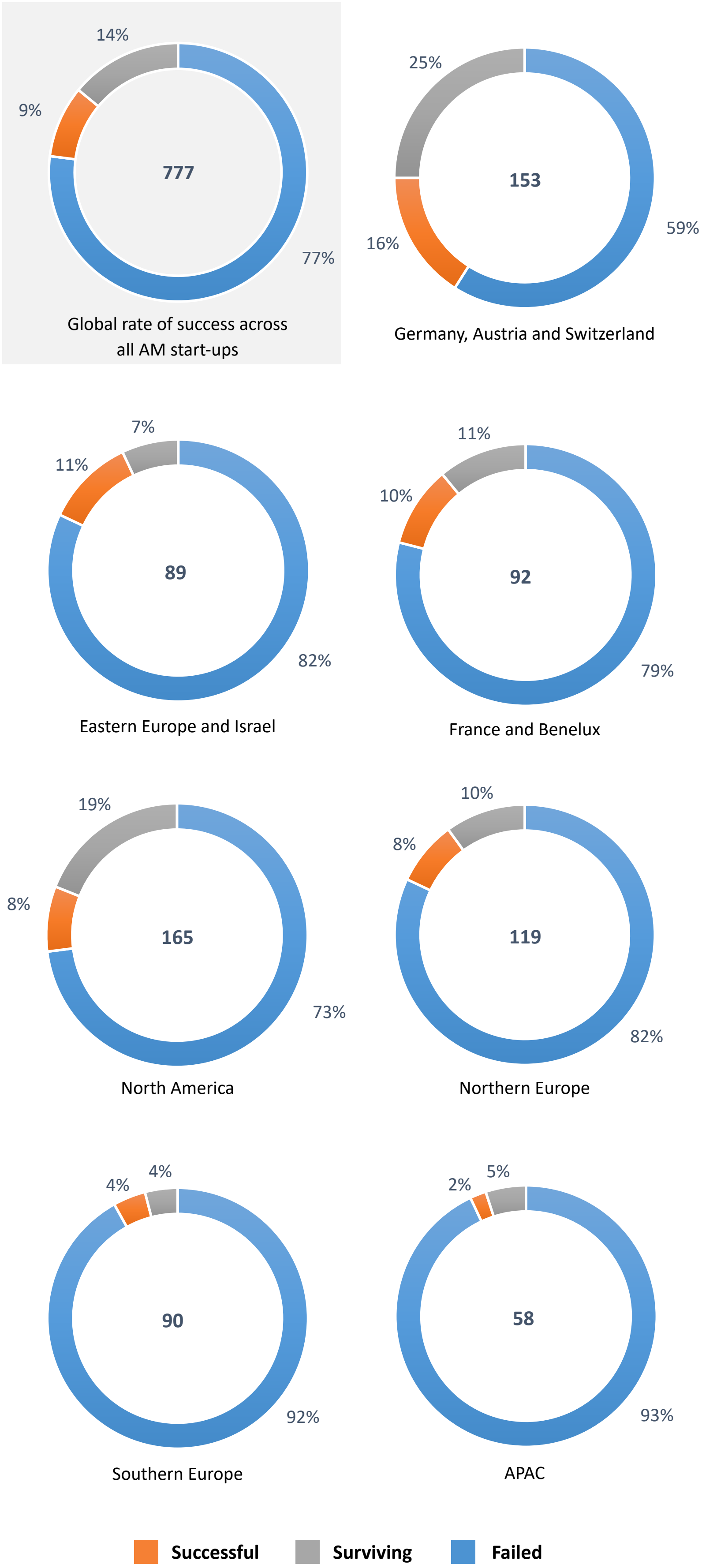


Fig. 4 AM start-up survival rates globally (top left) and by world region

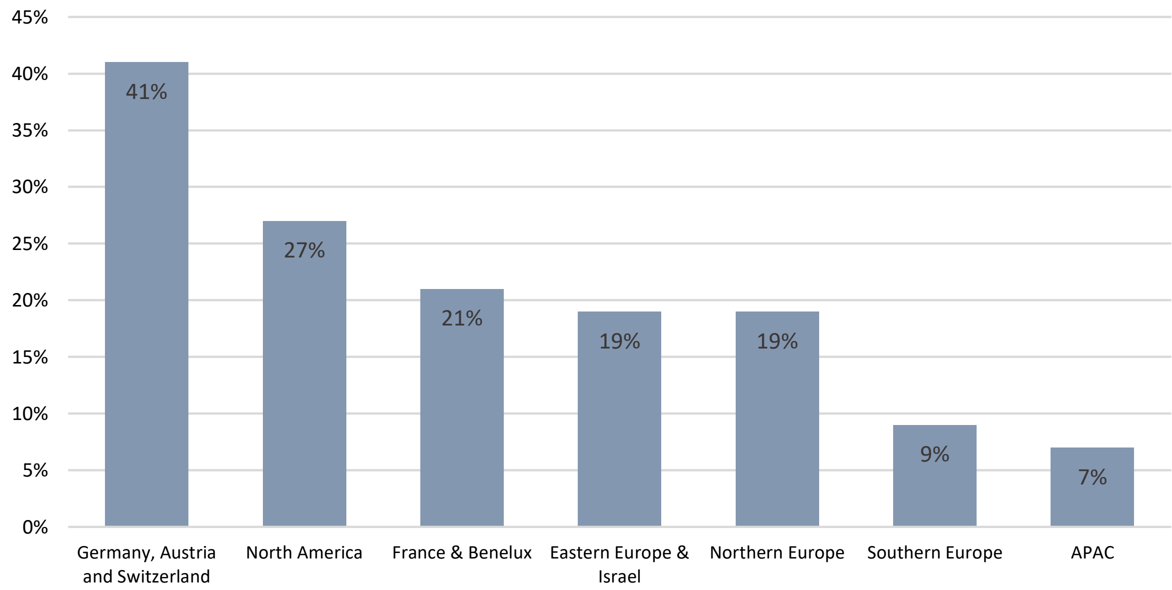


Fig. 5 Rate of survival and success by region for AM start-ups

distribution of survival rates across geographical regions and technical categories.

From a geographic perspective, there are two global areas which stand out in terms of the numbers of AM start-ups that they have produced over the past five years. Northern Europe (represented by the UK, Denmark, Sweden, Norway and Finland), the so-called DACH-region (Germany, Austria and Switzerland), and North America have each produced far more than one hundred AM start-ups between 2015 and 2019.

What especially stands out is the extremely high survival rate of start-ups in German-speaking Europe. This fact can be explained by two facts: firstly, a very strong technical infrastructure is in place, with world-leading industrial players who can help incubate and accelerate start-ups as pilot customers and development partners; and secondly, a very risk-averse culture exists in these three countries.

On the one hand, this leads to a much smaller number of start-ups founded per capita, but on the other hand it increases the likelihood of success for those who find the courage to found their own start-ups. In English-speaking cultures, where failure is much more accepted and the entrepreneurial spirit is more wide-spread, the decision to start a company is taken much quicker.

"...focus on your core competence, and do not try to do everything by yourselves. There are great partners for everything out there; especially for the development and manufacturing of machines..."

An insider's perspective on Venture capital in AM

At AM Ventures, our typical investment target is a very early stage start-up. A team of passionate entrepreneurs with a diverse set of technical, commercial and financial skills makes a perfect match for us. The field of business in which the start-up operates should be within the industrial side of Additive Manufacturing – for example a new type of hardware or software, a unique material or an AM-based application. Two points of advice for a start-up to become attractive for investors would be to firstly focus on your core competence, and do not try to do everything by yourselves. There are great partners for everything out there; especially for the development and manufacturing of machines. Secondly, know exactly where you are making a difference and build on this. High-tech investors do not like copycats.

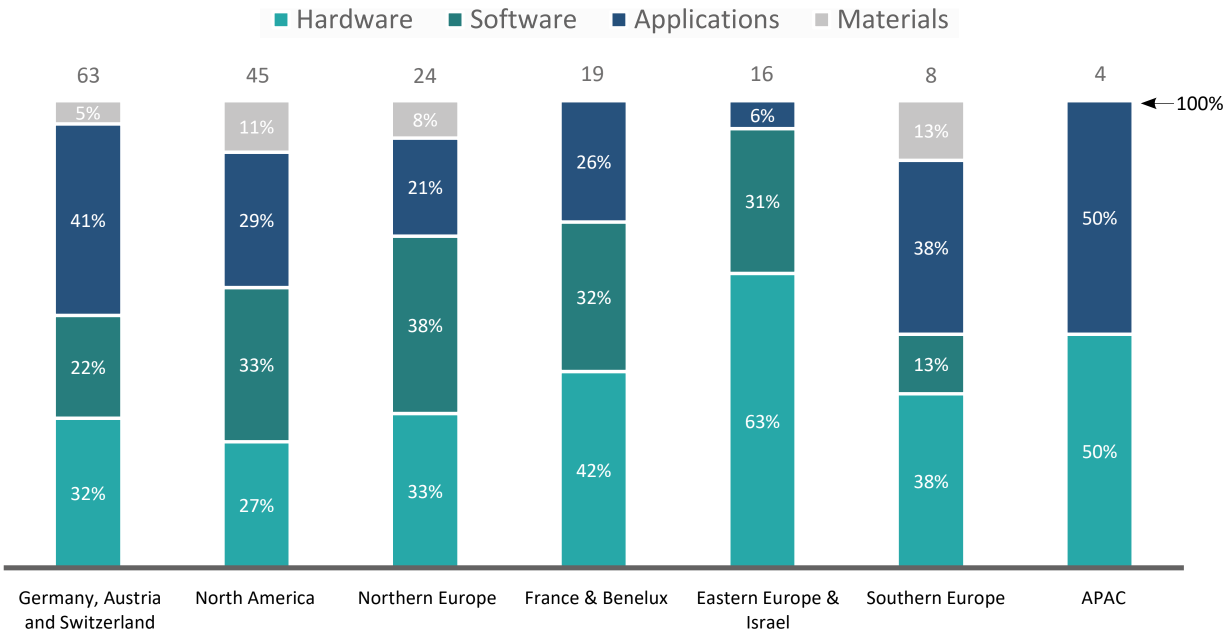


Fig. 6 Specific areas of AM activity by world region

As to the question of whether a company should 'go it alone' or seek an investor, a key consideration is that – aside from the fact that developing scalable industrial technology requires a lot of great talent and costs a lot of money – in a digitised and globalised world, those who can convince the most customers, quicker than their competitors, win. Building up global sales networks, hiring experienced talents and finding the right key partners requires not only a lot of money, but also the right strategic advisors. Of course, you can also build a network on your own and earn the money to scale your company by yourself, but the right VC will help you with both in a small fraction of time.

In our discussions with start-ups, we are hardly ever faced with the concern that accepting VC funding is in some way 'giving away control'. Most entrepreneurs take the VC route because they deliberately want to give parts of the company to people who bring them value. It's nothing else but aligning interests and giving something for a return in the form of very specific technological know-how or an unmatched network within an industry. But do not be too generous with the shares you give away; there is no more expensive capital than equity, and many deals have failed because certain angel investors or advisors received too many shares too early in the company's life.

An industry still hungry for innovation

Despite the growing maturity of the AM industry, we at AM Ventures believe that there is a continuing appetite for new process technologies and we have all been impressed by the wide variety of hardware concepts that have emerged over the past year and a half: we see new ways of exposure and recoating, we see the rebirth of Cold Spray, and it is great to see how new hardware enables new materials to be processed, which again results in new applications being developed. Although we have already been doing this for five years, I feel as though we have only just scratched the surface of start-ups in our industry.

Examples of impressive metal AM start-ups

One example of a very successful applications-focused start-up is Australia's Conflux Technology, run by a team of former Formula 1 engineers masterminded by Michael Fuller, which decided to revolutionise thermal management systems by developing highly-complex heat exchangers. These use geometries which dramatically outperform their conventionally designed and manufactured counterparts, not only in terms of efficiency but also weight, volume and lead time. Conflux was seed funded just three years ago by AM Ventures and is today a global player, supplying the biggest names in aerospace, oil & gas, motorsport and industry with its highly innovative and patent protected solutions (Fig. 7).

Metal Additive Manufacturing, however, is not only a technology which is gaining market acceptance in the industrial world. Even super-high-volume consumer applications such as keys for residential housing are becoming viable and even strongly improved through AM. A perfect example of this is Alejandro Ojeda,

Fig. 7 An AM heat exchanger designed and manufactured by Australia's Conflux Technology, a company seed funded three years ago by AM Ventures (Courtesy Conflux Technologies)

who founded Urban Alps, a Swiss-based start-up that has reinvented the design of the key and, as a consequence, also locks (Fig. 8).

The company's AM-derived solution is not only copy-proof, but more durable and even more cost-efficient, because of AM's design freedoms. That this company, in which AM Ventures has no investment, is making so many waves in such as large and mature industry, is exactly the reason why people at AM Ventures love to work in AM.

Conclusion

All in all, the world of Additive Manufacturing-related start-ups is booming as it has never done before. New hardware concepts are promising significantly higher productivity rates, and making new materials processable. Very well educated and highly creative engineering teams are continuing to develop new applications based on Design for Additive Manufacturing (DfAM), which will strongly boost the acceptance of our industry. It is on the established machine vendors and the advanced industrial users of our beloved technology to pave the way into the future by establishing quality standards and infrastructural interfaces in order to accelerate this adoption. If this can be established in the years to come, we will all witness how AM technology is going to enable batteries to last longer, vehicles to consume less fuel, and implants to heal faster.

Author

Arno Held
Chief Venture Officer
AM Ventures Holding GmbH
Petersbrunner Str. 1b
82319 Starnberg
Germany

info@amventures.com
www.amventures.com

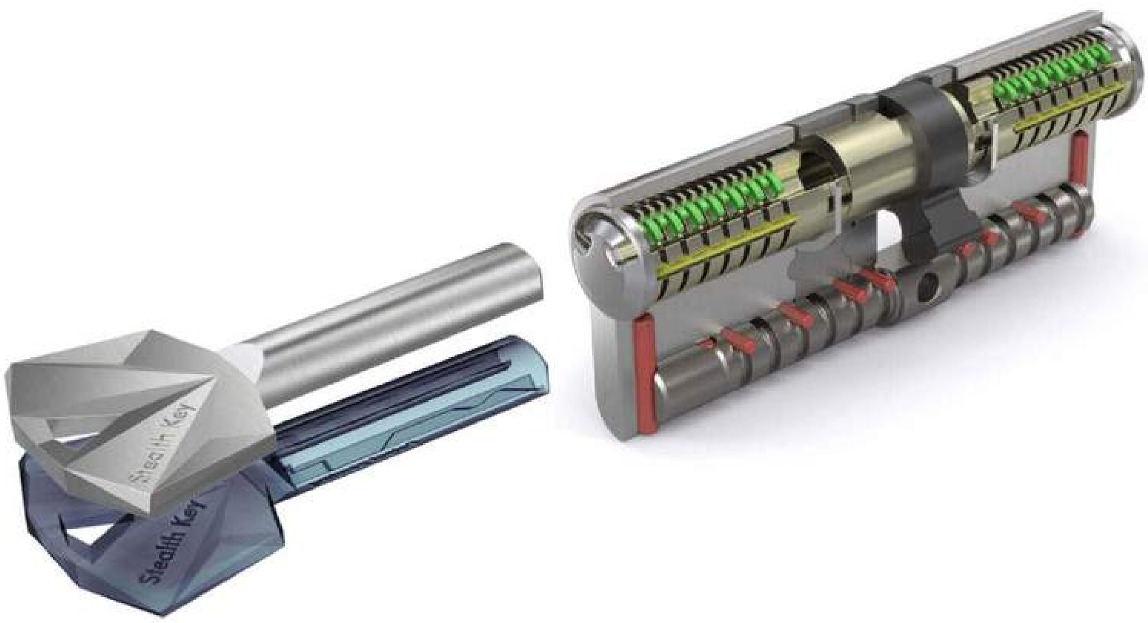


Fig. 8 Urban Alps, a Swiss-based start-up, has reinvented the design of the key and, as a consequence, locks (Courtesy Urban Alps AG)

20 – 24 APRIL 2020
TRANSFORMATION IS EVERYWHERE. ITS HEART BEATS IN HANNOVER.
For over 70 years we have driven, inspired, led and accompanied the course of industrial transformation. HANNOVER MESSE serves as a window revealing the world of tomorrow.
Be part of it: hannovermesse.com #HM20
MAKING INDONESIA 4.0
PARTNER COUNTRY 2020
HOME OF INDUSTRIAL PIONEERS
HANNOVER MESSE

HI-AM Conference

3rd | 2020

HOLISTIC INNOVATION IN ADDITIVE MANUFACTURING

JUNE 25 & 26
MONTRÉAL, QUÉBEC, CANADA

nserc-hi-am.ca/2020

Please join us for the 3rd HI-AM Conference

The HI-AM conference is the only academic conference in Canada focused exclusively on metal additive manufacturing. With over 100 additive manufacturing experts and decision-makers from academia, research institutes, industry and government participating, HI-AM 2020 is an event not to be missed.

NSERC HI-AM

UNIVERSITY OF WATERLOO

NSERC CRSNG

INNOVATION.CA
CANADA FOUNDATION FOR INNOVATION | FONDATION CANADIENNE POUR L'INNOVATION

Binder Jetting and beyond: Optimising the use of metal powders for Additive Manufacturing

The high cost of metal powders for Additive Manufacturing makes them a primary focus for cost management. Learning how to treat and store such powders in order to maintain and optimise their performance and value is one way to improve production economics. Here, Dr Rajeev Dattani, from Freeman Technology, UK, and Dr Animesh Bose, Desktop Metal, USA, review how to test powders in order to develop this knowledge, and examine treatment and storage regimes that can be beneficial.

Metal powders for Additive Manufacturing are relatively expensive. For example, a titanium powder for Additive Manufacturing can cost up to £200 per kg, depending on market fluctuations. This is an order of magnitude more than solid material in the form of bar stock [1]. As a result, powder feed represents a significant proportion of the manufactured cost of additively manufactured components. Easily measured and highly visible, the expenditure associated with powder feeds is routinely a target for cost management, making it vital to choose a supply well-matched to the specific application. Understanding how to optimise powder performance, for example through pre-treatment or by effective storage, supports this decision-making process and can pay dividends when it comes to minimising costs within the constraint of meeting demanding product quality targets.

In this article, we examine the factors that contribute to the costs of AM powders, comparing the manufacturing methods used in their production and how they impact critical powder properties. A collaborative study carried out by Freeman Technology, Tewkesbury, Gloucestershire, UK, and Desktop Metal, Burlington, Massachusetts, USA, a manufacturer of commercial metal Binder Jetting AM machines, illustrates how these properties can be modified or controlled by baking under air or nitrogen and by storage under different conditions. The results highlight potential strategies for optimising AM metal powder performance.

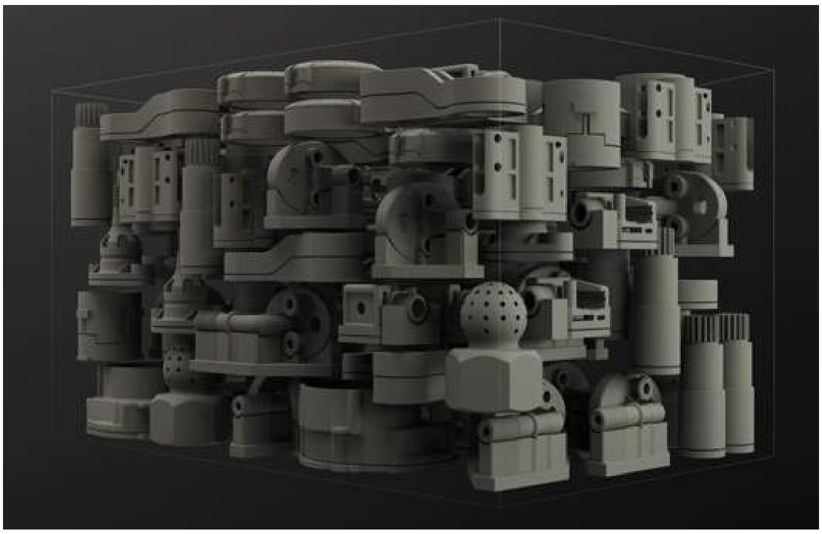


Fig. 1 Desktop Metal develops Binder Jet metal AM systems aimed at moving the industry closer to high volume AM production. As with all powder-based AM processes, an optimised and consistent starting material will pay dividends when it comes to process stability and repeatabilty in a machine such as the Shop System (Courtesy Desktop Metal)

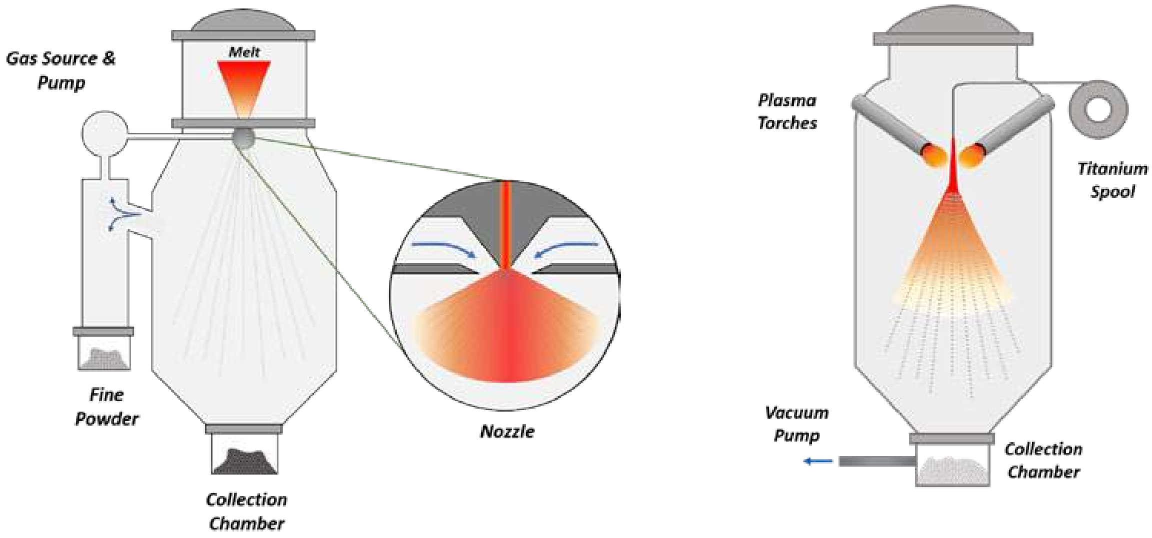


Fig. 2 Most AM metal powders are produced by gas atomisation (left); plasma atomisation (right) is a more costly alternative but produces particles with superior morphology

The economics of metal powder production

Metal powders for Additive Manufacturing are produced from metal bar, ingots, wire or even another powder, predominantly by atomisation. Gas atomisation is the most common manufacturing technology, but water and plasma-based processing are also routine. The technology used has a direct impact on powder properties and, by extension, the quality and cost of the product.

Water atomisation

In water atomisation, molten metal is atomised by the action of water jets, which break up the metal stream and simultaneously cool the resulting droplets; particles then collect at the base of the atomisation chamber. Powders produced by this technique, most commonly iron and steel, are used widely in the Powder Metallurgy industry, but have a highly irregular morphology that makes them less suited to many AM processes. Drying prior to use is a prerequisite, and particle size distributions for water atomised metal powders span up to 500 μm [2].

Gas atomisation

Gas atomisation is typically carried out using a chemically inert gas such as nitrogen, argon or helium. Air atomisation is also an option, but tends to give rise to relatively high levels of oxygen in the finished powder [3]. Molten metal is forced through a nozzle into the atomisation chamber where it is broken up by the action of high-velocity gas jets, as shown in Fig. 2 (left). The low heat capacity of the gas, relative to water, results in slower cooling of the atomised metal, providing time for the formation of more spherical particles, though satellites are often observed, as with water atomised materials. It is common for the particle size distribution of a gas atomised product to also span up to 500 μm, depending on the conditions applied, with higher gas flows associated with the production of finer particles, at higher cost. The use of gas at elevated temperatures has also shown promise for the production of finer powders [3].

The need to control interstitial elements and reduce the risk of contamination, particularly for high-performance applications, has led to the greater use of vacuum induction melting in gas atomisation and the development of processes such as Electrode Induction Gas Atomisation (EIGA). In EIGA, which is principally used for reactive alloys or metals such as titanium, the metal feedstock takes the form of a rod, which is melted by an induction coil, immediately prior to entering the chamber, eliminating contact with either the electrode or crucible. These characteristics make EIGA a clean process, well-suited to the production of small batches of high-specification powders [4].

Plasma atomisation

In plasma atomisation processes, the metal feed takes the form of either a wire or powder, which is simultaneously melted and atomised within the atomisation chamber through the action of plasma torches and gas jets, as shown in Fig. 2 (right). The particles produced are highly spherical, with minimal levels of satellites. The Plasma Rotating Electrode Process (PREP) is closely comparable, but the metal feed takes the form of bar, which rotates, melting as it contacts plasma torches within the atomisation chamber. The resulting droplets solidify before reaching the walls of the chamber.

Plasma processes are inherently more costly than either water or gas atomisation, but, alongside superior particle morphology, offer the benefit of finer particle size distributions. These typically range up to 200 µm for plasma atomisation and up to 100 µm with PREP, which is additionally prized for product purity [2].

In combination, these atomisation processes account for the majority of AM metal powder manufacture, although alternatives, including centrifugal atomisation, plasma spheroidisation, the hydride-dehydride method and TiRO™ process, are also applied, depending on the application of interest [2,4].

Factors inhibiting significant cost reduction

There are now a significant number of metal powders to choose from for AM and the number of suppliers has proliferated over recent years, creating competition in the market. However, certain issues inhibit significant cost cutting [5]. These include:

Particle size distribution
None of the processes discussed above directly produce powders with an optimal particle size distribution for any AM technology. For example, for Powder Bed Fusion (PBF), a particle size of 15–45 µm is optimal; Electron Beam Melting (EBM) works well with a wider particle size distribution in the region of 45–106 µm. A gas atomisation process typically produces only 10–50% product in the 20–150 µm range [4]. This fraction is accessed via post-processing steps such as 'scalping', sieving or air classification, but, ultimately, the usable yield for a specific application can be very low.

Particle morphology
Processes vary in terms of their ability to produce the regular, highly spherical particles prized for the majority of AM applications, with greater sphericity directly associated with the more expensive manufacturing processes.

Chemical purity
The ability to control oxidation and levels of interstitial elements is also process-dependent, but high-purity and more demanding alloys call for powder production methods that are inherently more costly, typically plasma-based processes.

In summary, there are sound reasons for the high manufacturing costs of AM powders, with tight constraints on consistency, for a validated supply, further intensifying economic pressures. Maximising the value of an AM powder by optimising its properties is therefore essential. Minimising feedstock costs relies on not over-specifying a powder for the application and understanding how to maintain and use a chosen feedstock effectively, including reuse. Any choice to pay more for a powder should be based on a robust assessment of the advantages it delivers.

Defining the quality of AM powders

Defining the quality of AM powders requires an understanding of those properties that impact the efficiency of the manufacturing process and the attributes of a finished product. Beyond the chemistry of an AM powder, its purity and suitability for the application, how should the quality of an AM powder be defined and measured? What physical characteristics impact processing efficiency and the quality of the AM product?

AM technologies that can use, or which exclusively use powder feedstocks include Directed Energy Deposition (DED), Binder Jetting (BJT) and Power Bed Fusion. In DED, powder is melted as it deposits on the substrate, with feed blown onto the work area at a consistent rate. Binder Jetting and Powder Bed Fusion, in contrast, both depend on the rapid spreading of powders in fine, uniform, consistent layers. Desktop Metal specialises in the Binder Jetting process, which is examined in more detail to elucidate the impact of physical properties of the powder.

In Binder Jetting, a printhead deposits liquid binder into defined areas of a powder bed to selectively bond particles. Successive layers of powder are dispersed across the build platform, with binder deposited into each to construct the object layer-by-layer. Binder Jetting is suitable for a range of different materials, but particularly metal and ceramics. The finished object is analogous to the 'green' body produced by the Metal Injection Moulding process and is subsequently heated to 'burn out' the binder, and then fusing the powder particles to form a dense, stable component by sintering.

For processing to be viable, an AM powder for Binder Jetting – and the same is true for Powder Bed Fusion – must discharge readily and consistently from a feed hopper and disperse rapidly to a uniform layer. This is a defining requirement that underlines the importance of the flowability of AM powders, both new and recycled. The need to characterise flowability is not unique to the AM industry and there are a number of techniques in routine use. For example, flow through a funnel in methods such as Hall or Carney flow testing are standard for metal powders. However, there is a growing body of evidence that such techniques cannot detect subtle differences between AM powders that impact their performance [6]. Powders with an identical Hall Flow Index may, in fact, go on to deliver different processing performance or components of inconsistent quality.

The size and shape of particles within a powder both impact flowability, but so too do many other particle properties including surface texture, hardness, cohesion and density. Regular, spherical particles tend to exhibit better fluidity than irregularly shaped particles and also pack more efficiently, minimising voidage in the powder layer, which is important from the perspective of finished product density and porosity. The fine particle size distribution specifications for AM powders are also, in part, linked with the need for efficient particle packing. However,

Particle size	Baking conditions	Storage
PSD1	N/A (Virgin)	Desiccant
PSD1	N/A (Virgin)	Ambient
PSD1	Air baked	Desiccant
PSD1	Air baked	Ambient
PSD1	N_2 baked	Desiccant
PSD1	N_2 baked	Ambient
PSD2	N/A (Virgin)	Desiccant
PSD2	N/A (Virgin)	Ambient
PSD2	Air baked	Desiccant
PSD2	Air baked	Ambient
PSD2	N_2 baked	Desiccant
PSD2	N_2 baked	Ambient

Table 1 Summary of a range of stainless steel samples created to determine the impact of different storage and treatment conditions

finer particles are beneficial from the perspective of response to thermal energy input. Finer particles sinter more quickly and at lower temperature than coarser ones, reducing the risk of slumping and dimensional distortion of the additively manufactured green part.

In practice, the quality of an AM feedstock is rigorously assessed and maintained by monitoring multiple physical characteristics. Characterisation includes measurements of particle size, shape and density (which helps to validate purity and influences bed formation and sintering behaviour), detailed surface and morphological characterisation by Scanning Electron Micrography (SEM) and relevant flowability measurement. The measurement of dynamic flow properties has proven particularly beneficial with respect to this last requirement, notably for the prediction of processing performance [6,7]. Dynamic flow testing, in combination with these other techniques, makes it possible to securely identify powders that will perform reliably in an AM machine, without performing a trial run, making it a powerful technique for the assessment of AM powders.

The following experimental study showcases the use of dynamic powder testing to assess changes in the behaviour of stainless steel powders, caused by changes in treatment and storage conditions. The aim of the work is to demonstrate how testing can be applied to determine strategies for optimising the performance and value of AM powders.

Investigating the impact of storage and treatment on stainless steel powders

In a collaborative study between Desktop Metal and Freeman Technology, stainless steel AM powders were subject to different storage and treatment regimens to assess their impact on powder properties. Twelve powder samples were tested in total, six samples of two different particle size distributions, PSD1 (D50 = 12 µm) and PSD2 (D50 = 15 µm); three sub-batches of PSD1 and PSD2 were created as shown in Table 1. One sub-batch was maintained in its 'as-received' virgin state and the other two were baked at 200°C for 12 hours, one in air, the other in nitrogen (N_2). Each sub-batch was then further divided, to produce one sample for

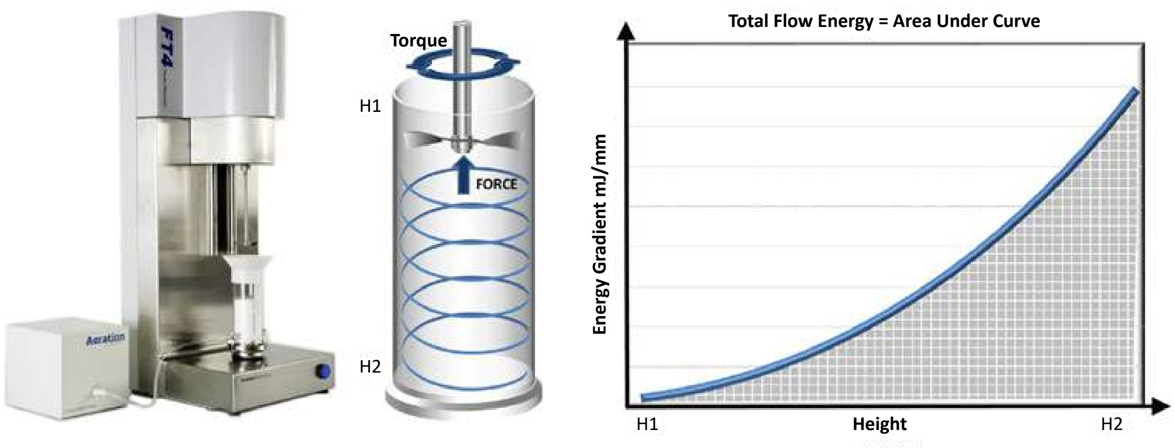


Fig. 3 Schematic illustrating the measurement principle that underpins dynamic powder testing

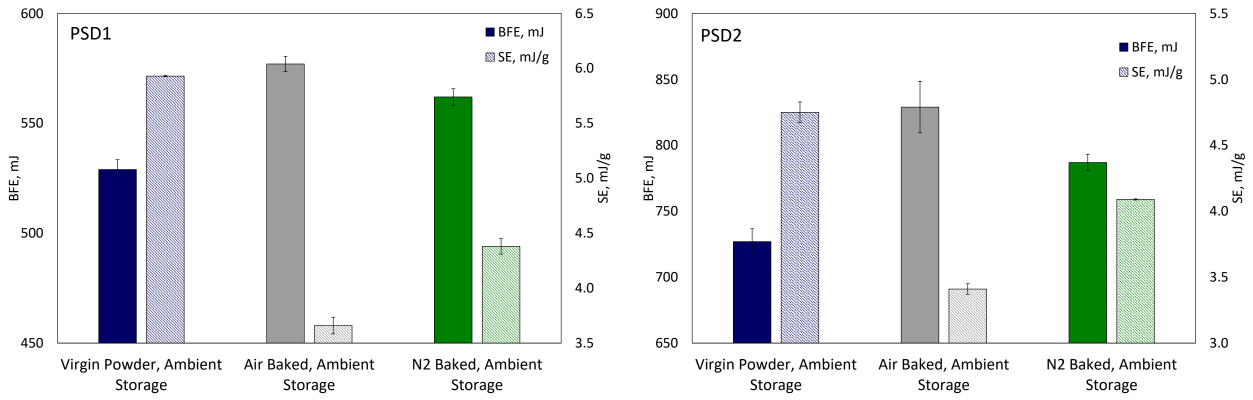


Fig. 4 Dynamic flow measurements contrasting the properties of virgin and baked (under air or nitrogen) PSD1 (left) and PSD2 (right) powders (storage under ambient conditions)

storage under ambient conditions and a second for storage with a desiccant. Calcium oxide was used as the desiccant, with 16.5 g stored in a pouch for a sample of 1600 g of metal powder. All samples were stored in sealed bottles throughout the experimental study.

Dynamic properties were measured for each of the samples using an FT4 Powder Rheometer®, Freeman Technology (see Fig. 3). Specifically, the samples were characterised in terms of Basic Flowability Energy (BFE) and Specific Energy (SE) using the standard test protocols for the instrument [8]. Dynamic powder testing involves measurement of the axial and rotational force acting on a twisted blade as it proceeds along a prescribed path through a sample of defined volume. BFE values are generated during a downward traverse of the blade, which pushes the powder against the confining base of the test vessel. SE, in contrast, is measured with an upward traverse and is more closely associated with powder behaviour in an unconfined environment, for example, during gravity flow. Both BFE and SE have been shown to reliably reflect the performance of powders in AM processes [6,7].

The impact of baking

Fig. 4 shows the impact of baking on the BFE and SE of PSD1 and PSD2 samples, for samples subsequently stored under ambient conditions. Baking, in either air or nitrogen, increases BFE and decreases SE, with baking in air having a more pronounced effect. SE values are strongly influenced by the level of mechanical interlocking between particles and inter-particle friction. These results suggest that baking reduces these interactions and promotes more efficient packing in the powder bed. More efficient powder packing is typically associated with higher values of BFE, since, in a densely packed bed, the compressive action applied in this test transmits more efficiently, giving rise to a large flow zone and a correspondingly high value of flow energy. The observed trends can be attributed to changes in the surface properties of the powders, caused by the baking process.

The impact of storage conditions

Fig. 5 contrasts the impact on BFE and SE of storing virgin powder samples under ambient conditions

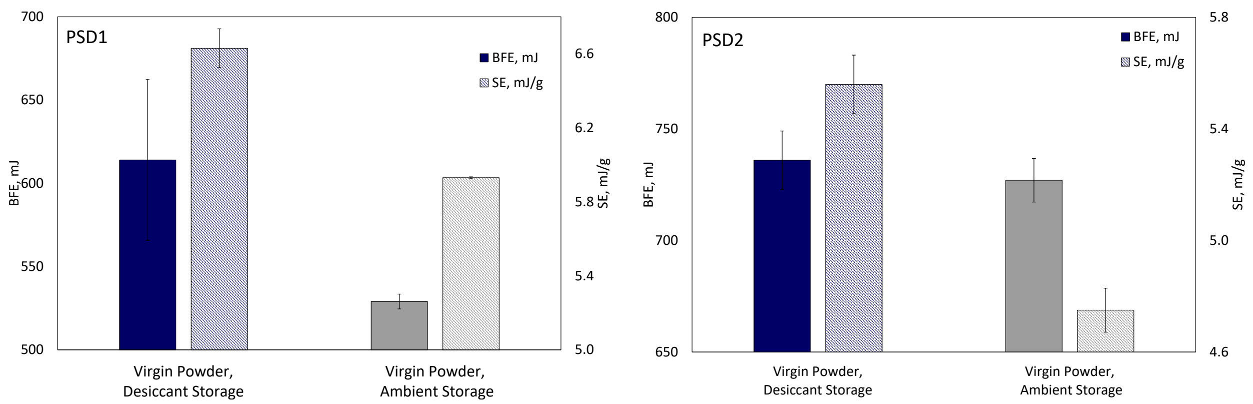


Fig. 5 Dynamic flow measurements contrasting the properties of virgin PSD1 (left) and PSD2 (right) powders stored with a desiccant or under ambient conditions

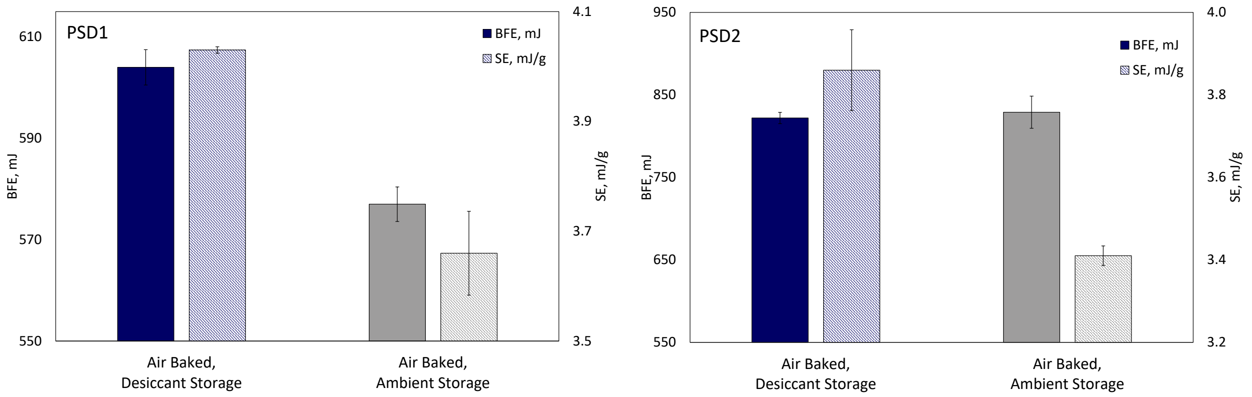


Fig. 6 Dynamic flow measurements contrasting the properties of air baked PSD1 (left) and PSD2 (right) powders stored with a desiccant or under ambient conditions

or with a desiccant. For both PSD1 and PSD2 samples, storage with a desiccant results in substantially higher SE values than storage under ambient conditions. BFE values are also higher for the powders stored with desiccant, though, for the PSD2 sample, the effect is marginal. These trends indicate that moisture is retained in the samples – the desiccant clearly has a marked effect – and that the presence of water enhances the flowability of the powders, decreasing the resistance of the powder to the movement of the instrument blade, particularly under unconfined conditions. A rationale for this is that the water present at ambient conditions acts as a lubricant, reducing the levels of friction between particles, a particularly important mechanism for SE.

Fig. 6 shows comparable data for samples baked in air. The PSD1 sample displays the same trend as the virgin powders, with BFE and SE values higher for the powder stored with desiccant than for the powder stored under ambient conditions. The PSD2 sample also exhibits an increase in SE when stored with desiccant but a slight reduction in BFE. This result highlights how the combined impact of baking and storage can vary markedly from powder to powder, even for the same material.

Fig. 7 shows a final data set contrasting the impact of storage conditions for samples baked under nitrogen. The PSD1 nitrogen baked samples display the same trends observed with both the virgin and air baked samples, with lower BFE and SE values observed for the samples stored under ambient conditions. However, the PSD2 sample mimics the trend of the sample baked in air. For all the PSD2 samples, the impact of drying on SE is more pronounced than on BFE, which, in fact, varies minimally, depending on the treatment method applied.

Fig. 8 shows the trends in flowability associated with baking, for samples stored with desiccant. A comparison of these data with the results shown in Fig. 3 (for storage under ambient conditions) indicates that changes in flow properties due to storage conditions are significant, relative to those associated with baking, and in some instances are sufficient to alter flowability rankings. For example, for the PSD1 samples, the marked increase in BFE associated with baking, particularly baking under air, is not observed in samples stored with

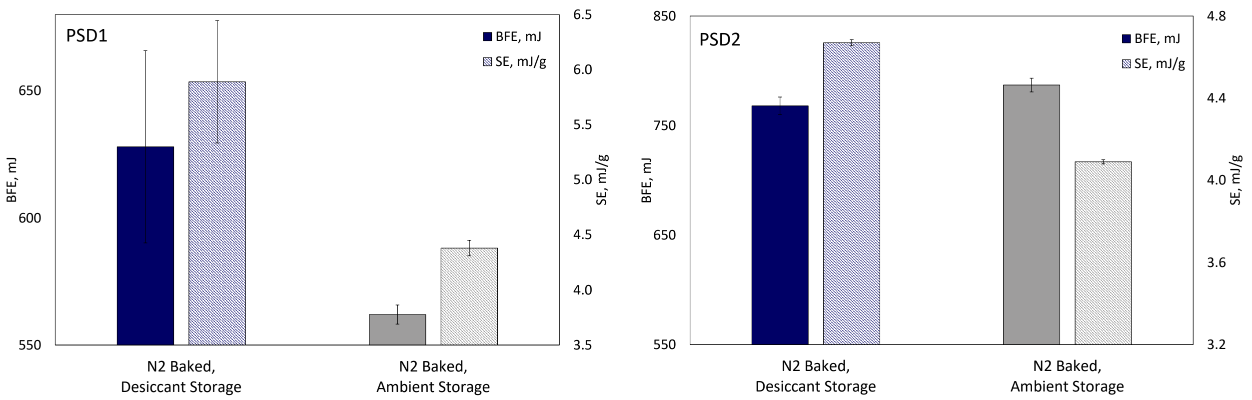


Fig. 7 Dynamic flow measurements contrasting the properties of N2 baked PSD1 (left) and PSD2 (right) powders stored with a desiccant or under ambient conditions


REGISTER NOW!
LASER APPLICATIONS
OF TOMORROW
MAY 6–8, 2020
IN AACHEN
AKL'20
INTERNATIONAL LASER
TECHNOLOGY CONGRESS

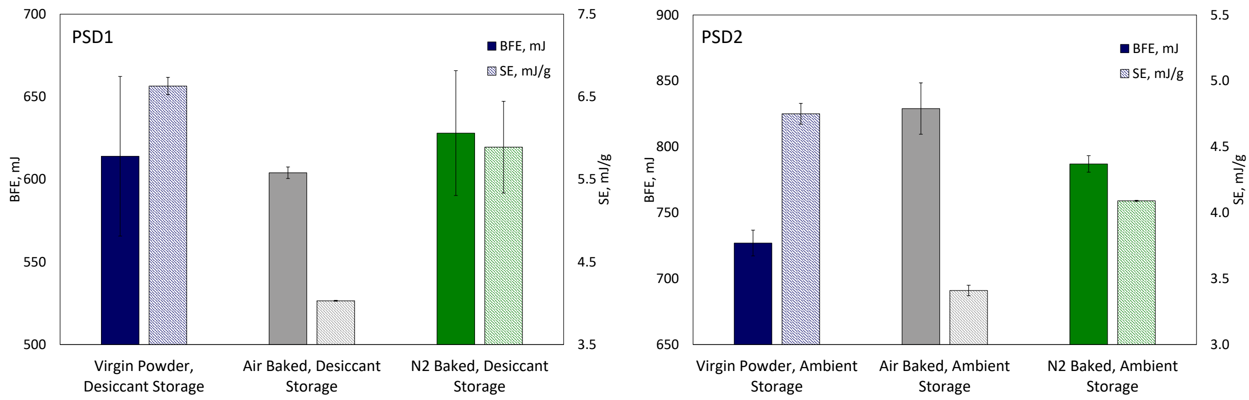


Fig. 8 Dynamic flow measurements contrasting the properties of virgin and baked (under air or nitrogen) PSD1 (left) and PSD2 (right) powders (storage under desiccant conditions)

desiccant. Changing the storage conditions essentially eliminates the differentiation introduced by baking. This observation highlights the need to consider storage conditions carefully to maintain any improvement in flow properties achieved through baking or via any other pre-treatment process.

More generally, this study highlights the importance of measuring the effect of storage and treatment strategies to assess their impact. A statistical analysis, a multi-factor analysis of variance and effect tests carried out to further analyse the data, confirms that baking and storage conditions and PSD are all statistically significant factors in terms of influencing both BFE and SE (significance level $p < 0.01$). The mechanisms underpinning the observed trends are complex, influenced by changes to the surface induced by baking, the lubricating impact of low levels of moisture, particle size distribution and, potentially, by other additional differences between the two grades; PSD1 and PSD2 display markedly different relationships with baking and storage conditions despite being only marginally different in terms of D50 (12 cf. 15 µm). Measuring the net result of these effects is the only practical way to determine their potential impact and requires characterisation tools that can generate data that correlate with process and product performance.

In conclusion

The high cost of AM powders stems from the economics of production and, despite increasing competition in the marketplace, is likely to remain an ongoing focus for the industry. Sound decision-making about feedstocks and recycling relies on recognising the characteristics that define AM powder performance and learning how to optimise them. The chemistry of AM powders is crucial, but so too are multiple physical properties, notably bulk powder flowability. Safeguarding and enhancing the flowability of a powder through appropriate storage and treatment is potentially a productive strategy for value enhancement.

The experimental study presented here showcases the use of dynamic powder testing to assess the impact of baking and alternative storage strategies on the behaviour of stainless steel powders for Binder Jetting. Dynamic properties, such as BFE and SE, are highly sensitive and have proven capable of successfully differentiating closely similar AM powders in terms of their process performance. These parameters are therefore extremely useful for assessing the quality of AM materials and the impact of any treatment strategies.

The results reveal that baking under air or N_2 impacts both BFE and SE and would therefore be expected to alter process performance. Contrasting the flow properties of powders stored under ambient conditions with those stored with a desiccant suggests that, for these materials, water acts as a lubricant for particle-particle movement, enhancing flowability. The results were clearly influenced by particle size distribution, although relation-

"Sound decision-making about feedstocks and recycling relies on recognising the characteristics that define AM powder performance and learning how to optimise them. The chemistry of AM powders is crucial, but so too are multiple physical properties."

ships are complex. Predicting how a powder will respond to a certain environment is not practical, but the described study shows how samples can be relevantly differentiated to provide insight for the development of sound powder management strategies. Such strategies are important for optimising the value of AM powders and boosting process economics.

Authors

Rajeev Dattani
Applications Specialist
Freeman Technology
Bristol
United Kingdom
Email: info@freemantech.co.uk

Animesh Bose
VP Special Projects
Desktop Metal
Burlington, MA
USA

References

[1] J. T. Ray ' Calculating the cost of Additive Manufacturing' available to view at: www.linkedin.com/pulse/calculating-cost-additive-manufacturing-jason-t-ray/

[2] J Dawes *et al* 'Introduction to the Additive Manufacturing Powder Metallurgy Supply Chain' *Johnson Matthey Technol. Rev.*, 2015, 59, (3), 243–256

[3] J Dunkley 'Metal powder atomisation methods for modern manufacturing' *Johnson Matthey Technol. Rev.*, 2019, 63, (3), 226

[4] Powder production: Methods of AM metal powder production. Web page available to view at: www.carpenteradditive.com/technical-library/powder-production/

[5] Controlling metal powder costs in Additive Manufacturing. Carpenter Technology technical article available to view at: www.carpentertechnology.com/en/alloy-techzone/technical-information/technical-articles/controlling-metal-powder-costs/

[6] J Clayton *et al* 'The application of powder rheology in Additive Manufacturing' *Journal of Materials*, March 2015, 67, (3), 544 - 548.

[7] A Klein 'The importance of powder flow in 3D printing' Insights from Industry interview available to view at: www.azom.com/article.aspx?ArticleID=17453

[8] Freeman, R., Measuring the flow properties of consolidated, conditioned and aerated powders — a comparative study using a powder rheometer and a rotational shear cell. *Powder Technol.* 2007:174:25-33.

AMUGexpo showcases AM companies from around the world.


2019 Innovator Recipient Winner Gideon Levy.


Diamond and Platinum sponsor sessions all week.


Technical Competition highlights advanced concepts and finishing.

2020 AMUG CONFERENCE
HILTON CHICAGO
CHICAGO, ILLINOIS
MARCH 22 - MARCH 26, 2020

ADDITIVE MANUFACTURING USERS GROUP
32ND ANNUAL EDUCATION & TRAINING CONFERENCE

- Technical Presentations and Panel Discussions
- AMUG Tracks include:
  - Aerospace, Defense, Military and Transportation
  - AM Technologies (Non-Metal and Metal)
  - Casting
  - Education and Training (Design/Software, Post Processing, Finishing, Tips and Tricks)
  - Materials (Plastic and Metal)
  - Medical and Dental
  - Software
  - Scanning and Metrology
- Daily Diamond and Platinum Sponsor Sessions
- Hands-on Workshops for Plastics and Metals
- AMUGexpo Showcases New Developments in AM
- Networking with AM Industry Experts and OEMs

From lightweighting and material efficiency to energy consumption: Where are we on AM's sustainability journey?

Additive Manufacturing has been heralded as a game-changing technology of the future. But while many 'green' and ecological initiatives have bloomed from the AM movement, the question remains: "Is AM environmentally friendly?" As Olaf Diegel, Ray Huff, and Terry Wohlers explain, the short answer is: it can be, in the hands of good designers and well-informed manufacturers. As with any tool or process, knowledge and experience are key. It is important to explore the many ways AM is applied in sustainable ways and whether it is improving.

Amongst its many benefits, Additive Manufacturing is becoming well-known as a weight saving manufacturing process. Strong, organic structures can be integrated within parts, yielding significant reductions in weight. For example, the bracket shown in Fig. 1 was redesigned for metal Binder Jetting (BJT) by a major car manufacturer. The work resulted in a 47% lighter part compared to a conventional design. The redesign also reduced the necessary welding of the part, saving further assembly costs down the line. The long-term benefit is in fuel savings; every gram removed from a car's weight translates to fuel that is never burned, coupled with less brake wear required to slow it down. With aircraft, ships, trains, mining vehicles, assembly robots and all other moving machinery and transportation systems, these savings are felt in greater energy efficiency over the service life of a product. The contribution of AM to weight reduction and reduced material usage is therefore crucial when considering its sustainability credentials.

AM processes are also attractive with regard to dramatically reducing scrap and waste. With subtractive methods of manufacturing, the material for a part is often sourced using the bounding box of the design. With machining, material is removed until only the part is left. In many designs, this results in 90% or more of the stock becoming chips. With Additive Manufacturing, objects are 'grown' from stock powder, producing little waste by comparison. Support material and partially sintered or melted powder are the exceptions, but these may represent 10% or less of the total material used. When producing parts using high-value materials, such as

Fig. 1 Topology optimised bracket weighing about half of the conventional design (Courtesy The ExOne Company)

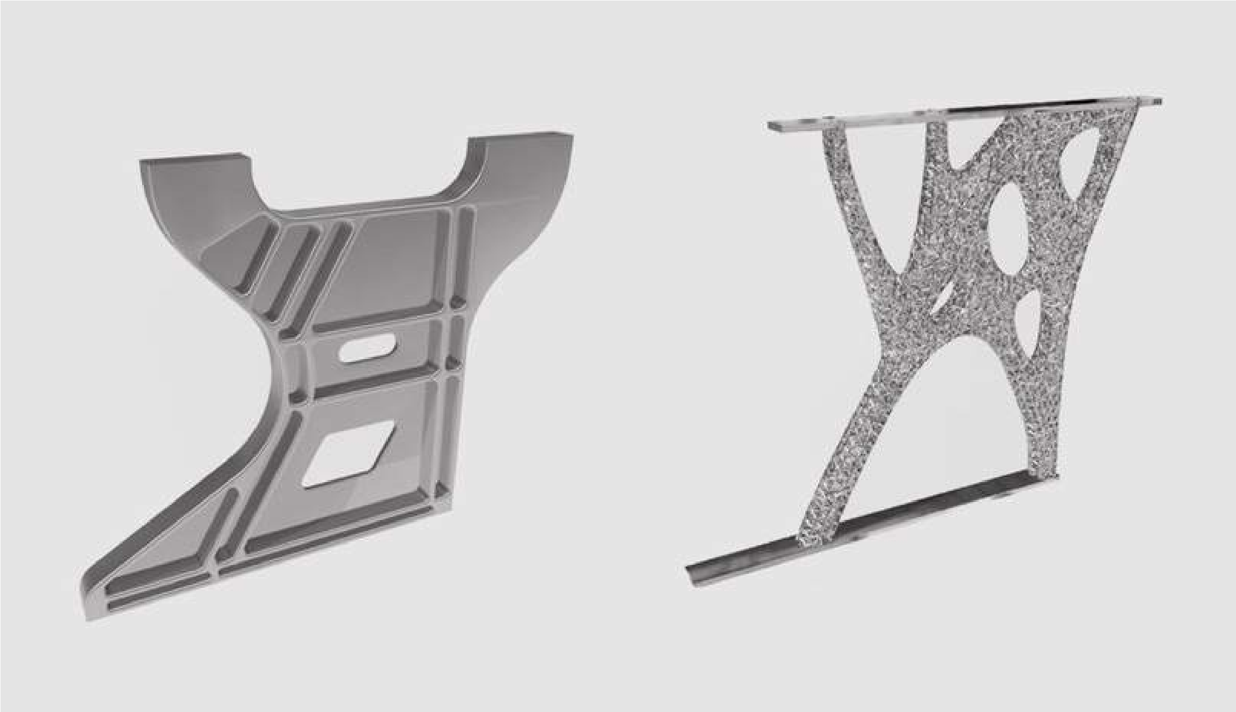


Fig. 2 Left; Aircraft seat frame made by CNC milling. Right; Aircraft seat frame redesigned for AM using topology and lattice optimisation (Courtesy Wohlers Associates)

titanium and cobalt alloys, the cost savings quickly add up.

It has often been said that the best defence is a solid offence. The greatest offensive strategy in AM is design. Design for AM (DfAM) is a framework for evaluating and making design decisions that make the most of the many benefits of AM, while balancing some of the shortcomings. In an example used in the DfAM training courses conducted by Wohlers Associates, an aircraft seat frame is considered. When made by machining, 67% of the billet is machined away to make the bracket shown in Fig. 2 (left). When topology and lattice optimised, as shown in Fig. 2 (right), a waste reduction of 87% is achieved, while preserving the frame's strength.

Raw materials considerations

The metal powder used in AM is most commonly made using gas atomisation. Different atomisation processes include gas, vacuum induction (EIGA), plasma, centrifugal and water. Most atomisation processes produce powders with the characteristics suitable for metal AM. These characteristics include spherical particle shape, good powder packing density thanks to the spherical shape and particle size distribution, and good reproducibility of particle size distribution.

In gas atomisation, a stream of molten metal is blasted with an inert gas jet, which results in highly spherical particles. Such a process adds several steps beyond those required to make materials for conventional manufacturing. These steps include melting, atomising, multiple sieving operations, and then blending the powder to produce a suitable mixed powder grain size distribution. This adds to the energy and cost requirements for metal AM materials. Typically, metal AM powders can be ten to thirty times more expensive than their conventional manufacturing counterparts such as bar stock.

The relatively low volumes of AM materials required, compared to those needed for other manufacturing processes, is also a contributing factor to higher price points.

Greener powders?

Whilst the use of metal powders to make net shape or near-net shape parts, be it by Additive Manufacturing, 'press and sinter' Powder Metallurgy or Metal Injection Moulding is inherently more energy efficient than subtractive processes, the Earth only has so many precious metals near its surface. As such, the recycling of materials has become a focus for many companies.

The high cost of extracting and transporting weighty ore around the globe has been a motivating factor for the aerospace industry in particular. As an example, about 30% of the minerals used to produce the world's titanium are mined in South Africa and shipped to other countries for refinement and transformation into material suitable for manufacturing. Often, this material is then purchased by South African manufacturing companies at a hundred times the cost of the original ore.

For typical machining applications, particularly in the aviation industry, up to 95% of the material is machined away from the billet of titanium, then recycled or taken to the landfill. This is one of the factors that makes the reduced material usage profile of metal AM so attractive.

When scrap material is produced close to an AM production site, recycling becomes an interesting possibility. Premium AEROTECH, a subsidiary of Airbus, has worked on a recycling method for the production of AM materials since 2013. In its process, scrap titanium is compacted and gas atomised into spherical powder for use in metal AM. The work has resulted in more than 100 kg of titanium powder passing quality inspection for use in metal AM systems.

6K, formerly Amastan Technologies, is taking a different approach to metal recycling for AM. Rather than consolidating scrap into ingots before atomisation, 6K uses a proprietary method of mechanically grinding scrap into fine particles that can then be fed through a plasma system to produce high-quality, high-sphericity powder free of any satellites. This process is said to be economical at high volumes, with commercially-available powders expected this year.

A notable recycling project with a heavy societal focus is Humanium Metal. The Swedish-based movement collects and melts firearms into ingots of a material that is 'the equivalent of 316L stainless steel' and can be used for other purposes – potentially including atomisation. The organisation estimates that $4 billion in gun-related damages occur annually worldwide and hopes to create new value while offsetting that cost. Guns themselves have been produced by AM in recent years, so the Swedish initiative could help raise AM's image as a responsible and sustainable technology.

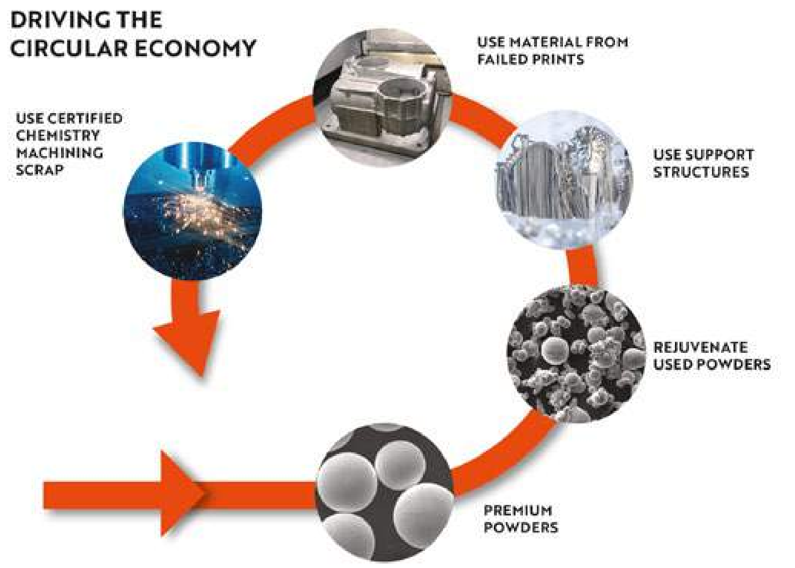


Fig. 3 How the re use of scrap can drive the circular AM economy (Courtesy 6K)

Waste streams from Additive Manufacturing

Despite AM's relatively high material efficiency compared to conventional subtractive processes, metal AM processes produce a number of waste by-products that must be taken into consideration when examining AM from a sustainability point of view. Typical examples include:

Support material

Metal Powder Bed Fusion (PBF) requires support material to anchor the parts to the build plate, and to act as heat-sinks to help reduce part distortion. After the part is produced, this support material is removed and recycled or trashed. The building of parts on typical metal PBF systems results in about 10% waste, largely due to the support structures. With good design, it is possible to reduce this number to around 2%. Whether one takes the best- or worst-case scenario for support material waste, it is generally much better than the waste from machining. With casting, waste material is usually fed back into the crucible for remelting, although most castings also require machining, resulting in energy consumption and further waste.

"The building of parts on typical metal PBF systems results in about 10% waste, largely due to the support structures. With good design, it is possible to reduce this number to around 2%."

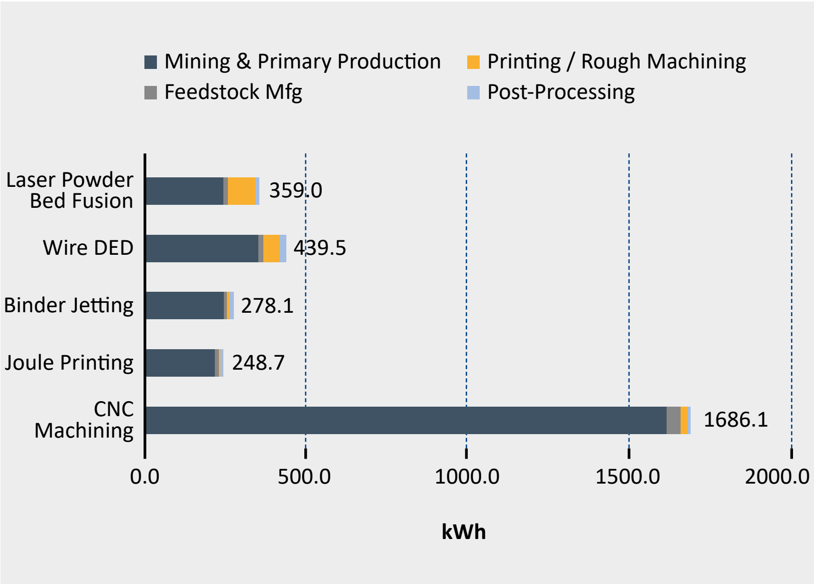


Fig. 4 Manufacturing energy consumption for an example 1 kg titanium aerospace part, based on various AM processes plus CNC machining, taking into account the energy used in mining and primary material production (Courtesy Digital Alloys)

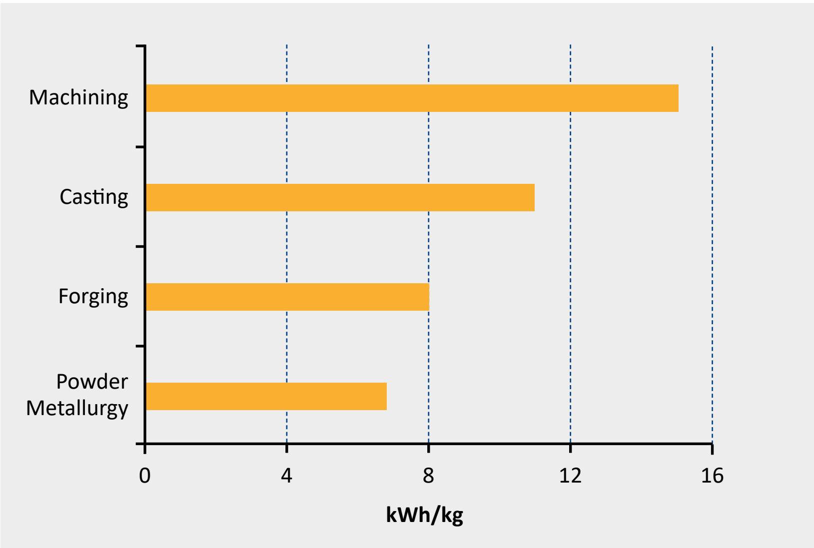


Fig. 5 Energy consumption per unit mass for various manufacturing processes, including Powder Metallurgy, which can broadly be seen as representative of a range of sinter-based processes (Powder Metallurgy figure includes 2 kWh/kg for powder production (From the paper 'Energy Consumption in Powder Metallurgical Manufacturing', Vladislav Kruzhanovand and Volker Arnhold (GKN Sinter Metals), Powder Metallurgy, Vol. 55 No. 1, 2012)

Poorly designed parts and build failures

One of the largest streams of waste in AM is poorly designed parts. This waste occurs, often at great cost, before users realise a design is not quite right, or not a good fit for AM. These parts are often redesigned and rebuilt, with the original part being scrapped. When additively manufacturing a part for the first time, it is often built more than once in different orientations or with different support strategies. Most service providers have bins full of scrap parts that were used to determine the best build strategies. Whilst most AM system manufacturers provide little in the way of build guidance, the effective use of the latest simulation technologies and the development of digital twins can go some way towards addressing this issue.

Spatter

As the powder is being melted by the energy beam in PBF processes, some particulate and spatter is ejected from the melt pool and sucked away by the constant flow of inert gas across the powder bed. This quantity of material is relatively low, at around 0.5%, but it should still be taken into account, if only from an environmental perspective.

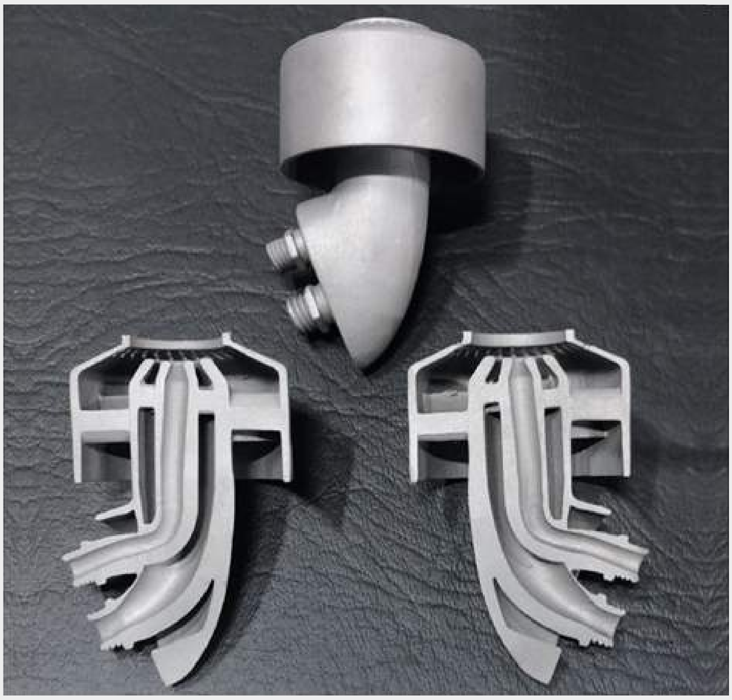
Consumables

Metal AM machines require the use of consumables, chief among them inert gas, which is used to prevent material oxidation and to remove spatter and particulate. Reactive metals, such as aluminium and titanium, typically require the use of argon, while non-reactive metals, such as steels, normally use nitrogen. This gas is pumped into the machine from bottles or by a nitrogen generator, and disposed of after use. Take into account the cost of the inert gas and its disposal.

As part of the powder spreading mechanism, most metal AM systems use a wiper blade, a consumable that may need to be replaced after every build. Consider not only the disposal of the wiper blades, but the energy and material used in their manufacture.

Energy use in AM

Whilst metal Additive Manufacturing encompasses a diverse range of processes with varying energy needs and is by no means low-energy industry, it is significantly more energy efficient than most conventional manufacturing processes



How AM contributes to energy saving in conventional metalworking processes

Looking at AM's broader contribution to energy saving, in the casting industry, AM is used to make complex ceramic investment casting moulds and cores. They do not require casting patterns and tooling, nor do they need to be dipped multiple times in a ceramic slurry and burned out, but AM offers the potential to raise the energy efficiency of even the most long-established technologies.

The double-inlet nozzle casting with internal channels, shown here, was produced with an additively manufactured ceramic mould and cores (Courtesy Aristo-Cast)

(Fig. 4). In PBF systems, material is heated to its melting point by a laser or electron beam. For high-temperature superalloys, such as Inconel 718, this is at about 1,300°C. Additional energy may be required to heat the build chamber and maintain an elevated temperature during the build.

Metal Binder Jetting systems use temporary binders to bond particles prior to sintering. These binders are eventually burned out or chemically removed, so they are another consumable. When sintering, parts are brought to elevated temperatures just below the material's melting point and held for extended periods of time. For parts with thicker cross-sections, this time can be extended to ensure sufficient densification. All of this contributes to the cost of energy.

Despite this, sintering-based processes have been shown to be significantly less energy consuming than forging, casting, and machining, even when taking the energy used in metal powder atomisation into account. Fig. 5 shows data from research undertaken at GKN Sinter Metals, which is primarily focused on PM and MIM processing. It is possible to use the data generated to understand the energy consumption of mid-to-high volume sinter-based AM processing.

Energy costs are present in any forming process in which metal is melted. AM's energy advantage is the heating of minimal material to form a part, harkening back the argument for DfAM to minimise part mass.

Conclusion

Metal AM processes are complex, and require experience, testing, qualification and parameterisation in order to use them as a reliable method of production. With conscience, common sense, and some ingenuity, the technology progresses toward becoming a sustainable solution.

Authors

Olaf Diegel, Ray Huff and Terry Wohlers
Wohlers Associates, Inc.
Fort Collins
Colorado 80525
USA
www.wohlersassociates.com

AM's industrial impact celebrated as Sweden hosts ASMET's fourth Metal Additive Manufacturing Conference

The fourth Metal Additive Manufacturing Conference (MAMC 2019), organised by the Austrian Society for Metallurgy and Materials (ASMET), took place in Örebro, Sweden, from November 25–27, 2019. The event, which attracted an international audience, covered a broad range of metal AM technologies and considered the technical challenges that need to be overcome to make the industry more economically competitive with conventional manufacturing. Prof Dr Jürgen Stampfl, Prof Nader Asnafi, Dr Bruno Hribernik, and Dr Gerhard Hackl review the event for *Metal AM* magazine.

MAMC 2019 was the fourth in the Metal Additive Manufacturing Conference series organised by the Austrian Society for Metallurgy and Metals (ASMET) and attracted over 220 decision-makers, engineers, developers, industry experts, scientists and students from more than twenty countries. For 2019, the event moved from its previous home in Vienna, Austria, to the city of Örebro, 200 km to the west of Stockholm.

Örebro was for many centuries one of the most important ports for the trade of iron from the Bergslagen mining district, and this long metallurgical tradition, in combination with Sweden's current position as an important player in metal Additive Manufacturing, made the city a natural home for an AM conference that focuses exclusively on the processing of metals.

The conference venue, Örebro's medieval castle, lies in a picturesque setting on an island in the river Svartån. The name Örebro comes from the word for small stones, called 'ör' in Swedish, that are washed down a river, with the second part of the word coming from the bridge ('bro') that was built over this ford. This was historically a strategic location, because from here one could control traffic and trade with Sweden's interior. In 2015, the historic town celebrated its 750th anniversary.

The MAMC 2019 technical programme consisted of more than sixty oral presentations and identified the latest trends and developments along the entire AM process chain, as well as numerous applications that have had a real and positive impact in industry. The opportunities connected with such a dynamic technology are raising interest in both the raw materials and manufacturing equipment industries, and an indication of the relevance of AM to Swedish industry was given in a welcome address by Anna Olofsson, County Director on the Örebro Administrative Board.

Fig. 1 Örebro Castle, the historic venue for MAMC 2019 (Courtesy John Chahrestan)

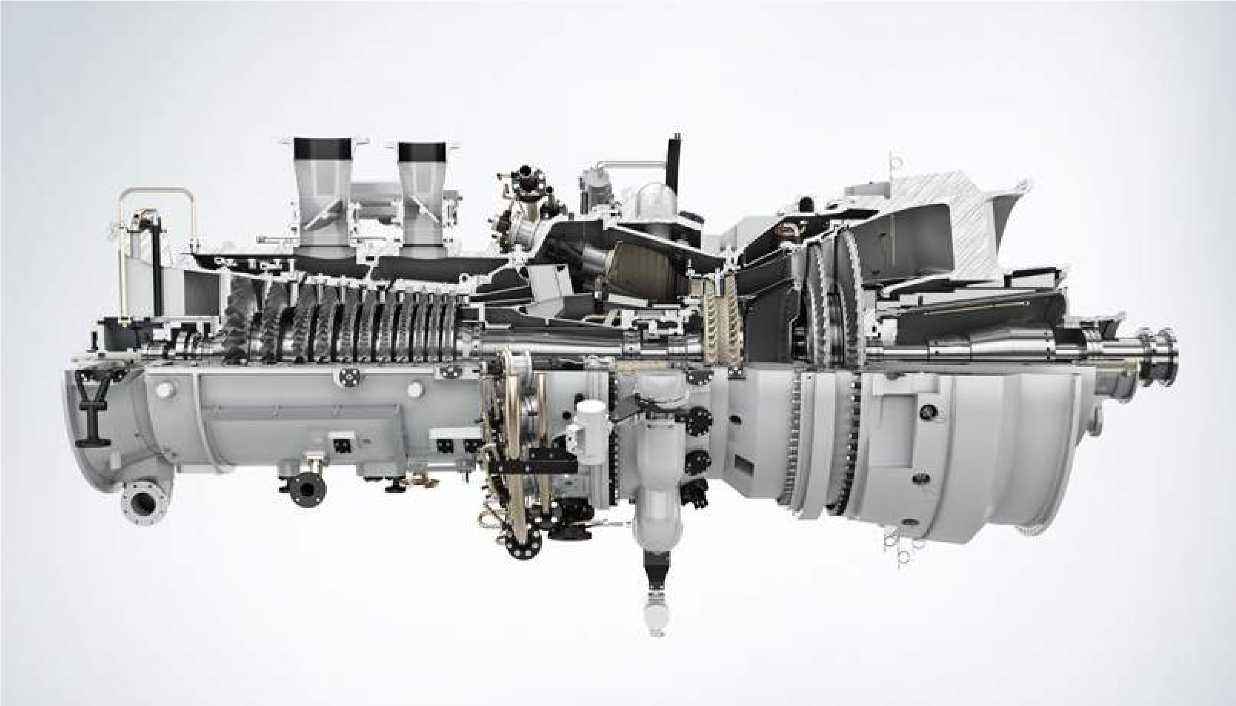


Fig. 2 A Siemens SGT-700 industrial gas turbine, featuring ground-breaking additively manufactured burner solutions developed and manufactured at the company's nearby Finspång AM facility (Courtesy Siemens)

Opening keynotes highlight AM success stories

The conference's opening keynote presentations set the stage for the more detailed discussions on materials, processes and systems for metal Additive Manufacturing that would come later in the programme. Andreas Graichen, of Siemens Turbomachinery, presented ongoing projects and research efforts taking place in Siemens' energy business unit, which also hosted a guided tour of its Finspång AM facility. Siemens has invested heavily in the development of metal AM since 2006 and, in 2016, used additively manufactured burner heads in its SGT-1000F gas turbines for the first time. Many other 'mission-critical' parts have since been added to the company's growing list of successes, and metal AM is, in the meantime, at the heart of Siemens' digitalisation strategy (Fig. 2).

"Binder Jetting technology offers an interesting cost structure thanks to the high throughput offered by the process and the use of low-cost components, such as inkjet heads, in comparison with laser-based systems."

Edmar Allitsch, Managing Partner at AM Ventures Holding GmbH and Chairman of the Supervisory Board of EOS Holding AG, Munich, Germany, gave insight into the eco-system surrounding EOS's metal AM activities. On a technical level, his presentation focused on the suitability of Laser Powder Bed Fusion (L-PBF) in comparison with metal Binder Jetting technologies (BJT). With the advent of a number of new players in both fields, potential users are now seeking to understand which AM technology is best suited for their specific applications. Binder Jetting technology offers an interesting cost structure thanks to the high throughput offered by the process and the use of low-cost components, such as inkjet heads, in comparison with laser-based systems. Nevertheless, the sintering process required to obtain fully-dense metal parts by Binder Jetting limits certain applications, especially for larger parts with non-uniform wall thicknesses.

Highlighting applications in aerospace engineering (Fig. 3), Allitsch pointed out the challenges and achievements of the recent years, resulting in EOS's leading position in the metal AM market thanks to its installed base of around 3,500 machines.

In his keynote, Jürgen Stampfl, TU Wien, Austria, spoke on the topic of '3D Printable Materials: Design principles for strong and tough polymers, ceramics and metals', describing the common design principles in AM fabricated polymers, metals and ceramics, with a focus on highlighting the importance of fracture mechanics in the development of AM materials.

Later, Tobias Brune, SMS Group, Germany, presented the current status of one of the most advanced metal powder atomisation plants developed by the SMS Group. SMS provides turnkey solutions for the production of metal powders with the highest purity requirements, thanks to in-house expertise that ranges from CFD simulation to decades of experience providing integrated engineering systems to industry.

Fig. 3 An Ariane 6 Vinci Engine injector printed as one single piece, including 8000 holes, using Laser Powder Bed Fusion (Courtesy EOS)

MAMC 2019 'best paper' awards

A highlight of the conference were three presentations given by the recipients of the MAMC 2019 'best paper' awards. In a paper titled 'Automotive stamping tools, dies and injection moulds made by L-PBF AM', Nader Asnafi and colleagues from Örebro University focused on automotive stamping tools, dies and injection moulds made by Laser Powder Bed Fusion. Following the procedures of Volvo Cars, he and his co-workers certified solid and topologically optimised tools additively manufactured in maraging steel 1.2709 for the forming and trimming/blanking/cutting of 2 mm thick hot-dip galvanised DP600 sheet steel. Asnafi also showed an additively manufactured punch from a production tool that was designed both conventionally and using topology optimisation. This was produced using the same maraging steel and used for the stamping of 1 mm-thick hot-dip galvanized DP600 sheet.

Fig. 4 A punch in an industrial production tool for the stamping of 1 mm thick hot-dip galvanised DP600 sheet. From left to right: the conventional design with a honeycomb inner structure, topology optimised with LS-TaSC, and topology optimised using Siemens NX12. All three punches are additively manufactured in maraging steel 1.2709 (Courtesy Nader Asnafi)

The conventionally designed punch was first additively manufactured with a hollow honeycomb inner structure, before a variant was topologically optimised using two different software packages, LS-TaSC (LS-Dyna) and Siemens NX12. The purpose of the topology optimisation using LS-TaSC was to obtain reasonable maximum displacement during loading. The topology optimisation using Siemens NX12 then aimed at reducing the tool's weight by 70% and to study how large the maximum displacement was during loading. All versions of the same punch are shown in Fig. 4.

The team showed also a core used in the injection moulding of a medical container. This core was first optimised through simulations and

Fig. 5. Core for the injection moulding of a medical container: Cooling performance was improved by 15% and cycle time was reduced by 8%. After optimisation, the core was additively manufactured in a voestalpine material [Courtesy Anton Alveflo]

Fig. 6 Three jet nozzles for Directed Energy Deposition with additional shielding gas shroud

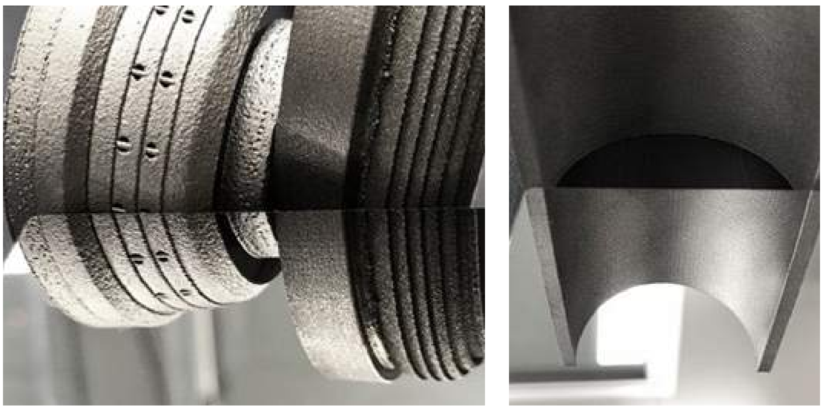


Fig. 7 Surface roughness directly after AM (left) and after AM and polishing (right). Produced from AM Corrax on an EOS M290 (Courtesy Petter Damm)

then additively manufactured using a voestalpine material. Improved cooling and reduced cycle time were the targets of this optimisation (Fig. 5). In production testing of this core, cooling was improved by 15% and cycle time was reduced by 8%.

In their presentation, 'Low-defect AM of high strength aluminium alloy by Direct Energy Deposition', Anika Langebeck and co-authors from BIAS Bremen, Germany, presented results on the Directed Energy Deposition (DED) of 7075 aluminium alloy, a material which can be used in applications such as roller bearings designed for lightweight applications. The alloy is sensitive to residual porosity when it is processed using DED; however, by developing a dedicated setup featuring multiple nozzles and an additional gas shroud for shielding gas (Fig. 6), the team was able to gain a detailed understanding of its processing and material properties.

The setup that was developed was designed in such a way that it can be operated without an inert gas chamber, enabling the manufacturing of large components. The challenges presented by the omission of a process chamber are mostly related to a difficult-to-control deposition atmosphere within the process zone. An additional gas shroud, which protects the multi-nozzle head from the surrounding atmosphere, is one of the key elements to reduce contamination with oxygen. Further measures to better control and monitor the process conditions helped to achieve a stable and reproducible deposition state, leading to alloys with 220 MPa Ultimate Tensile Strength.

Finally, Mihaela Albu and colleagues from Graz Centre of Electron Microscopy, Austria, presented their paper 'Ex- and in-situ microstructure investigations of powders and AM parts', in which they used Scanning Electron Microscopy (SEM) and Scanning Transmission Electron Microscopy (STEM) to investigate in-situ and ex-situ how the microstructure of

Al-alloys and N700 steel powders evolve during a heat treatment procedure that matches the processes that occur within a Laser Powder Bed Fusion system.

STEM images made by high angular annular dark field experiments and differential phase contrast images, and Electron Energy Loss Spectrometry (EELS) spectrum images, were used to localise and identify the elements and their stable and metastable phases. In-situ STEM observations were used to gather information regarding the crystallisation of amorphous phases and the development of metallic microstructures at different temperatures.

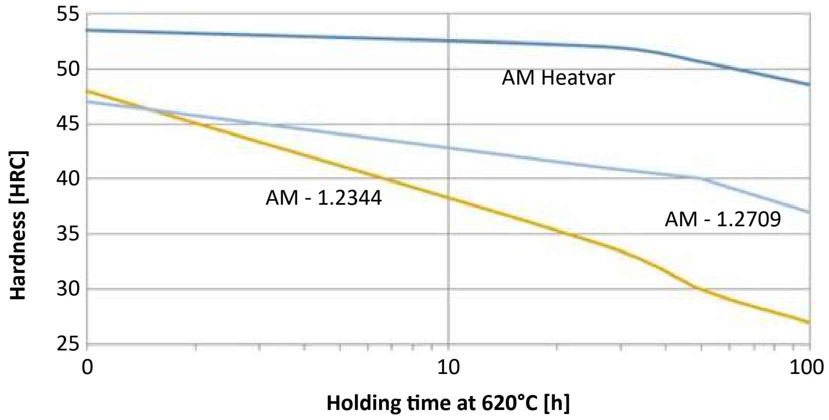


Fig. 8 The temper back resistance at 620°C for three different tooling AM materials: AM Heatvar, maraging steel 1.2709 and 1.2344/H13 tool steel (Courtesy Petter Damm)

Success for AM tooling applications

Production tooling made by AM processes has today reached a high manufacturing readiness level and tooling is becoming a competitive market for the AM industry. This was reflected in a number of related presentations at MAMC 2019. In addition to the previously highlighted presentation by Nader Asnafi, Petter Damm and Anton Alveflo focused on why, how and where to use Additive Manufacturing in tooling.

Damm addressed metal AM powder made for tooling and described the benefits of AM in three different tooling application areas: plastic injection moulding, hot work applications and cold work applications. Conformally cooled and additively manufactured cores and inserts for the injection moulding of plastic components reduce cycle times and improve the part quality through both direct improvements and by reducing scrap rate. Part quality is highly related to mould quality, which in turn is determined by several factors, of which the polishability of the mould material is one. The high polishability of AM Corrax is shown in Fig. 7, where the surface roughness is presented both directly after AM and after AM plus polishing.

Tools for hot stamping (or press hardening) and High Pressure Die Casting (HPDC) are two important hot work applications. As far as HPDC is concerned, Damm addressed downtime, maintenance and scrap rate reduction as well as product quality improvement. He described how soldering and erosion constitute challenges in HPDC, particularly regarding part quality and die life. To improve die performance from these perspectives, he stated that the following was of greatest importance:

- A die material with high temper back resistance, high hot hardness and low affinity to Al
- The ability to avoid hot spots and control shrinkage through conformal cooling specifically where it was required.

"Production tooling made by AM processes has today reached a high manufacturing readiness level and tooling is becoming a competitive market for the AM industry. This was reflected in a number of related presentations at MAMC 2019."

Fig. 8 shows the temper back resistance at 620°C for three different AM tooling materials, Uddeholm AM Heatvar, maraging steel 1.2709 and DIN 1.2344 / H13 tool steel. In relation to cold-work applications, Damm highlighted AM's benefits as avoiding the need to stock bar material, integrating advanced lubrication and venting, and superior process control through integrated sensor.

Anton Alveflo described the AM approach and solutions provided by voestalpine along the value chain for powders and parts. voestalpine carries out material development and powder production, design optimisation and component production. Besides Inconel L718, L625, 17-4PH and W722, Böhler and Uddeholm, as divisions of voestalpine, are providing proprietary materials such

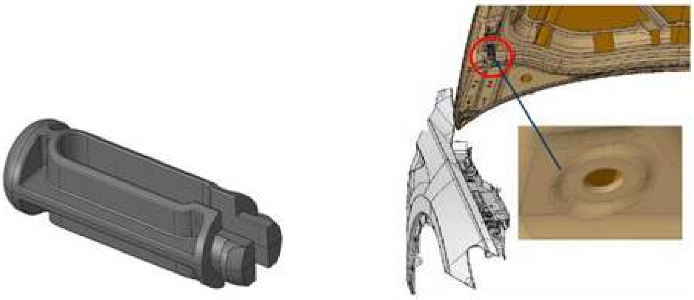


Fig. 9 Tooling insert for the plastic injection moulding of a separator piece in Polyamide 66 for a car body application. Part dimensions are 108 x 60 x 42.5 mm (Courtesy Anton Alveflo)

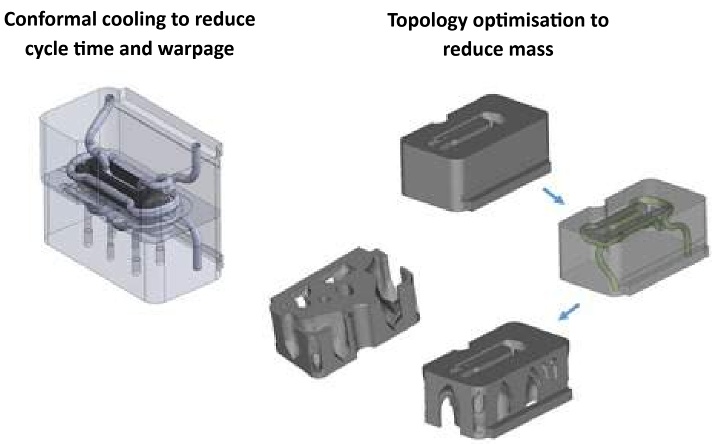


Fig. 10 To reduce cooling time, warpage and weight, conformal cooling and topology optimisation were conducted. After these optimisations, the tool was additively manufactured in AM Corrax (Courtesy Anton Alveflo)

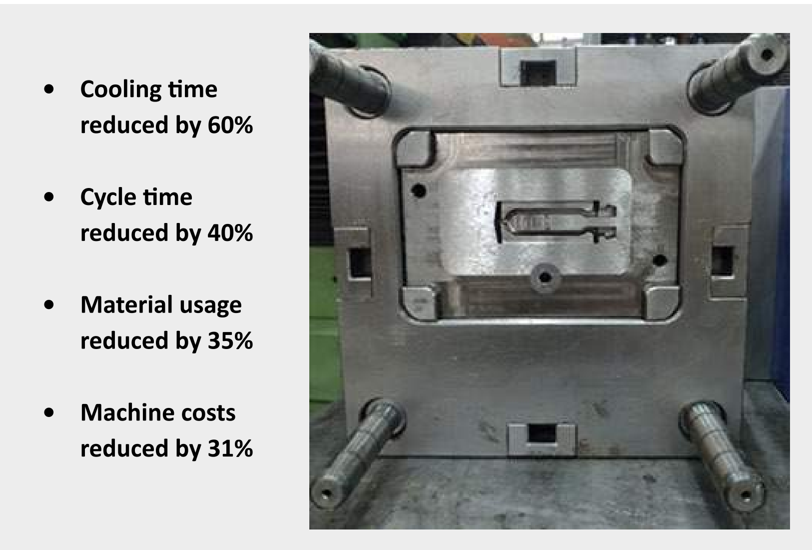


Fig. 11 The improvements achieved with the cooling and topology optimised inserts additively manufactured from AM Corrax (Courtesy Anton Alveflo)

as E185, W360, M789, Corrax and Heatvar for AM applications. Alveflo showed industrial tooling cases from HPDC and plastic injection moulding, with the tooling for the plastic injection moulding of a Polyamide 66 component for a car body application being one of these cases (Fig. 9). To reduce cooling time, warpage and component weight, conformal cooling and topology optimisation were conducted (Fig. 10). After these optimisations, the tool was additively manufactured using the Corrax material. With this tool, cooling time was reduced by 60%, cycle time by 40%, material usage by 35% and machine cost by 31% (Fig. 11).

Drivers of AM innovation

Several contributions covered the further development of advanced systems and processes for metal AM. Presentations made by Franz Haas (TU Graz, Austria), Sebastian Dirks (RWTH Aachen, Germany) and Ulf Ackelid (Freemelt AB, Sweden) highlighted opportunities and barriers in the context of process innovations for the further development of the field. This topic is also closely connected with the advances achieved in the field of software and simulation tools, as outlined in the contributions of Andreas Markström (Thermo-Calc Software AB, Sweden), Johannes Zielinski (RWTH Aaachen), and Tobias Ronneberg (Imperial College London, UK). These presentations highlighted how crucial software's role in the evolution of AM is, from enabling the optimisation of AM parts to meltpool simulations and the in-situ imaging of microstructures.

To further enhance the economic and technical benefits of metal AM, innovative and AM-targeted materials, especially powders, are a critical issue. This was reflected by the large number of contributions covering powder production and characterisation, a topic with a very strong tradition in Sweden. Presentations given by, among others, speakers from Fraunhofer ILT, RWTH

The conference was formally opened by County Director Anna Olofsson

The MAMC conference's organisers, left to right: DI Dr Gerhard Hackl, Prof Dr Nader Asnafi, DI Dr Bruno Hribernik and Prof Dr Jürgen Stampfl

The best paper award ceremony, Left to right: Nader Asnafi, Juergen Stampfl, Anna Olfsson, Bruno Hribernik, Mihaela Albu, Anika Langebeck and Anton Aveflo

MAMC 2019 delegates in Örebro Castle

Two-day Design for AM tutorial

Directly following MAMC 2019, Nader Asnafi, Professor of Mechanical Engineering, held a two-day course in Design for Metal Additive Manufacturing in collaboration with Jürgen Stampfl, Professor for Materials and Additive Manufacturing Technologies, TU Wien, Austria, and Olaf Diegel, Professor and Head of the Creative Design and Additive Manufacturing Laboratory, the University of Auckland, New Zealand. The course, which was held at Örebro University, attracted participants from Australia, Austria, France, Japan, South Korea and Sweden.

Tours showcase Sweden as a centre of innovation in AM

AMEXCI was founded by ABB, Atlas Coco, Electrolux, Husqvarna Group, Höganäs, Saab, Scania, SKF, Stora Enso, and Wärtsiläand FAM on the principle of accelerating the industrial adoption of AM (Courtesy AMEXCI)

The morning of November 25 was dedicated to visits to AMEXCI and Lasertech LSH in Karlskoga, a thirty-five minute drive from Örebro Castle. AMEXCI was founded by ABB, Atlas Coco, Electrolux, Husqvarna Group, Höganäs, Saab, Scania, SKF, Stora Enso, and Wärtsiläand FAM on the principle of accelerating the industrial adoption of AM and helping to bring a new generation of innovative engineers and products to the market. AMEXCI has in-house capacity for both metal and polymer AM and strives to be the best partner in applying know-how throughout the product lifecycle in the field of AM. Design for AM, qualification, certification, training and education are some of the focus areas.

Lasertech LSH AB began its operations in 2000 with the aim to become a leading supplier of laser welding services. The company now has nineteen employees and its focus has evolved to encompass other laser processing services such as laser marking, laser hardening, and laser cladding or Laser Metal Deposition (LMD). At the end of 2018 the company invested in an all-new '3D factory' with the ambition of creating a world class AM facility. This began operations in 2019.

The afternoon of November 27 offered a visit to Siemens Industrial Turbomachinery's AM plant in Finspång, located eighty minutes from Örebro Castle. Siemens is a global engineering powerhouse with a focus on the areas of electrification, automation and digitalisation. In infrastructure and industry solutions, the company plays a pioneering role.

Siemens' Finspång operation is world-leading in the field of metal Additive Manufacturing and the company has invested in a complete factory with all the necessary physical and digital support systems for series production using L-PBF. More than eighty full-time employees at the facility work on the development, manufacturing and quality assurance of advanced gas turbine components, hybrid repairs, spare parts on demand and other manufacturing activities. Siemens uses single and quad laser L-PBF systems for the AM of primarily nickel-based superalloys for combustion systems, as well as stainless steels. Siemens also develops proprietary special alloys for its most demanding applications.

Aachen, KTH Stockholm, Uddeholm AB, Luleå University of Technology and Mimete Srl can be seen as proof of the vibrant European metal powder production scene.

Demanding and promising applications, where features offered by AM enhance the economic or engineering value, are still the key drivers for AM. In order to guarantee the reliability necessary for such applications, quality assurance and process monitoring are instrumental. Several sessions therefore covered these topics, giving a broad insight. The importance of further developing this field is also indicated by the presentation of one of the three 'best paper awards' to a paper on this topic.

Finally, since surface quality and defect control are both critical in powder-based metal AM, post-processing and final quality inspection are key elements of the whole process chain. Post-processing approaches based on both electrochemical and mechanical routes were showcased in a number of presentations, including those from Hirtenberger Engineered Surfaces, Sandvik Additive Manufacturing, the University of Trento and DTU, reflecting the increasing levels of activity in this field.

Conclusion

When compared to MAMC 2014, 2016 and 2018, the conference programme at MAMC 2019 demonstrated significant progress regarding materials, the understanding of the Additive Manufacturing process, and the exploitation of new applications. For lightweight applications, such as those in the aerospace and space sectors and complex parts in gas turbines, there is now a clear argument for using metal AM. The final decision between conventional manufacturing processes and AM remains a matter of economics for many applications. Yet, as recent presentations show, there is a significant increase of effort in all fields to implement AM for a rapidly growing range of additional applications.

Authors

Prof Dr Jürgen Stampfl
Jürgen Stampfl is Professor for Materials and Additive Manufacturing at the Institute for Materials Science and Technology at TU Vienna, Austria.
Tel: +43 1 58801 30862
juergen.stampfl@tuwien.ac.at

Prof Dr Nader Asnafi
Nader Asnafi is Professor of Mechanical Engineering at Örebro University, Sweden.
Tel: +46 19 30 14 93
nader.asnafi@oru.se

DI Dr Bruno Hribernik
Dr Hribernik is Member of the Managing Board at ASMET – The Austrian Society for Metallurgy and Materials, Leoben, Austria
Tel: +43 66411 01010
bruno.hribernik@asmet.at

DI Dr Gerhard Hackl
Dr Hackl is Executive Member of the Managing Board at ASMET – The Austrian Society for Metallurgy and Materials, Leoben, Austria
Tel: +43 3842 402 2294
gerhard.hackl@asmet.at

Proceedings

Details of the presentations can be found in the MAMC 2019 proceedings, which can be ordered from ASMET (please contact lisa.loeschnauer@asmet.at)

MAMC2020

The Metal Additive Manufacturing Conference 2020 will take place at the Wirtschaftskammer Österreich, Vienna, Austria, September 30–October 2, 2020.

www.mamc2020.org

Euro PM2019: Effects of humidity and storage conditions on Additive Manufacturing powder quality

A technical session at the Euro PM2019 Congress, organised by the European Powder Metallurgy Association (EPMA) and held in Maastricht, the Netherlands, October 13-16, 2019, focused on the impact of storage conditions, particularly exposure to humidity, on the characteristics and quality of powders used in Powder Bed Fusion Additive Manufacturing. Dr David Whittaker reviews selected papers presented during this session.

Influence of humidity in Ti-6Al-4V powder during storage – Part 1

A paper from K Dietrich, T Arun-prasad and P Foret, of Linde AG, Germany; O Messe and B Szost, of Oerlikon AM GmbH, Germany; A Schobert, of Airbus Central Research and Technology, Germany; and G Witt, of the University of Duisburg-Essen, Germany, investigated the potential degradation of powder flowability in powder-bed AM through exposure to humidity, specifically in relation to the alloy Ti-6Al-4V [1].

Reactive metal powders such as this alloy could be highly influenced by humidity through the resultant formation of oxides and consequent degradation of flowability. If this proposition holds true, it could lead to inhomogeneity in the final product. The authors' study comprised two parts; in the first part (reported in this paper), the evolution of powder attributes as a function of storage duration was investigated, while, in a second part (reported in a separate paper in a later technical session at the congress), the effects of the moisture level on the build process and the resultant mechanical properties were considered.

The powder used in the study was Ti64 grade 23, supplied in containers and sealed under argon to limit the possibility of any degradation during transportation. The supplied powder characteristics are given in Table 1. The powder was recombined and subsequently blended to remove any possibility of batch to batch variation. Two-litre, wide-mouth, low-density polyethylene (LD-PE) bottles were used to store 3 kg of powder. The powder was sampled to fill thirty-six

Fig. 1 The EPMA's Euro PM congress and exhibition series is firmly established as the leading European technical event on PM, MIM and metal AM (Photo Andrew McLeish / EPMA)

Oxygen (wt.%)	Hydrogen (wt.%)	D10 (µm)	D50 (µm)	D90 (µm)	Hall Flow (sec/50g)	AD (g/cm³)	TD (g/cm³)	PYC (g/cm³)
0.05	0.002	19	33	44	26	2.47	2.8	4.4

Table 1 Powder characteristics of the as-received Ti-6Al-4V powder [1]

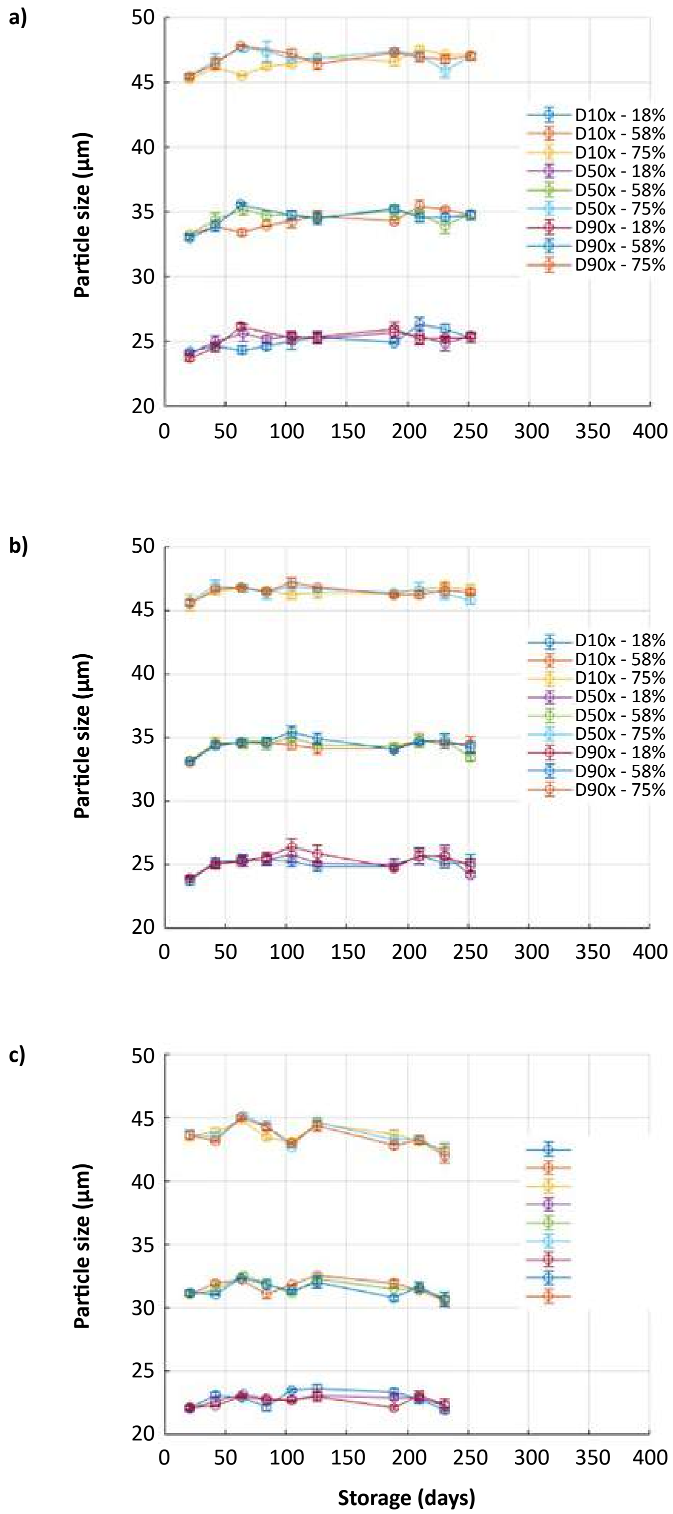


Fig. 2 Particle Size Distribution D10, D50 and D90 for (a) top, (b) conditioned and (c) reclaimed powder [1]

of these plastic containers. For every twelve, the remaining powder was blended to ensure homogeneous sampling through the entire process.

The containers were randomly assigned and stored at three different moisture contents (MC) (18%MC, 58%MC and 75%MC). The containers were stored as opened to the box's atmosphere. The boxes were hermetically sealed and the humidity content and temperature were monitored using a humidity and temperature transmitter probe. The temperature remained stable at 22 ± 5°C throughout the experiment, whereas the humidity in each container was kept stable by using different salts such as potassium acetate (18%MC), sodium bromide (58%MC) and sodium chloride (75%MC).

One container from each of the humidity levels was taken from its box every three weeks to carry out an AM build job in a Trumpf Tru-Print 1000 equipped with Linde's ADDvance® O_2 precision to monitor oxygen and humidity content in the build chamber. The powder was sampled from the top (directly exposed to the humidity), after the powder was blended and after the build on the reclaimed powder from the baseplate. Subsequently, these conditions were referred to as 'top', 'conditioned' and 'reclaimed'. Powders to be used for the build process were then stored in sealed aluminium containers to prevent any subsequent degradation.

Particle size distribution was measured for each of the powder storage conditions, to ensure that powder in each of the containers was identical and that no difference was measured between the top and conditioned states. The fact that both the top and conditioned states displayed the same powder size distribution, shown in Fig. 2 with

D10, D50 and D90, illustrated that no granular convection occurred when the containers were placed in the storage box or during storage (Fig. 2a–b). This also demonstrated that, for the results of each of the tests performed, no normalisation was required for the moisture content. A noticeable shift in the PSD of the reclaimed powder was, however, observed. The measured moisture contents in the powder in both the top or conditioned states did not show any trend (Fig. 3a–b). However, visual inspection revealed loosely bound agglomerates on the surface developing as the storage duration increased (Fig. 3c). These were most visible in the powder stored under 75%MC and were not observed at all for the powder stored at 18%MC. The formation of these agglomerates was also accompanied by slight but distinguishable darkening of the powder (surface of containers only) stored at both 58 and 75%MC.

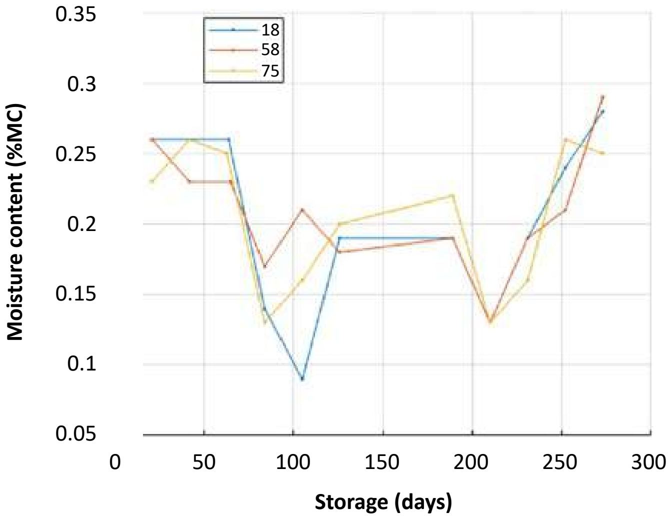
Oxygen and hydrogen contents were measured for all of the powders to evaluate the presence of oxide, water adsorbed at the particle surfaces or hydrogen seeping into the particle because of oxide formation. Both oxygen and hydrogen contents did not show any significant variation over storage time, suggesting that the powder sampled from the top did not markedly oxidise (below the detection limit) during storage, despite the formation of the loosely bound agglomerates and powder darkening for both 58 and 75%MC (Fig. 4).

Particle shape was monitored as part of the experiment. In this case, powder circularity has been plotted as a function of the storage time. The data were discretised so that only C10, C50 and C90 are shown. Both Aspect Ratio (not shown) and Circularity remained constant, or within their initial range, suggesting that the powder does not change or degrade during storage and is marginally affected by the build process.

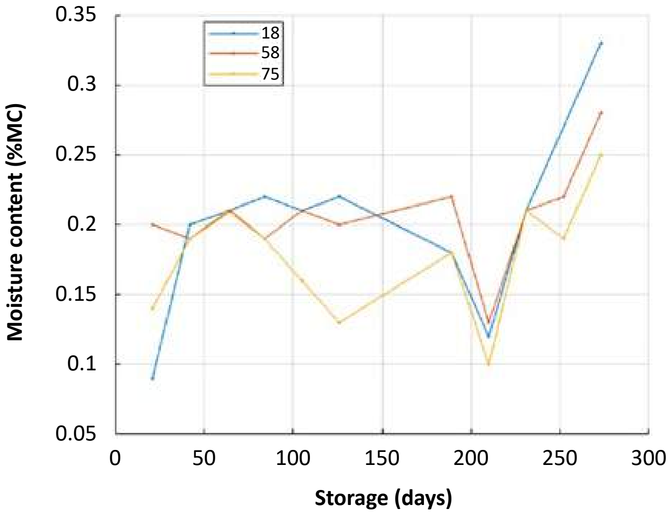
Pycnometric density was measured for the conditioned powder to assess any change in the density that may be linked to a change in the powder. Table 2 shows the pycnometric densities measured for the conditioned powder. The results do not show any trend over storage time or for specific humidity levels. The results obtained are also similar to those for the virgin powder.

The combined data from PSD, Particle Morphology, Oxygen and Hydrogen suggest that the powder degradation, if occurring, is below the detection limit of these methods.

a)



b)



c)

Fig. 3 Moisture content measured from a) top and b) conditioned states for the powders stored under 18, 58 and 75 %MC. c) Picture of the loosely bound agglomerates from the surface of the powder stored at 75 %MC for 273 days [1]

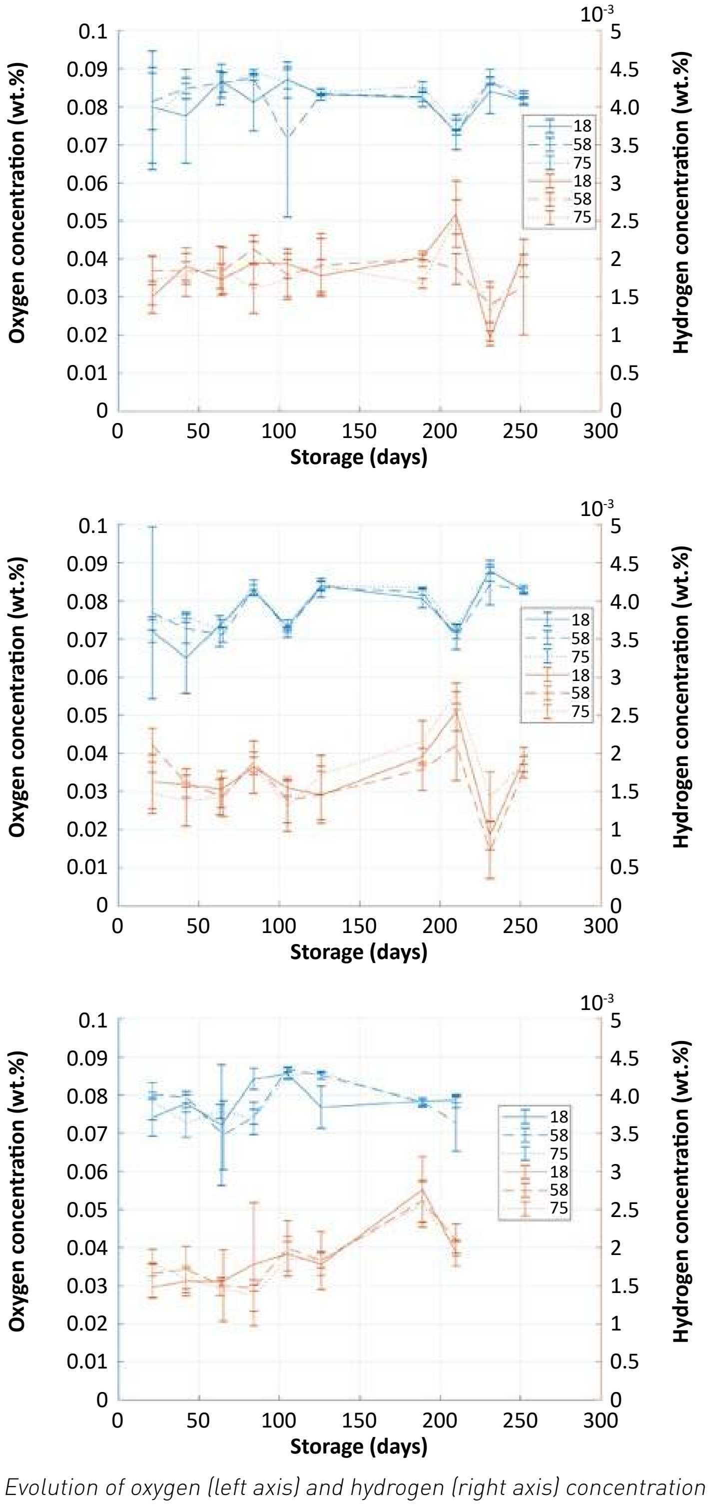


Fig. 4 Evolution of oxygen (left axis) and hydrogen (right axis) concentration measured in the powder for each humidity level from (a) top, (b) conditioned, (c) reclaimed states [1]

The results obtained are at odds with the visual changes observed from the top surface of the containers and suggest that any change in moisture, oxygen or hydrogen may be very local beyond the sampling and instruments' resolution or detection limits. Also, these storage conditions do not affect powder attributes, which could affect, through varying powder rheology, the build process and bulk properties. The colour change observed is presumably attributed to small changes from the powder surface located at the top of the container. To test this hypothesis, additional sampling was carried out at the very top of the container for SEM investigation for all the powder which were stored for more than 150 days. These powders were sampled by gently pressing an aluminium stub covered with a carbon tape on the powder to obtain only particles located at the surface.

SEM micrographs showed very few differences between 18 and 75%MC. The overall powder morphologies for these powders were nearly identical. The lack of a relationship between the formation of agglomerates and any measured powder attributes during this study suggested that the Ti-6Al-4V powder was not affected by the storage condition.

It is possible that the observed colour change may be attributed to a TiO_2 oxide layer increase combined with impurities in the oxide. A few parts per million of certain metals (Cr, V, Cu, Fe, Nb, Al) can distort the crystal lattice, generating defects. The reported study demonstrated that, for L-PBF and titanium alloys, specifically Ti-6Al-4V, storage condition is not a process variable. Additional work would need to be carried out to evaluate the origin of the darkening observed at the powder surface.

Days	21	42	63	84	105	126	189	210	231	252
18%MC	4.414	4.412	4.406	4.406	4.407	4.409	4.409	4.418	4.403	4.409
58%MC	4.405	4.411	4.410	4.407	4.410	4.406	4.406	4.409	4.407	4.410
75%MC	4.409	4.409	4.415	4.405	4.409	4.405	4.406	4.420	4.407	4.410

Table 2 Pycnometric density for the conditioned powder prior to the builds [1]

The influence on additively manufactured part quality using AlSi10Mg powder aged in different humidity levels

Attention was next switched to the possible influence of humidity levels in aluminium alloys, specifically AlSi10Mg, in a presentation from Matthew Schultz-Sciberras of SLM Solutions Group AG, Germany. Aluminium materials, including powders, form a native oxide film on the surface once exposed to oxygen. This oxide layer is typically only a few nanometres thick and acts to passivate the particle against additional oxidation. While this holds true for aluminium-based powders in relatively dry air at ambient temperatures, it is not necessarily the case for powders in humid air at ambient or elevated temperatures. When the metal powder is exposed to water vapour, the water molecules adsorb onto the metal powder surface and become either chemi- or physisorbed. In the former case, water molecules attach to the oxide surface and chemically react to form metal hydroxides. [2]

The surface of the oxide layer is always hydroxylated to a degree under typical powder storage conditions. It is, however, not known what exposure limits to humidity exist for such metal powders before the surface layer changes enough to influence powder and built part quality. In addition, while reaction kinetics may be very slow at ambient temperature, they could become significant at elevated temperatures. This has implications not only for build jobs with some water vapour in the build chamber, but also for the various powder drying approaches using ovens in air.

The reported study aimed to show the changes in powder and part quality using AlSi10Mg powders exposed to humidity in their lifetime and then dried before use.

A single batch of gas atomised AlSi10Mg powder was used. The PSD of the batch of powder was measured by laser diffraction. For each experimental condition, 10 kg of AlSi10Mg was used. Powders were aged in their original containers under different conditions in a climate chamber. The conditions used to age the powders are presented in Fig. 5. One method to mitigate powder exposure to environmental humidity is to add a desiccant bag to the powder container; for this reason, the desiccant bag was removed prior to ageing experiments. The containers were placed open in the climate chamber for 168 hours (1 week) at the specified condition. After this period, typically the containers were removed from the climate chamber, a fresh desiccant bag was added and the containers were sealed tightly by hand. However, powders aged under the conditions 20°C, 70% RH, 20°C, 90% RH and 30°C, 90% RH were dried in a fan forced oven at 60°C for approximately 24 hours.

Powder flowability was measured using an SLM® Flowmeter. This device follows a similar principle to the Hall Flow test, but has a modified orifice in the funnel. Using this device, the flow time and packing density could be determined. For each ageing condition, if the powder passed the flow test, then it was used in a single build job on an SLM® 125 machine. The SLM® 125 was equipped with a 700 W laser and the layer thickness used in the build was 60 µm.

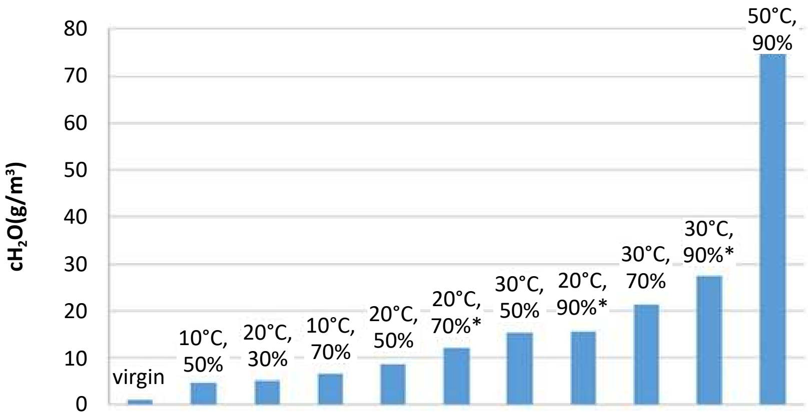


Fig. 5 The experimental conditions used to age AlSi10Mg powder for 168 hours. Each column shows the temperature (°C) and relative humidity (%) of the test conditions, which have been converted to absolute moisture cH_2O (g/cm³) for comparison. Powder aged under conditions marked with an asterisk were dried in an oven [2]

Samples of the virgin AlSi10Mg powder were analysed to determine the PSD. The following D values were obtained: D10 = 24.84 µm; D50 = 43.68 µm; D90 = 72.66 µm; mean particle size = 46.65 µm. When conducting powder flow tests, the laboratory environment was 19°C with a relative humidity of 52.0%. The residual humidity in the powder container prior to the test was 4.0% at the same temperature. Flow tests indicated that 82.0 g of powder had good flowability of 47.0 s through the SLM® Flowmeter. This amount of powder corresponds to an apparent density of 1.45g.cm³.

Following ageing experiments, all powders showed visible signs of exposure to the humid environment. For all conditions examined, except 30°C, 90% RH and 50°C, 90% RH, the static flowability and packing density data were between 40 to 50 sec and 1.42 to 1.43 g.cm³, respectively. Powder agglomerates formed during exposure to the condition 30°C, 90% RH were large and mainly confined to the top volume of powder, while the top 4 cm of powder from the condition 50°C, 90% RH had sintered together into a solid mass that was difficult to break apart. For these reasons, powders from these conditions were not used in build jobs.

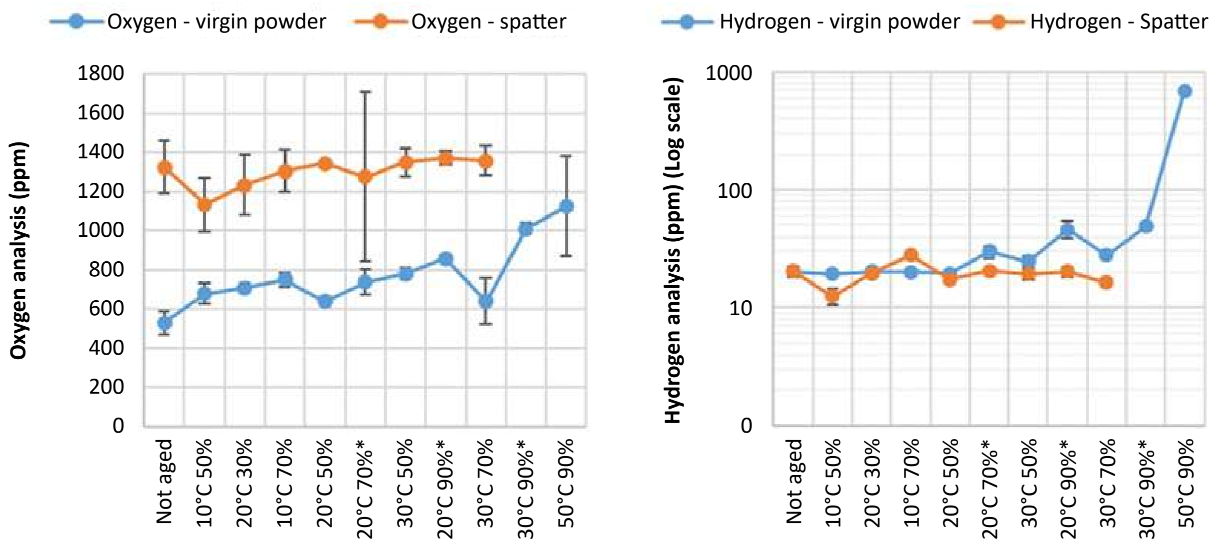


Fig. 6 The oxygen analysis (left) and hydrogen analysis (right) of AlSi10Mg powder aged under different conditions and then dried (blue) and the corresponding spatter analysis from one build job (orange). The powders from conditions 20°C, 70% RH, 20°C, 90% RH and 30°C, 90% RH were dried at 60°C in an oven for about 24 hours (marked with an asterisk) [2]

Fig. 6 displays the results for oxygen analysis in the virgin and aged powders, after drying, as well as the oxygen in the spatter from the respective build job. The oxygen level trended upward from an initial value in the unaged virgin powder of 530 ppm to 1125 ppm for the powder aged at 50°C, 90% RH. The oxygen analysis of the spatter powder from each respective build job showed the rapid accumulation of oxygen in the build chamber for such particles. There was no observable increase in the oxygen accumulation due to the drying procedure in an oven at 60°C for about 24 hours.

The hydrogen analyses for aged virgin powders are displayed in Fig. 6. No significant increase was observed in the hydrogen content of the powders aged under the conditions 10°C, 50% RH, 20°C, 30% RH, 10°C, 70% RH and 20°C, 50% RH, when compared with the value for unaged virgin powder. All the following conditions showed a gradual increase in the hydrogen content of the sample from 20.3 ppm in the unaged virgin sample to 48.9 ppm in the sample aged at 30°C, 90% RH. Samples dried in an oven showed a greater increase in the hydrogen content compared with samples dried at room temperature with a desiccant. The sample aged at 50°C, 90% RH showed a rapid increase in the hydrogen content to 691.9 ppm.

The hydrogen analysis of the powder spatter after one build showed an almost constant average baseline of hydrogen content at 19.4 ppm across all samples. As the solubility of hydrogen in aluminium increases rapidly at the melting point of the metal, the lack of a hydrogen increase beyond levels seen in the unaged virgin powder indicated that the temperature of the ejected powder spatter did not exceed the alloy's melting point.

Analysis of particle surface morphology by SEM revealed differences in surface features

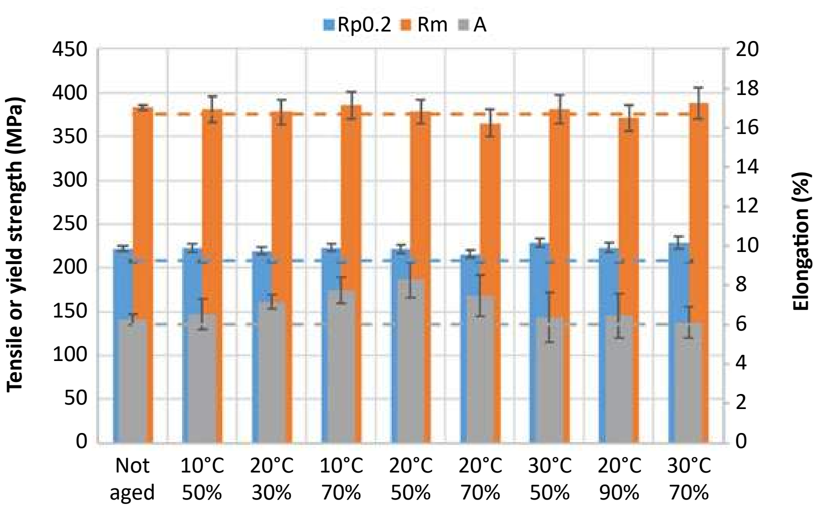


Fig. 7 The mechanical properties of tensile rods produced using AlSi10Mg powder aged at the given condition. The average reference values for each property from previous jobs using this parameter set and on the same SLM® 125 are also given [2]

between unaged virgin powder and spatter after one build job from the unaged powder. The latter showed the formation of nodules approximately 50–100 nm in size, which are not present in the original virgin powder. These surface nodules are probably the result of oxide layer growth from exposure to heat near the laser scanning track during a build job. The hot powder spatter is ejected from the powder bed and reacts with the low residual oxygen and other reactive gasses in the inert gas stream. This observation fits with the increase in oxygen content of the unaged virgin powder versus its spatter after one build job (Fig. 6). The corresponding hydrogen analysis (Fig. 6) for this sample maintained the same level between the virgin and spatter particles, indicating that the oxide growth in the spatter is due to increases in the Al_2O_3 amount, probably through the reaction $4Al(s) + 3O_2(g) = 2Al_2O_3(s)$. In contrast, the increase in oxygen content of the samples aged under different conditions was not observable here through changes in the surface morphology of the particles.

The density rods produced on the SLM® 125 and analysed in the as-built state revealed some minor porosity. Parts produced using powder that was not aged resulted in a porosity of 0.34% in the specimens. This level dropped on average for specimens built using powder that was aged in the respective condition, up until the condition 20°C, 90% RH where the residual porosity peaked in the sample at 0.48%.

Fig. 7 shows the mechanical properties of parts built using powder from each condition. The yield strength and tensile strength values for all conditions tested were similar to reference values for AlSi10Mg, using the same machine and parameter set. The ductility of the tensile rods did vary between samples from about 6% to 8% elongation, but average values were either similar to or better than the reference value. It was considered likely that the gradual increase in oxygen content of the virgin powders through ageing did not exceed a critical limit. While these static mechanical properties did not show significant deviations from the reference values, this study did not investigate dynamic mechanical properties of the built parts. The oxidation kinetics under the tested conditions are not well understood and it is considered likely that the exposure time of one week for each ageing condition may be too short to observe significant oxidation.

The author concluded that further research should be conducted in order to determine the oxidation kinetics under different ageing schemes.

	D10	D50	D90
316L	25,8	37,8	54
AlSi7Mg06	27,5	44,9	78,29

Table 3 Particle size parameters, determined by laser diffraction [3]

Study of acceptance criteria and good practices to follow during powder handling to limit hydrogen trapping in aluminium L-PBF

Finally, a paper from Olivier Rigo, David Reuter, Nathan Routiaux, Regine Van Den Berge, Pauline Tritiaux, Hanane Mekkaoui and Celia Parmentier, of Sirris, Belgium, continued the focus on the effects of humidity in the Laser Powder Bed Fusion (L-PBF) of aluminium alloys, considering the definition of acceptance criteria and good practice for powder handling to limit hydrogen trapping. The L-PBF of parts made from aluminium alloys, such as AlSi7Mg0.6, is extremely problematic due to porosity problems related to the tendency of such alloys to absorb hydrogen when powder with traces of moisture is used. The main source of hydrogen is the reduction of moisture by the oxidation reaction of aluminium [3].

Up to now, standardisation organisations and large companies active in Additive Manufacturing have established acceptance criteria for aluminium powders based on the usual method of measuring free moisture level. However, since moisture in the presence of aluminium powder gradually binds to form hydroxides, these methods are only valid to show the free moisture content of the powder at the time of analysis. This means that the result should depend on the initial exposure of the powder batch to a humid atmosphere, the condition of the powder at that time and the storage duration and conditions of the batch following exposure, but also to the storage time of the samples analysed. The goal of this reported study was therefore to establish acceptance criteria to obtain better process practice for aluminium powder handling.

A single aluminium-silicon alloy (AlSi7Mg06) powder was investigated in the study. A stainless steel type 316L powder was also studied, in order to compare the reactions of the two materials with moisture. The two powder samples were chosen to be as close as possible in terms of size range and morphology (Table 3).

All moisture measurements were carried out following the standard test method for Loss-On-Drying (LOD) by thermogravimetry by using an automated moisture balance. This method measures the humidity level of the powder by heating a specimen of known mass at a constant temperature, while its mass is continuously measured as a function of time. At the end of a pre-determined time interval, the specimen is recorded as a percentage of the original mass, this value being identified as the LOD value.

In the reported experiments, the 316L powder and AlSi7Mg06 powder were exposed to two different climatic

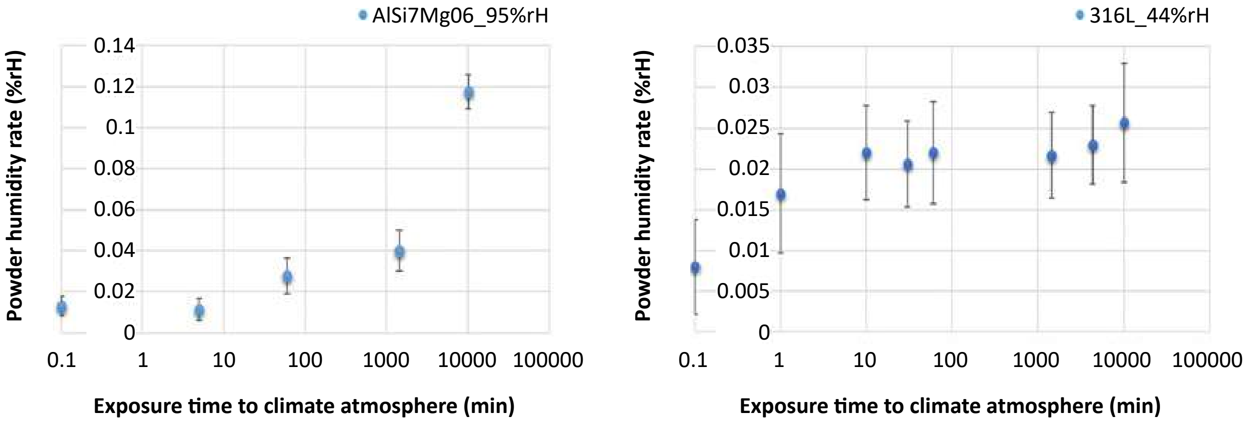


Fig. 8 LOD humidity rate evolution of LBM powder exposed for different durations to different atmospheres [3]

atmosphere conditions for a range of durations. The first condition was fixed at a high humidity level of 95%, to verify the sensitivity of the LOD method and estimate the time needed to expose a powder to force a drift.

The moisture content of the AlSi7Mg06 powder reached 0.12%rH after one week of exposure (Fig. 8a). Particles deviated from the initial spherical shape and the bayerite surface layers started to form bridges between particles. The scatter of the data led to the conclusion that probably the bounding reaction of water with the aluminium alloy in hydroxide would have affected the measurement. To highlight this link between the measurement difficulties and specific characteristics of aluminium powder, the same approach was adopted with the 316L powder, which is not subject to hydroxide formation.

Fig. 8b shows that, in the case of 316L powder, there was a clear evolution of the powder moisture content during the first ten minutes of exposure. This led to the conclusion that, for a typical L-PBF powder, ten minutes of exposure to ambient air would be sufficient to reach the maximum moisture level.

To evaluate the effect of hydroxide formation on the moisture measurement, firstly AlSi7Mg0.6 powder was exposed to atmospheres with high humidity level (95%rH) and controlled room condition (44%rH). All samples were exposed for one day. Fig. 9a and Fig. 9b show the evolution of free humidity rate during different storage times in airtight containers. For both conditions, the storage duration had a direct impact on the LOD moisture content measurement. At the time that the samples were stored, the reaction of the passivated powder grain surface to bayerite was not yet complete. As a result, this reaction was completed in the container, continuously modifying the measurable free moisture content. Therefore, to have consistent measurements for all further analyses, a storage time was applied for each sample in the sealed container before proceeding with analyses. This step was referred to as a stabilisation step.

The next issue of interest was to evaluate the impact of the hydroxide layer on quality after melting. Four different AlSi7Mg0.6 powder batches were exposed to different controlled atmospheres (Table 4) with different

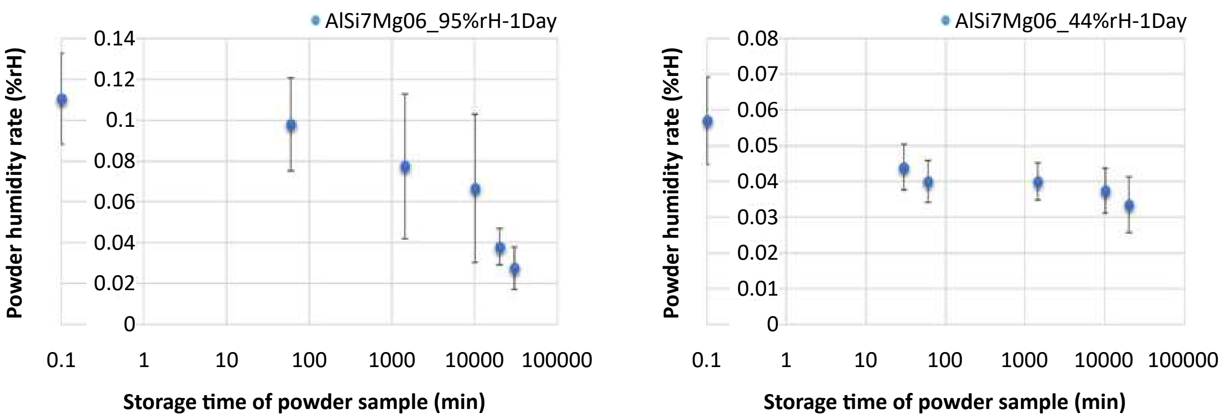


Fig. 9 Evolution of AlSi7Mg powder free moisture content after different storage times in airtight containers [3]

Conditions	Fresh powder	AR/22°C/24 h	44%/22°C/24 h	95%/22°C/24 h	Stabilisation (168 h)	rH% after stabilisation
C1	x				x	0.038
C2	x	x			x	0.039
C3	x		x		x	0.037
C4	x			x	x	0.043

Table 4 Conditions the samples were exposed to during preparation [3]

moisture levels from extra dry to extremely wet. The exposure period was for twenty-four hours and this was followed by a stabilisation time of one week.

The evolution of Hausner ratio and apparent density was studied. Climate conditions, shown in Table 4, were chosen to represent process conditions linked to real powder handling in the L-PBF process chain (e.g. 44%/22°C/24 h), but also to consider extreme conditions (e.g. 95%/22°C/24 h). The sensitivity of the physically measurable variables to surface powder changes impacted by hydroxide formation was studied. It seems that the drift due to hydroxide layer formation is detectable by controlling the combined evolution of bulk density and Hausner ratio (Fig. 10a).

Fig. 10b shows the impact of the conditions experienced by the different powder batches on the mechanical properties after using the resulting powder in the L-PBF process. The same build configuration in the L-PBF machine was maintained, with horizontal tensile samples followed by a post-machining step. No impact of the first three conditions applied to the powder on the mechanical properties was noted. However, a clear increase in yield strength and an indication of a decrease in elongation at fracture were noted for the last condition, which corresponded to the longer exposure time in moisture. This result was not anticipated. However, the authors intend to continue the investigations; in particular, the analyses of the specimen fractographs, in order to understand the mechanism of this strengthening.

Author

Dr David Whittaker
Tel: +44 1902 338498
whittakerd4@gmail.com

References

[1] Influence of Humidity in Ti-6Al-4V Powder during Storage – Part 1, K Dietrich *et al.* As presented at the

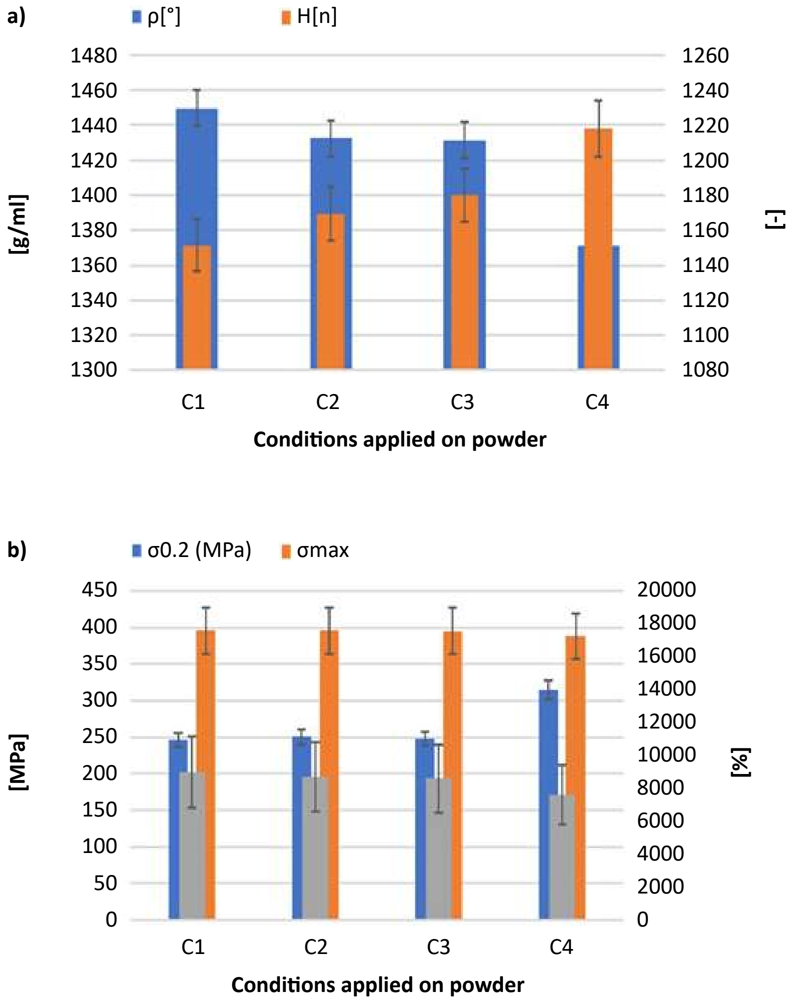


Fig. 10 Variation of the physical parameters and impact on horizontal tensile samples of the powder as a function of the different drifts applied to the AlSi7Mg06 powder [3]

Euro PM2019 Congress, Maastricht, the Netherlands, October 13-16, 2019, and published in the proceedings by the European Powder Metallurgy Association (EPMA).

[2] The Influence on Additively Manufactured Part Quality Using AlSi10Mg Powder Aged in Different Humidity Levels, Matthew Schulz-Sciberras. As presented at the Euro PM2019 Congress, Maastricht, the Netherlands, October 13-16, 2019, and published in the proceedings by the European Powder Metallurgy Association (EPMA).

[3] Study of Acceptance Criteria and Good Practices to Follow During Powder Handling to Limit Hydrogen Trapping in Aluminium Alloy During Laser Beam Melting Process, Olivier Rigo *et al.* As presented at the Euro PM2019 Congress, Maastricht, the Netherlands, October 13-16, 2019, and published in the proceedings by the European Powder Metallurgy Association (EPMA).

Proceedings

The full proceedings of the Euro PM2019 Congress are available to purchase from the European Powder Metallurgy Association. Topics covered include:

- Additive Manufacturing
- PM Structural Parts
- Hard Materials & Diamond Tools
- Hot Isostatic Pressing
- New Materials & Applications
- Powder Injection Moulding

www.epma.com

Additive Manufacturing Module

ADDITIVE MANUFACTURING

PM Life

LIFELONG LEARNING IN POWDER METALLURGY

24-28 August 2020 | Dresden, Germany

For those wishing to gain profound insights into the current state of Additive Manufacturing technologies for metal and ceramic parts, including non-beam methods like binder jetting and fused filament fabrication, this is the perfect place to be.

The unique abundance of dedicated AM labs of four Fraunhofer institutes, as well as the strong industry presence, ensures that this intense course is up-to-date and of practical relevance. Important AM-related topics such as powder analysis, mechanical testing of parts, life cycle assessment, and materials efficiency are also covered.

In addition to lectures given by experts from academia and industry, the program includes plant and lab visits as well as practical hands-on exercises.

TRAINING FEES*

Module:
Regular: €2,000
Academics: €1,000
Individual (unemployed): €400

Module Plus 3 Week Internship:
Regular: €3,000
Academics: €1,500
Individual (unemployed): €600

*The fee for each module includes course materials, 5 nights accommodation, refreshments during the day, two evening meals per module as well as materials and training. Participants will need to arrange and pay for their own travel to and from the hotel at the start and end of each module (i.e. air, rail and car transport is not included). The fees depend on the status of the participant ("regular" industrial, academic, individual).

With PM Life you can choose to register for one module or save up to €1,000 when registering for multiple modules. For more information visit **www.pmlifetraining.com/register/fees**

In partnership with Fraunhofer IFAM

Find out more information at:
www.pmlifetraining.com/additive-manufacturing

REGISTRATION DEADLINE | 10 August 2020

Email: dn@epma.com | **Website:** www.pmlifetraining.com

eit RawMaterials ACADEMY

EPMA european powder metallurgy association

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

Partner events

Pick up your free print copy of *Metal AM* magazine at the following partner conferences, exhibitions and seminars. For our complete events listing visit www.metal-am.com

METAV 2020
March 10-13, Düsseldorf, Germany
www.metav.com

4th AM Forum Berlin 2020
March 11–12, Berlin, Germany
www.additivemanufacturingforum.com

DDMC2020
March 18-19, Berlin,Germany
www.ddmc-fraunhofer.de

AMUG 2020 Conference
March 22–26, Chicago, IL, USA
www.amug.com

Additive World 'Industrial 3D Printing Conference'
April 1–2, Eindhoven, Netherlands
https://additiveworld.com/Home

Manufacturing World Nagoya 2020
April 15–17, Nagoya, Japan
www.japan-mfg-nagoya.jp/en-gb.html

RAPID + TCT 2020
April 20–23, Anaheim, CA, USA
www.rapid3devent.com

Hannover Messe – Home of Industrial Pioneers
April 20–24, Hannover, Germany
www.hannovermesse.de

The 3D Printing / Additive Manufacturing Value Chain
April 21–22, Geleen, Netherlands
www.3dprintingevent.com

AKL'20 – International Laser Technology Congress
May 6-8, Aachen, Germany
www.lasercongress.org/en/home/

Space Tech Expo USA
May 18–20, Long Beach, CA, USA
www.spacetechexpo.com

Additive Manufacturing for Industry
May 26-27, Ludwigsburg, Germany
www.amforindustry.com

MAPP 2nd International Conference
June 1-2, Abingdon, United Kingdom
mapp.ac.uk/events/mapp-2nd-international-conference

3D PRINT Congress & Exhibition 2020
June 16-18, Chassieu, France
www.3dprint-exhibition.com/en/

EPHJ Trade Show
June 16-19, Le Grand-Saconnex, Switzerland
https://ephj.ch/en/

HI-AM Conference 2020
June 25-26, Montréal, Canada
http://nserc-hi-am.ca/2020/

WORLDPM2020
June 27–July 1, Montréal, Canada
www.worldpm2020.org

Additive International
July 15-16, Nottingham, United Kingdom
www.additiveinternational.com

PM Life - Additive Manufacturing Module
August 24-28, Dresden, Germany
www.pmlifetraining.com/about/additive-manufacturing

Formnext + PM South China
September 9–11, Shenzhen Shi, China
www.formnext-pm.hk.messefrankfurt.com/shenzhen/en.html

TCT 3SIXTY
September 29-October 1, Birmingham, UK
www.tct3sixty.com/event/en/page/home

Metal Additive Manufacturing Conference 2020
September 30-October 2, Vienna, Austria
www.mamc2020.org

Euro PM2020
October 4–7, Lisbon, Portugal
www.europm2020.com

AMTC4
October 20-22, Aachen, Germany
www.munichtechconference.com/#!amtc4-preview.php

Formnext
November 10-13, Frankfurt am Main, Germany
www.formnext.com

advertisers' index