Vol. 4 No. 3 AUTUMN 2018

THE MAGAZINE FOR THE METAL ADDITIVE MANUFACTURING INDUSTRY

METAL AM

in this issue

AM AT SIEMENS' FINSPÅNG FACILITY

GKN AND HP: BINDER JETTING EVOLVES

CHINA'S AM MACHINE PRODUCERS

Published by Inovar Communications Ltd

www.metal-am.com

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

Managing Director, Features Editor
Nick Williams
Tel: +44 (0)1743 211993
Email: nick@inovar-communications.com

Publishing Director, News Editor
Paul Whittaker
Tel: +44 (0)1743 211992
Email: paul@inovar-communications.com

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

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

Advertising
Jon Craxford, Advertising Sales Director
Tel: +44 (0)207 1939 749
Fax: +44 (0)1743 469909
Email: jon@inovar-communications.com

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

Printed by
Cambrian Printers, Aberystwyth, UK

ISSN 2057-3014 (print edition)
ISSN 2055-7183 (digital edition)
Vol. 4 No. 3 Autumn/Fall 2018

INOVAR
COMMUNICATIONS

METAL ADDITIVE MANUFACTURING

It’s the time of year when Frankfurt’s on our minds...

There is a palpable sense of excitement in the air at this time of year as the international AM community prepares for Formnext, the largest and fastest-growing exhibition dedicated to the world of Additive Manufacturing.

Taking place from November 13–16, the event, which is only in its fourth year, serves not only as a platform to launch the latest innovations in materials, production technology and applications, but also as an opportunity to reflect on the past year and celebrate the huge strides made by the industry as a whole.

The last three months alone have seen some truly exciting developments in the industry, most notable of which was HP’s launch of its metal Additive Manufacturing system, the HP Metal Jet. There is certainly a sense that metal Binder Jetting and related technologies are growing in momentum as a new wave of processes that promise to open up new, higher-volume opportunities in markets such as the automotive industry.

What new innovations emerge from Formnext 2018 remains to be seen, but what is certain is that the industry is firmly on the path towards a wider industrialisation, a theme that runs clearly through each of the articles in this issue.

Nick Williams
Managing Director
Metal Additive Manufacturing

Cover image
A part of the Siemens metal Additive Manufacturing operation in Finspång, Sweden.


HOEGANAES

AncorAM™
METAL POWDERS FOR ADDITIVE MANUFACTURING

AncorAM™ POWDERS

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

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

Stainless Steel & Nickel Based AM Powders
- AncorAM 17-4 PH
- AncorAM 316L
- AncorAM 1.2709
- AncorAM IN625
- AncorAM IN718
- Additional alloys are available upon request

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

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

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

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

TECHNOLOGY... QUALITY... SUPPORT

FOLLOW US ON SOCIAL MEDIA AT:
@HoeganaesCorp
YouTube LinkedIn

MOBILE DEVICE APPS NOW AVAILABLE FOR DOWNLOAD
App Store Google play

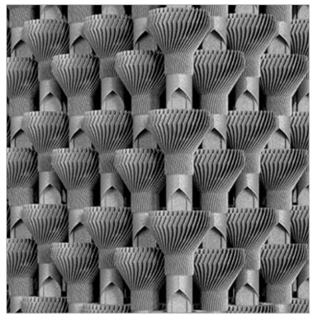
www.gkngroup.com/hoeganaes

ENGINEERING > THAT MOVES THE WORLD

© 2017 GKN Hoeganaes

METAL ADDITIVE MANUFACTURING


40


74

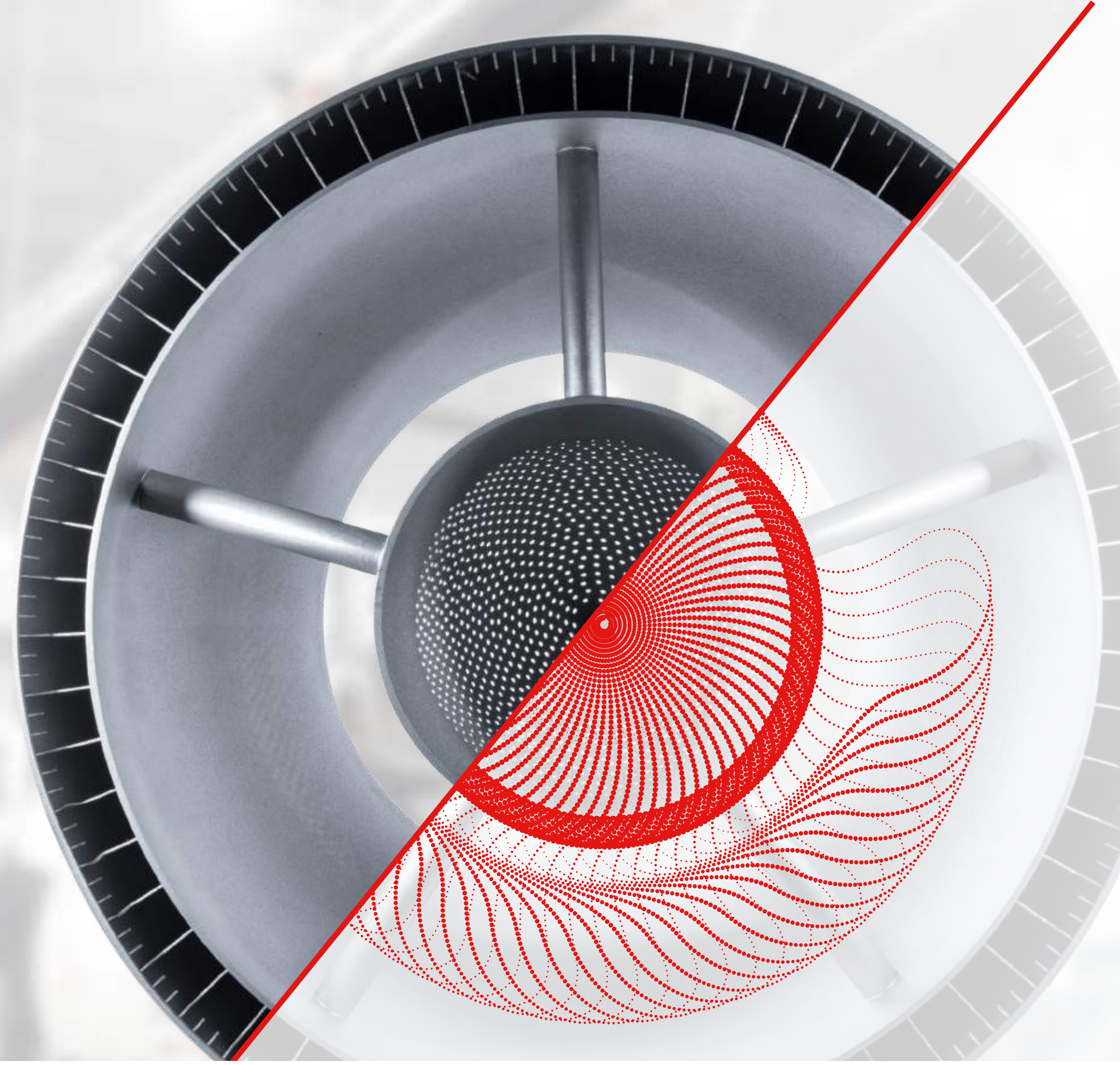

84


123


138

Contents

Regular features



industry news

HP Metal Jet: HP launches its first metal Additive Manufacturing system

HP Inc., launched its HP Metal Jet, the company's first metal Additive Manufacturing system, at this year's International Manufacturing Technology Show (IMTS) in Chicago, Illinois, USA. The new system is said to provide mechanically functional parts with up to fifty times more productivity, at a significantly lower cost, than other binder jet or laser powder bed fusion technologies.

Utilising a voxel-level binder jetting technology, the first material available for use with the HP Metal Jet will be stainless steel, providing finished parts with properties that meet or exceed ASTM and MPIF Standards for tensile strength, yield strength and elongation. The new system has a build chamber of 430 x 320 x 200 mm and will be offered at around $399,000, with shipping commencing in 2020.

"We are in the midst of a digital industrial revolution that is transforming the $12 trillion manufacturing industry. HP has helped lead this transformation by pioneering the 3D mass production of plastic parts and we are now doubling down with HP Metal Jet, a breakthrough metals 3D printing technology," stated Dion Weisler, CEO and President, HP Inc. "The implications are huge – the auto, industrial, and medical sectors alone produce billions of metal parts each year. HP's new Metal Jet 3D printing platform unlocks the speed, quality and economics to enable our customers to completely rethink the way they design, manufacture and deliver new solutions in the digital age."

It was also announced that HP has partnered with GKN Powder Metallurgy and Parmatech, who will be the first companies to adopt the technology. GKN Powder Metallurgy will use the HP Metal Jet system in its factories to produce functional metal parts for auto and industrial customers including Volkswagen and Wilo. Producing more than three billion components per year, the company expects to additively manufacture millions of production-grade parts for its customers from as early as 2019. "We're at the tipping point of an exciting new era from which there will be no return: the future of mass production with 3D printing. HP's new Metal Jet technology enables us to expand our business by taking on new opportunities that were previously cost prohibitive," stated Peter Oberparleiter, CEO of GKN Powder Metallurgy.

Volkswagen is said to be integrating HP Metal Jet into its long-term design and production roadmap. The collaboration has resulted in the ability to move quickly to assess the manufacturing of mass-customisable parts as well as higher performance functional parts. As new platforms, such as electric vehicles, enter mass production, HP Metal Jet is expected to be used in additional applications.

Wilo, a global leader for pumps and pump system solutions, will also look to HP's Metal Jet technology to produce hydraulic parts such as impellers, diffusers and pump housings with widely variable dimensions that must withstand intense suction, pressure and temperature fluctuations.

Parmatech, an ATW Company, stated that it will use the HP Metal Jet system to expand mass production of medical parts for its customers, including OKAY Industries and Primo Medical Group. As an established user of Metal Injection Moulding (MIM) technology, Parmatech believes the technology will play a key role in developing innovative solutions for the unique challenges of its customers.

"HP Metal Jet represents the first truly viable 3D technology for the industrial-scale production of metal parts," explained Rob Hall, President of Parmatech. "We are excited to deploy HP Metal Jet in our factories and begin manufacturing complex parts, such as surgical scissors and endoscopic surgical jaws, and new applications and geometries not possible with conventional metal fabrication technologies.

www.hp.com/go/3dmetals
www.gkn.com/hp
www.parmatech.com ■■■

The HP Metal Jet System is HP's first metal AM machine (Courtesy HP Inc.)

Optomec's new large-format metal AM system with hybrid machining


Optomec's new LENS 860 Hybrid Machine (Courtesy Optomec)

Optomec, Albuquerque, New Mexico, USA, launched its LENS 860 Hybrid Controlled Atmosphere (CA) System at the 2018 International Manufacturing Technology Show (IMTS), Chicago, Illinois. The large-format hybrid metal Additive Manufacturing system is a new addition to the Optomec LENS Machine Tool Series and reportedly offers a larger build volume and higher laser power than the company's previous offerings.

The system is equipped with a hermetically-sealed build chamber that maintains oxygen and moisture levels below 10 ppm for the processing of reactive metals such as titanium. The system has an 860 x 600 x 610 mm build volume and can be configured with closed loop controls and a high-power 3 kW fibre laser, said to be ideal for building, repairing or coating mid- to large-size parts. In addition to the LENS 860 Hybrid CA model, three further configurations are available. The LENS 860 Hybrid Open Atmosphere (OA) system is suitable for processing non-reactive metals such as stainless steel, tool steel, Inconel, etc, while two additive-only models, available with both open and controlled atmospheres, are also available.

All systems in the Machine Tool series incorporate Optomec's LENS 3D Metal Printing technology, which it states has been enhanced for higher power and faster Additive Manufacturing. One key advantage of the LENS Hybrid configuration is said to be its ability to use the milling capability to perform finish machining on an additively manufactured part without re-fixturing or aligning the component on a second machine.

"The new LENS 860 suite of systems builds on the success of our Machine Tool Series, first launched at IMTS in 2016," stated Dave Ramahi, Optomec's president and CEO. "These new larger machines continue to demonstrate our ability to transition Optomec production-proven 3D Metal Printing capability onto traditional CNC platforms that match the cost, performance and ease-of-use demands of the traditional machine tool market. These products are a key element of our strategy to bring metal Additive Manufacturing into the industrial mainstream."

The LENS 860 Hybrid CA system can be used to produce and repair larger parts cost-effectively, and also offers the ability to print fine-features for thin wall structures and perform wide area cladding for wear coating applications. Optomec's software enables 5-axis build strategies that combine additive and subtractive operations in a single tool path. A range of material starter recipes are also available to help speed adoption.

Optomec stated that it will begin shipping the new system to customers this year. The LENS Machine Tool Series has a starting price of under $250,000.

www.optomec.com ■■■

ExOne adds 304L stainless steel to its material range

The ExOne Company, North Huntingdon, Pennsylvania, USA, has added 304L stainless steel to its range of materials, both through its Production Service Center (PSC) and as a qualified material on its AM machines.

Stainless steel 304L is the latest high density, single alloy material to be offered by ExOne. The company has been offering 316L and 17-4PH as qualified materials since 2017; however 304L is the most commonly used stainless steel and is suitable for applications in a wide range of industries due to its high durability, corrosion resistance and low cost. Some common applications include components for appliances, marine, medical, kitchenware, fasteners and heat exchangers.

Rick Lucas, Chief Technology Officer at ExOne, stated, "304L is another example of our binder jet 3D printers being used to make high density, single alloy components for use in a multitude of industries. By using the same metal powders that are used in the Metal Injection Moulding industry we are able to quickly develop materials that meet MPIF Standard 35 and cost significantly less than parts produced using other 3D technologies such as Powder Bed Fusion technologies."

www.exone.com ■■■

InfiniAM process monitoring software from Renishaw

Renishaw plc, Wotton-under-Edge, Gloucester, UK, has released its new process monitoring software, InfiniAM Spectral, for use on Renishaw systems. The software package provides real-time spectral monitoring technology that enables manufacturers to gather melt-pool data to enable traceable production and process optimisation.

The InfiniAM Spectral software is part of a developing line of products designed for users of the company's Laser Powder Bed Fusion (LPBF) systems. The software offers two measurement functions in the sensor modules: LaserVIEW, which uses a photosensitive diode to measure the intensity of the laser energy, and MeltVIEW, which captures emissions from the melt pool in the near-infrared and infrared spectral ranges. These two sensor signals can be compared to help identify discrepancies.

Data collected from LaserVIEW and MeltVIEW is streamed across a conventional computer network on a layer-by-layer basis, enabling manufacturers to analyse process monitoring data in real-time. As the build progresses, the data is rendered live in 3D for viewing in InfiniAM Spectral. The engineer can then compare the data from each sensor to identify any deviations, which may indicate the presence of anomalies that could lead to defects.

"For Additive Manufacturing to become a truly ubiquitous manufacturing technology, users and practitioners require a deep understanding of the process," explained Robin Weston, Marketing Manager at Renishaw's Additive Manufacturing Products Division. "The software will be hugely beneficial to manufacturers looking to achieve consistent processing with AM."

"The amount of process data generated during an AM build is immense, which means it can be difficult to make practical use of it without the correct interpretation tools," he continued. "InfiniAM Spectral enables manufacturers to easily interpret data and gain a more detailed understanding of their AM processes. Access to real-time data opens the door to future developments in process control–detecting and correcting problems in real-time."

InfiniAM Spectral is expected to be most useful for the series production of identical parts in high-value applications. When producing the first part in a series, data from LaserVIEW and MeltVIEW can be compared with existing X-Ray or Computed Tomography (CT) data from a known 'good' part. The manufacturer can then use this signal data as the 'gold standard' to compare data from subsequent parts against.

www.renishaw.com

View of InfiniAM Spectral showing 3D data reveal (Courtesy Renishaw)

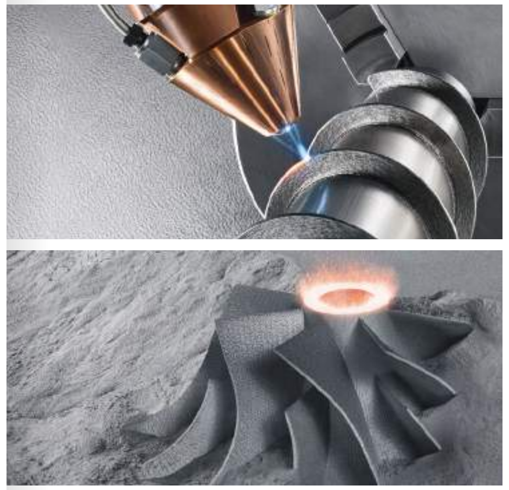
DMG Mori USA to relocate its HQ closer to Illinois Institute of Technology

DMG Mori USA plans to move its North American headquarters from Hoffman Estates, Illinois, USA, in order to be closer to the Illinois Institute of Technology (IIT) in Chicago, Illinois. The company and the IIT are currently said to be seeking a suitable location near the campus, while also seeking opportunities for further cooperation.

"Being nearby the local faculties and students will promote synergy effects in research and development of new technologies on the one hand, and recruiting of young talents will be easier on the other," explained James V Nudo, President, DMG Mori USA Inc. As part of the relocation, a large showroom will be established at the new facility, giving the company the opportunity to demonstrate a representative cross-section of its product portfolio.

A temporary office at the IIT is set to be established shortly to help DMG Mori to work together more closely with the faculties and students prior to relocation. Following the move, the Chicago Technical Center at Hoffman Estates will continue to be operated by DMG Mori USA and the company stated that it also plans to open its North American Engineering & Automation Center at this site.

www.us.dmgmori.com



BASF invests $25 million in Materialise as companies seek to optimise AM materials and software

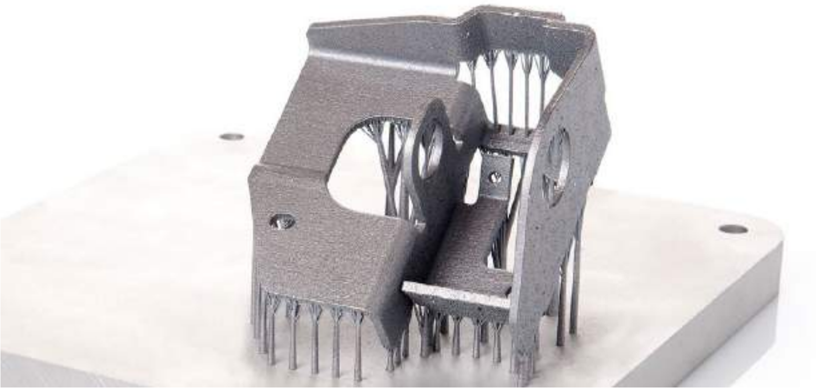
BASF, Ludwigshafen, Germany, has invested $25 million in Materialise, Leuven, Belgium, and announced further cooperation between the two companies to improve materials and software for various Additive Manufacturing technologies. The companies are focusing on applications in the automotive and aviation industries as well as in the consumer goods sector. The agreement will reportedly allow for systematic, wider-scale testing and further optimisation by BASF of its materials on the machines and within the infrastructure of Materialise.

"Our two companies' business areas complement each other very well and our cooperation will put us in an even better position to find and develop new business opportunities," stated Volker Hammes, Managing Director of BASF 3D Printing Solutions GmbH. "With its 3D printer facilities in Leuven and innovative software solutions, Materialise has an outstanding infrastructure. Together, we can exploit our strengths even better to advance the 3D printing sector through the development of new products and technologies together with our partners and our customers."

"To increase the adoption of 3D printing as a complementary manufacturing technology for final products, our industrial customers increasingly demand more control, more choice and ultimately lower cost," added Fried Vancraen, Materialise CEO. "We are confident that this collaboration with a leading manufacturer of materials will help to accelerate the adoption of 3D printing in existing vertical markets and create significant business opportunities in new markets."

www.basf.com

www.materialise.com ■■■



A part demonstrating support structures automatically generated by Materialise's Magics software (Courtesy Materialise)

Rostec announces $44.5 million investment in Russian AM industry

Russia's Rostec State Corporation has announced that it will invest almost three billion roubles (approximately $44.5 million) in the creation of a new centre for Additive Manufacturing Technologies. The main objective of the centre is to introduce industrial Additive Manufacturing to high-tech industries, providing a full range of services from design development to mass production and product certification.

Anatoly Serdyukov, Industrial Director at Rostec's Aviation Cluster, stated, "Industrial 3D printing is becoming one of the indispensable attributes of modern industry. We see the high potential of this technology and want to introduce it into our production practice." The company plans to use AM in the production of gas turbine engines, due to be certified in 2025–2030.

The centre is expected to produce its first batch of parts in 2019 and will serve not only Rostec, but also a wide range of third-party companies, including internationally."The creation of a specialised centre will expand the scope of this technology and produce parts for such industries as aircraft building, space, high technology medicine and automotive," added Serdyukov.

First EOS M400-4 in Russia

Following the news of the new Additive Manufacturing Technologies centre, Rostec also announced that it has become the first Russian company to purchase an EOS M400-4 Additive Manufacturing system from Germany's EOS. The system will be installed at the new centre and will be used for the production of metal parts for the corporation's aviation cluster. Rostec will use the system in combination with EOS Shared-Modules, a number of peripheral modules used to automate material supply as well as part flow.

One of the conditions of the partnership is the engagement between Rostec and Additive Minds, the EOS consulting unit. Its experts will train Rostec staff to work with the equipment and help the group to implement additive technology in manufacturing new products.

www.rostec.ru ■■■

EOS launches its new M 300-4 metal Additive Manufacturing system

EOS, Krailling, Germany, unveiled its new EOS M 300-4 Additive Manufacturing machine during the International Manufacturing Technology Show (IMTS) 2018 in Chicago, Illinois, USA, September 10-15, 2018. Described as an automation-ready, future-proof platform, the EOS M 300 is targeted at a range of markets including aerospace, industry, medical, tooling and automotive.

With a build volume of 300 x 300 x 400 mm, the modular platform offers a configurable and scalable equipment architecture, enabling customised system configurations. Customers can choose between a range of options across the series, opting for one, two or four lasers, multi-power laser set-ups, fixed or variable focus, different types of recoaters, new and expanded exposure strategies, manual or automated part handling, a range of monitoring options and three different clamping systems (3R, Delphin, Erowa).

Two powder dosing options are available and a permanent filter system has been integrated to eliminate the need to open the system up periodically for filter changes. A new lifetime recirculating filter system offers automated cleaning, meaning that longer jobs can be processed without interruption.

The new system will also be compatible with the EOS Shared Modules, in which manual or automated peripheral modules and transport logistics supply several EOS metal AM systems. As a result, all set-up, unpacking, transportation and sieving actions will be carried out independent of, and parallel to, the AM build process. In addition, the system line offers automatic job start procedures. Depending on the needs of the user, it can also include powder contact-free solutions for demanding health and safety standards.

Future models in the EOS M 300 series will be available with variable laser power sources, ranging from 4 x 400 W, to a mixed set-up of 2 x 400 W and 2 x 1,000 W, up to 4 x 1,000 W laser power.

"With its modular set-up and its scalable and flexible concept, the new system line clearly focuses on the high customer demands for AM production. It sets a clear focus on productivity and lowest costs-per-part and was developed for automation and (software) integration in current and future factories," stated Dr Tobias Abeln, Chief Technical Officer at EOS.

Automation and drive technology through Siemens partnership

In a statement highlighting the ongoing cooperation between EOS and Siemens, EOS revealed that the new EOS M 300 series uses automation and drive technology from Siemens' Totally Integrated Automation (TIA) portfolio.

Alfons Eiterer, Head of System Engineering, EOS, stated, "EOS puts a strong focus on high quality and reliability in its new developments, while at the same time ensuring dynamic and technological progress. This is the reason we chose Siemens control technology for our new EOS M 300 series. With Siemens we can rely on proven technical components and are well prepared to handle future requirements."

In addition to using Siemens components in the EOS M 300, the EOSPRINT 2 CAM tool is now included in Siemens' NX 12 AM module, a software solution for process steps from design, to topology optimisation and process simulation, to print preparation. The company stated that the functions of EOSPRINT 2 have been seamlessly integrated into Siemens' NX Fixed Plane (Powder Bed) AM software module to support the use of Siemens' module with EOS systems.

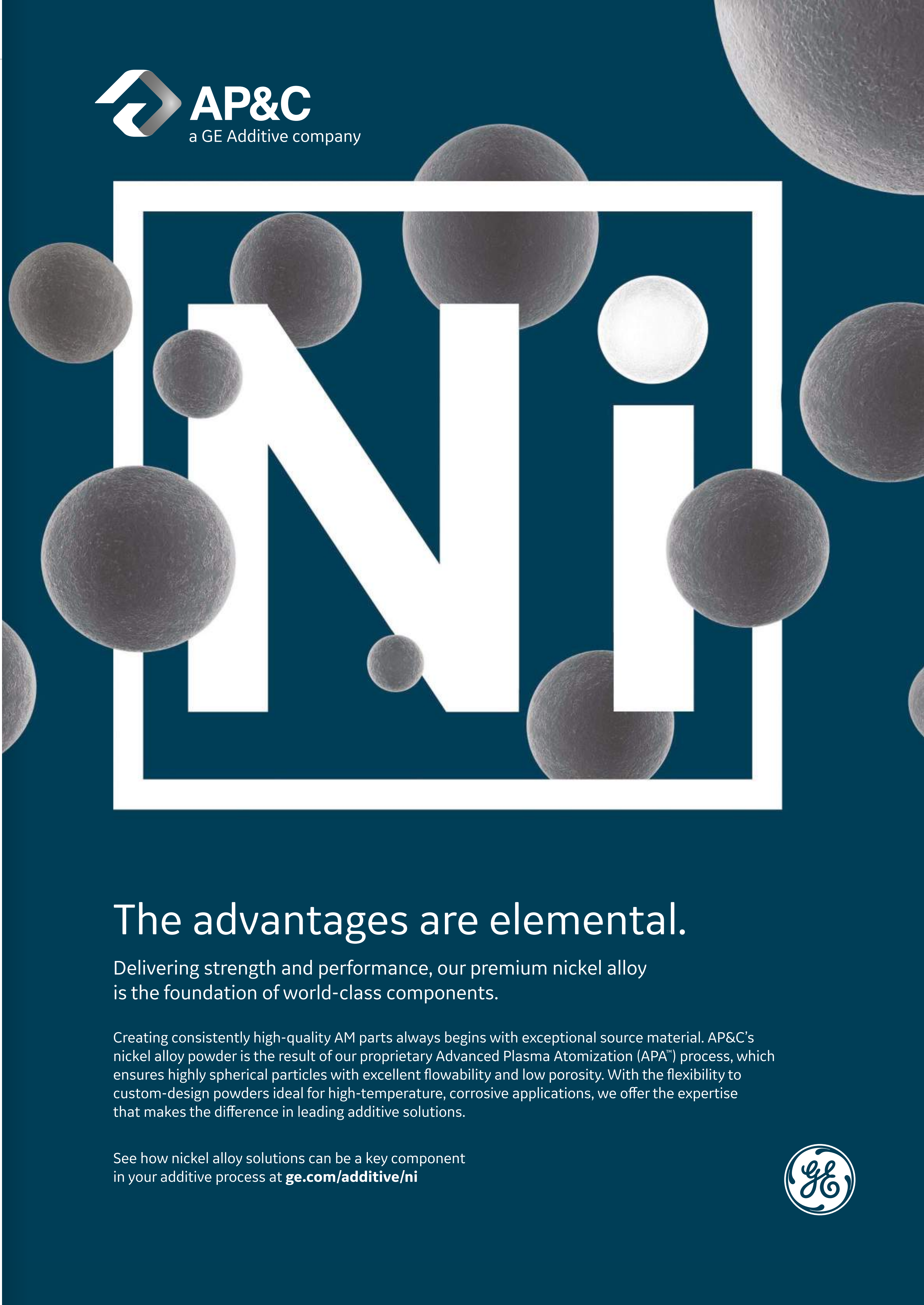
"A fast industrialisation of Additive Manufacturing can only be unleashed by a close cooperation of experts from a software, automation and drive system angle with industrial 3D printing experts, as is the case with Siemens and EOS," stated Dr Karsten Heuser, VP of Additive Manufacturing at Siemens AG. "We are therefore proud to move with EOS into the next level of industrialisation, which will help in transforming AM further from the prototyping phase into industrial serial production."

www.siemens.com

www.eos.info ■■■

The EOS M 300-4 is the first in the EOS M 300 Series for digital industrial metal Additive Manufacturing (Courtesy EOS)

Read the report on page 145 from our recent visit to the EOS facility in Krailling, Germany, where EOS discussed the new EOS M 300 series as well as its work towards automation in the AM factory of the future.



Desktop Metal expands range with Studio System+ and Studio Fleet

Desktop Metal, Burlington, Massachusetts, USA, has added a new metal Additive Manufacturing system to its range. The Studio System+ includes the office-suitable features of the original Studio System™ but is said to have added functionality for the production of small metal parts at higher resolutions. The company has also announced the introduction of Studio Fleet™, a custom-configurable solution which it states is designed to address challenges in low- to mid-volume part production.

"As our office-friendly systems are making their way to customers throughout the country, we're excited to announce the launch of Studio System+ and Studio Fleet, which together offer enhanced features for metal prototyping and low-volume production," stated Ric Fulop, CEO and Co-founder of Desktop Metal. "Engineers and designers who are looking to push the limits of metal 3D printing with small parts or parts with fine details can now achieve even higher-resolution, with a customisable system configuration for greater process efficiency and throughput right on the shop floor."

The original Studio System, which made its debut in 2017, was said to be the world's first office-friendly metal AM system for rapid prototyping, intended to make metal AM more accessible, thereby enabling design and engineering teams to produce metal parts faster and without the need for special facilities, dedicated operators or expensive tooling. The three-part solution includes the AM machine, a debinder and a furnace, and offers process automation by integration with Desktop Metal's cloud-based software.

The Studio System+ is said to incorporates new print capabilities as well as hardware updates designed for increased throughput. A new swappable high resolution printhead with supporting software profiles is said to allow the production of parts at higher resolutions, with finer features and improved surface finish. According to Desktop Metal, this opens up opportunities for new geometries and applications, with the ability to additively manufacture parts similar to those produced by Metal Injection Moulding (MIM).

In addition, a new in-chamber build plate camera captures a live stream video of the part as it is built, allowing users to closely monitor build progress. Improved software is reported to offer automatic mould lock prevention, part positioning and fleet management, while new stackable shelving within the debinding and sintering units increases part capacity for greater throughput.

A new retort box design is said to increase thermal uniformity, resulting in higher-quality parts. In addition, the system now offers the option to connect to external gas tanks or a house gas line, reducing the cost of consumables and resulting in lower cost-per-part.

Studio Fleet reportedly adds a custom-configurable, in-house metal AM solution to support a variety of production scenarios and scales for a wide range of low- to mid-volume applications across industries. It is expected to make it possible for on-demand metal AM to deliver accessible and scalable manufacturing which can be adapted to diverse business needs, part requirements and production volumes.

"Since the introduction of our original Studio System, we've worked closely with hundreds of customers across major industries - aerospace, automotive, consumer electronics, cosmetics and more - to identify key applications and their requirements to incorporate metal Additive Manufacturing into the design process" added Fulop. "This research continues to inform our product development, and we are excited to release an enhanced version of the world's first office-friendly metal 3D printing solution that will help customers more effectively meet those needs."

www.desktopmetal.com ■■■

An example of Desktop Metal's Studio Fleet showing five printers, two debinders and one furnace (Courtesy Desktop Metal)

Submitting news..

To submit news to *Metal AM* please contact Paul Whittaker:
paul@inovar-communications.com

AddUp to acquire majority stake in Poly-Shape

Metal Additive Manufacturing machine and systems manufacturer AddUp, Clermont-Ferrand, France, a joint venture of Fives and Michelin, has announced plans to acquire a majority stake in Poly-Shape, a company offering design and production services for metal AM parts.

Since its formation in 2007, Poly-Shape has developed a widely-recognised expertise in fields such as tooling, aeronautics, the medical and energy sectors, and most significantly in motorsports, working with a large number of Formula 1 teams. The company has a global service offering for the AM of parts, including support through the design and the optimisation of parts to finishing operations, and operates a range of machines in four facilities: Salon-de-Provence, Saint-Pierre-du-Perray and Le Coudray-Montceaux in France, and a facility in Carpi, Italy, also integrating post-treatment equipment.

The acquisition of a majority stake in Poly-Shape is expected to enable AddUp to expand its portfolio of applications and to strengthen its offering to the automotive industry. Vincent Ferreiro, AddUp's CEO, stated, "The proven know-how in the production of parts, in particular in the motorsports field, will help us improve our support to original equipment manufacturers, and demonstrate the benefits and capacities of 3D printing, especially for top-of-the-range vehicles."

In addition, AddUp expects that the acquisition will enable it to reinforce its support capabilities in assessing the opportunities offered by AM through its AddUpThink and AddUpStart services, with the integration of expanded production capacity for proof-of-concept parts including post-treatment and additional finishing. Using the technology housed in Poly-Shape's facilities, AddUp will have the ability to offer its customers access to a multi-supplier, multi-technology, multi-material and multi-application test platform.

Stéphane Abed, Chairman of Poly-Shape, commented, "AddUp and Poly-Shape share the same vision regarding the evolution of the world of 3D printing and the same passion for innovation. Poly-Shape will benefit from AddUp's proven expertise in the industrialisation and management of machines as well as a reinforced access to the world of motorsports thanks to Michelin's world-wide reputation."

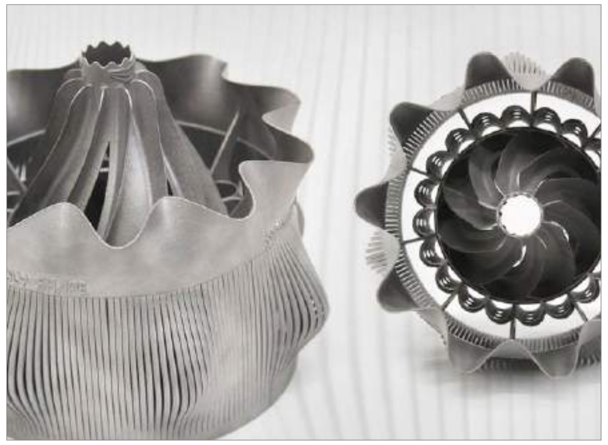
"AddUp will bring additional resources to Poly-Shape so that it can continue its development both in France and abroad. AddUp's entry into Poly-Shape's capital is a recognition of the expertise and work carried out by the teams during these last few years," added Philippe Veran, Chairman of Upperside and a founding shareholder of Poly-Shape.

"I have been happy to accompany Poly-Shape's wonderful teams since 2007 and to have participated in the evolution of a company with a recognised know-how. AddUp's investment into the capital represents a true opportunity for Poly-Shape and its employees to continue its development and growth."

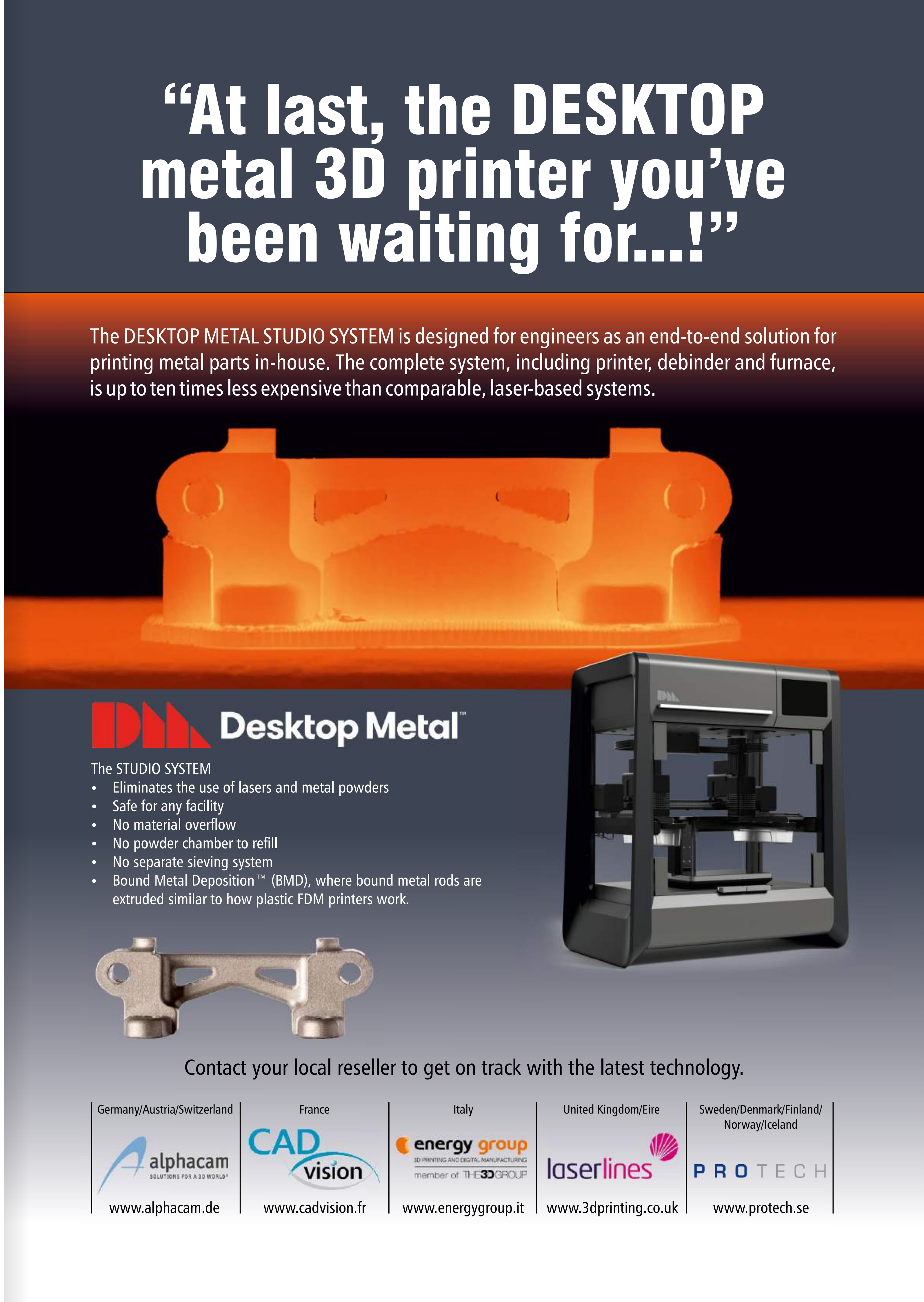
Readers can learn more about Poly-Shape and its development of metal AM for high-performance motorsports in the Summer 2018 issue of *Metal Additive Manufacturing* magazine, available to read online.

www.addupsolutions.com

www.poly-shape.com ■■■



Metal additively manufactured parts produced by Poly-Shape (Courtesy Poly-Shape)



Velo3D launches end-to-end metal AM solution

Velo3D, Campbell, California, USA, has launched its first end-to-end metal Additive Manufacturing solution. Comprised of the Sapphire™ Additive Manufacturing machine, Flow™ software and Intelligent Fusion™ technology, the company states that the integrated offering could solve some of the most difficult AM challenges.

Benny Buller, founder and CEO of Velo3D, stated, "Four years ago, we set out with the bold vision of creating technology that could manufacture parts with any geometry to take Additive Manufacturing mainstream. Our approach relies on creating deep insights in physics fundamentals, enabled by research, characterising and understanding of core mechanisms, developing intelligent process control through software simulation and in-situ metrology."

The Sapphire Laser Powder Bed Fusion (LPBF) metal AM system is said to be designed for high volume manufacturing. It comprises a 315 mm diameter by 400 mm high build envelope, with dual 1 kW laser operation. To deliver superior part-to-part consistency, Velo3D reported that Sapphire's integrated in-situ process metrology enables a closed loop melt pool control, which it says is the first of its kind. The system is said to be capable of building complex geometries and allows designs with overhangs down to five degrees without supports, as well as large unsupported inner diameters of up to 40 mm. Minimum feature size and wall thickness is reported to be below 250 μm. To maximise productivity, the Sapphire system comprises a module to enable automated change-over, enabling a new print to start without operator involvement within 15 minutes.

Velo3D's Flow build preparation software is said to offer support generation, process selection, slicing and simulation of complex part designs to validate feasibility before the build. Deformation correction technology makes it possible to produce parts without the need for repeated iterations, reportedly achieving a first-build success rate of up to 90%. The software also minimises the need for supports, reducing typical support volume by a stated 3-5 times, which removes or reduces the post processing necessary with conventional approaches.

Velo3D's new Sapphire Additive Manufacturing system, designed for manufacturing components in high volumes (Courtesy Velo3D)

The company's Intelligent Fusion technology powers both the Flow software and Sapphire system, enabling an end to end integrated workflow. Intelligent Fusion is said to optimise the AM process by combining thermal process simulation, print prediction and closed-loop control during build execution.

www.velo3D.com ■■■

A shrouded impeller produced on the Sapphire system. The only support required on this part is the radial extrusion that supports the outer lip (Courtesy Velo3D)

Sandvik reports record-high orders and revenues in its second quarter 2018

Sandvik AB, headquartered in Stockholm, Sweden, has reported record results for the second quarter of 2018. In the period, both order intake and revenues were said to have increased by 12% year-on-year, and strong positive development was reported in all three business areas, with book-to-bill amounting to 104%.

Adjusted operating profit rose by 36% year-on-year to SEK 5,067 million (Q2 2017: 3,718 million), which Sandvik stated was supported primarily by strong organic growth. Across the Sandvik Group, orders increased significantly in all three major global regions, with Asia showing 17% growth, Europe 16% and North America 8%. Underlying customer activity was said to be high in all customer segments and regions.

All three of the company's business areas reported more than a 20% increase in operating profit, underpinned by organic revenue growth. Sandvik Materials Technology reported an adjusted operating profit of SEK 558 million (Q2 2017: 189 million) and a 17% increase in order intake including the impact of large orders. Excluding the impact of these large orders, order growth amounted to 37%. Revenues grew organically by 8%, with higher alloy prices supporting both order intake and revenues by 4%, primarily related to nickel.

Sandvik Machining Solutions saw order intake and revenues reach record-high levels, with order intake increasing by 8% and revenues by 10% year-on-year, respectively. Operating profit was reported at a record SEK 2,761 million (Q2 2017: 2,110), an increase of 31% year-on-year, with the division increasing its workforce from 18,527 to 18,912 in Q2 2018.

Sandvik Mining and Rock Technology reported double digit growth in the equipment and aftermarket businesses and strong development in most product areas. Order intake was up 15% year on year and revenues increased 16%. Operating profit was reported at SEK 1,865 million (Q2 2017: 1,508), an increase of 24% year-on-year.

For the first six months 2018, demand for Sandvik's products improved year-on-year, with an order intake organic growth of 9% compared to the first six months 2017. Excluding the impact from large orders, the growth amounted to 11%. Revenues increased by 13%, thought to be attributable to a broad-based improvement in customer activity in all business areas and in most customer segments. Demand for Sandvik's products improved or remained stable in all regions. The six month operating profit was SEK 9,314 million (2017: 6,763 million).

www.home.sandvik.com ■■■

Sandvik offers a wide range of metal powders for Additive Manufacturing (Courtesy Sandvik)

Sumitomo Corporation of Americas announces investment in Sintavia

Sumitomo Corporation of Americas (SCOA), New York, USA, the largest subsidiary of Japan's Sumitomo Corporation, has announced a minority investment in Sintavia, LLC, Davie, Florida, USA. The parties jointly announced that the purpose of the investment was to leverage SCOA's network in the global aerospace and oil & gas industries, while accelerating Sintavia's plans for global growth. Terms of the deal were not disclosed.

"With SCOA as a long-term partner, we recognise that we are aligning ourselves with a global leader in multiple end markets that is committed to supporting our growth," stated Brian R Neff, Sintavia's Chairman and Chief Executive Officer. "Demand for Sintavia's brand of quality AM production has boomed this year, and we recognise that in order to fully meet this demand over the coming years, we will need to find a partner to help us manage growth. We believe we have found that partner in SCOA."

"SCOA has spent decades building an enormous global network within several industries, including aerospace and oil & gas," added Kenichi Hyuga, SVP and General Manager of SCOA's Construction and Transportation Systems Group. "We believe Sintavia's highly advanced technology will add immediate value to our current business relationships, and position us for even greater business opportunities in the future."

The parties see potential through Sumitomo group companies to develop solutions, alongside strategic partners in the Aerospace industry, to optimise products using AM technology. One example is through Sumitomo's wholly-owned subsidiary, Howco, an integrated supply chain partner for the global oil & gas industry. Howco provides steel alloys, turnkey machined and assembled components, and other products for upstream segments of the oil & gas sector, for which they will seek industry-specific business development opportunities together with Sintavia.

www.sintavia.com
www.sumitomocorp.com/en/us ■

VTECH showcases its range of metal powders for Additive Manufacturing


VTECH manufactures a range of metal powders and is currently developing a propriety 'Quick Atomisation' process (Courtesy VTECH)

Advanced metal powder supplier VTECH, headquartered in Changsha City, Hunan, China, showcased its wide range of metal powders suitable for Additive Manufacturing at the recent World Congress on Powder Metallurgy (WORLDPM2018), held in Beijing, China, September 16-20, 2018. The company's main focus is on titanium-based powders, but it also manufactures cobalt, nickel, stainless steel, copper and aluminium-based alloy powders.

The biennial World Powder Metallurgy Congress and Exhibition, which alternates between Europe, North America and Asia, was held in China for the first time this year. Organised by the Chinese Society of Metals (CSM) and China Powder Metallurgy Alliance (CPMA), the event brought delegates from China and the rest of the world together with a focus on metal powder-based technologies including Powder Metallurgy, Additive Manufacturing and Metal Injection Moulding (MIM).

In addition to fine spherical metal powders for Additive Manufacturing, VTECH can provide powders suited to thermal spray, Metal Injection Moulding (MIM) and laser cladding applications. The company can also provide custom powders and has a strict quality control process.

Established in 2014, VTECH holds a number of national patents in material manufacturing and Additive Manufacturing equipment. The company is currently developing what it calls a 'Quick Atomisation' process for the manufacture of micro-nano metal powders for AM. Working with partners in Hong Kong, VTECH has also collaborated to build a demonstration centre for Additive Manufacturing to boost the growth of science, technology and industry in Hong Kong.

www.vdaypowder.com ■■■

Star Rapid appoints new CEO following major revenue growth

Star Rapid, San Francisco, California, USA, has appointed David Hunter as its Chief Executive Officer following a period of what it says has been 'unprecedented' revenue growth for the company, which saw revenues grow by 40% for the full year 2017 and 10% year-on-year in the first half 2018. Hunter's appointment is part of an overall expansion of the company's staff, bringing the total to 280 employees worldwide.

Star Rapid stated that it sees future growth opportunities within the rapid prototyping and low-volume manufacturing of smart devices with Internet of Things (IoT) capabilities. These devices are said to be increasing in prominence across many of the company's core markets, including the automotive, medical and industrial sectors. Hunter reportedly brings to the company over thirty years of lean management experience and, under his leadership, Star Rapid is expected to incorporate Industry 4.0 processes and systems that rely upon real-time data to increase operational efficiencies by eliminating bottlenecks, preventing line down or asset under-utilisation and implementing defect prevention measures.

Most recently, Hunter served as VP of Operations and Quality at Multek, a division of Flex, where he is said to have helped lead the business turnaround and development. Prior to this, he was VP and general manager of Wuxi.

On his appointment to CEO of Star Rapid, Hunter commented, "Having experienced strong growth in 2017, we are focused upon continuously improving every aspect of customer engagement. Implementing robust, scalable processes utilising lean techniques and developing an outstanding talent pool will enable Star Rapid to enjoy sustainable growth. In addition, we are embarking upon the deployment of intelligent manufacturing technologies, connected equipment and IoT which we believe will create a true competitive advantage for both ourselves and our customers."

The company's founder, Gordon Styles, will serve as president and CTO. "David is a natural-born leader and his impact has been evident from day one," he added. "His in-depth practical knowledge about how to deploy intelligent and lean manufacturing, paired with his long-term vision, will be invaluable as Star Rapid continues to expand its global presence. We look forward to continuing our company's success and serving our global customers."

www.starrapid.com ■■■

Digital Alloys secures $12.9 million in Series B financing, announces new patents

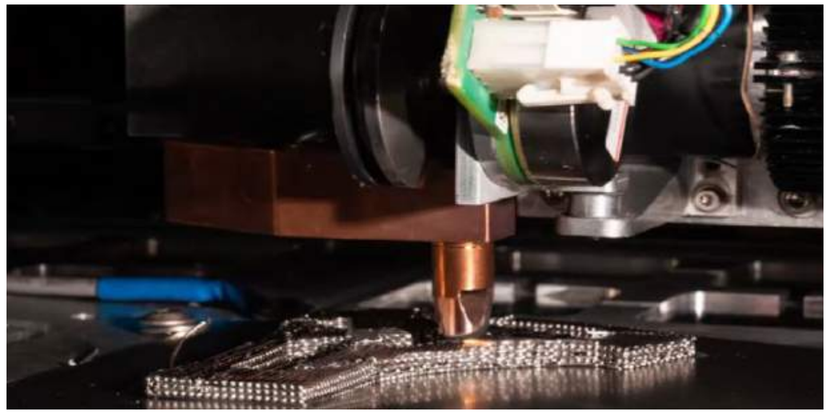
Digital Alloys, Inc., Burlington, Massachusetts, USA, has secured $12.9 million in Series B financing led by G20 Ventures and including Boeing HorizonX Ventures, Lincoln Electric, and prior investor Khosla Ventures. The company also announced two US patents for its Joule Printing™ metal Additive Manufacturing technology, a process which uses wire feedstock and high deposition rates to additively manufacture metal parts. According to Digital Alloys, Joule Printing is capable of producing parts faster and at lower cost than any other solution.

During the process, wire feed systems position the tip of the wire in contact with the desired starting point for the build process using rapid, precise motions. Once the wire is positioned, the system pushes a current through the wire and the part being built, and into the build plate. This current melts the wire tip using joule heating (or resistance heating). Both melting and wire feed continue while the feed system moves the tip of the wire across the build plate, laying down beads of metal which are fused together to form fully dense metal parts. Because melting and positioning of the wire occur simultaneously, Digital Alloys reports that significant cost and time savings can be achieved, along with enhanced repeatability. According to the company, its first Joule Printing system is capable of depositing metal at a rate of 5-10 kg/hour at less than 1 kWh of power consumption per kg.

Initial applications of the technology include the production of conformally cooled tools for the automotive and consumer products industries, and the delivery of high-quality titanium parts for the aerospace industry. "Our investment in Digital Alloys will further Boeing's ability to produce a higher volume of metal structural aerospace parts faster than ever before," commented Brian Schettler, Managing Director, Boeing HorizonX Ventures. "Through emerging Additive Manufacturing technologies, we aim to accelerate the design and manufacture of 3D printed parts to transform production systems and products."

Duncan McCallum, CEO of Digital Alloys, added, "Support from Boeing and Lincoln Electric will expand our expertise, technology and services. We are committed to providing the products and services manufacturers need to take advantage of metal 3D printing in production. We will save customers time, money and hassle by enabling great engineers to solve manufacturing problems in new ways. The next industrial revolution is here."

www.digitalalloys.com ■■■



The Joule Printing process is capable of deposition rates of 5–10 kg / hour (Courtesy Digital Alloys, Inc.)

Increasing AM standardisation efforts in Europe

The German Institute for Standardisation (DIN) has founded a new Additive Manufacturing Steering Committee as part of the NA 145 DIN Standards Committee Technology of Materials. The main purpose of the committee is to coordinate the development of AM across various projects. It is also tasked with coordinating work within NA 145-04 FB 'Section Additive Manufacturing', and will cooperate with other standards committees, taking into account economic feasibility, the state of the art, scientific insights, legal developments, financial conditions and the harmonisation of technical rules across Europe and the rest of the world. Under this commitee, the joint working group NA 145-04-02 GA has the task of working on standards and standardisation projects that deal with the application of Additive Manufacturing processes for metallic materials according to DIN EN ISO/ASTM 52900. NA 145-04-02 GA is the German mirror committee to the international working group ISO/TC 261/JWG 5.

Another European working group active in the area of standardisation is the ASD-STAN D04/WG14 AM (Additive Manufacturing). The Working Group represents European activities in the field of AM for aerospace applications. It prepares ASD-STAN prEN standards, EN standardisation projects and participates in other European and international projects.

The Working Group provides the opportunity to actively work on standardisation procedures, contribute ideas and suggestions and take part in the information exchange between national experts. A recent meeting of the group focussed on developing a new European standard for 'Aerospace Series – Metallic Materials – Mechanical Properties of Products by Additive Manufacturing'.

www.asd-stan.org

www.din.de ■■■

BASF highlights potential of its Ultrafuse 316LX fused filiment material

BASF SE's Catamold® feedstock is synonymous with the high-volume production of components by Metal Injection Moulding (MIM) and the product's launch, more than thirty years ago, was the catalyst for the MIM industry's global growth. Today, BASF has adapted this technology for metal Additive Manufacturing via Fused Filament Fabrication (FFF) with the development of its Ultrafuse 316LX filament.

This technology offers the company's existing MIM customers a low-investment route into metal AM, whether for prototyping or the development of entirely new applications. Ultrafuse 316LX can be used with almost any FFF AM system and once a part is built, no additional post-processing steps are required prior to its debinding and sintering.

Taking advantage of the reliability and high productivity of catalytic debinding, Ultrafuse 316LX enables the simple production of fully-sintered 316L stainless steel components, making it an ideal option for companies already using catalytic debinding and sintering in their manufacturing operations, who can easily step into and explore metal AM and debind and sinter their parts alongside traditional MIM components, eliminating the cost and time involved in special furnace runs, toll-sintering or equipment acquisitions.

BASF's 316LX filament presents a number of opportunities for companies entering into Additive Manufacturing (Courtesy BASF)

In an exclusive article for the September 2018 edition of *Powder Injection Moulding International* magazine (Vol. 12 No. 3), BASF 3D Printing Solutions GmbH highlights the significant potential of this technology as a cost-effective entry point into metal AM. *PIM International* can be read for free online or as a PDF download via the magazine website.

www.basf.com

www.pim-international.com ■■■

Tekna's five-year investment plan to expand metal powder production capacity

Metal powder manufacturer Tekna Plasma Systems Inc., Sherbrooke, Quebec, Canada, has revealed that it will invest up to $128 million over the course of a five-year plan to expand its global manufacturing output and boost its research and development capabilities. According to the company, these investments reflect a long-term commitment to both the metal Additive Manufacturing and microelectronics markets.

Tekna's investment plan is expected to help the company increase its global metal powder manufacturing capacity to over 1,000 tons per year; an expansion driven by growing demand from its active customer base. It will include an expansion to manufacturing floor space, the acquisition of production equipment and the purchase of resources for product development efforts.

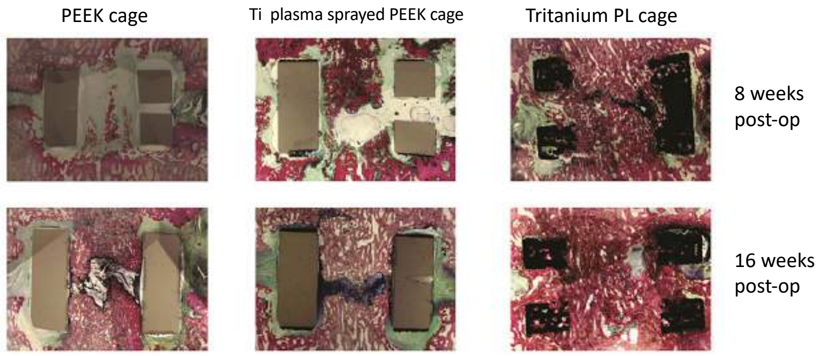
The project will benefit from $33 million in financing from the Canadian government. Morten Henriksen, Chair of the Board of Tekna Holdings Canada Inc., stated, "This investment project, though unprecedented, builds on twenty-eight years of commitment to excellence and is strategic to the company's development, growth and prosperity."

"Building on a portfolio of over one hundred cutting-edge metal powder options, as well as on our global manufacturing and sales infrastructure, these investments will ensure that Tekna maintains its leadership position," added Luc Dionne, Tekna's Chief Executive Officer, "with some of the broadest ranges of metal powders, and one of the greatest capacities available to the 3D printing and microelectronic markets, [we serve] the supply chains of giants in the aerospace, automotive, biomedical and microelectronics industries."

www.tekna.com ■■■

Tekna's planned capacity expansion will increase its global metal powder manufacturing capacity to over 1,000 tons a year (Rendering courtesy Tekna Plasma Systems Inc.)

Stryker publishes pre-clinical study on bone in-growth potential of metal AM spinal cages



Bone in-growth in Stryker lumbar interbody fusion cages at 8 weeks and 16 weeks post-op (Courtesy Stryker)

Stryker Spine, Kalamazoo, Michigan, USA, has announced the publication of a pre-clinical animal study comparing the performance of interbody spinal cages made of various materials. The results of the study illustrated significant differences in the performance of the company's interbody implants, with its metal additively manufactured Tritanium® cages showing a reduction in range of motion (ROM) and an increase in bone in-growth profile and construct stiffness.

The cages involved in this study included Stryker's traditional PEEK cages, plasma-sprayed titanium-coated PEEK cages, and Tritanium cages. The results demonstrated that the Tritanium cages exhibited significantly greater total bone volume within the graft window at both 8 and 16 weeks post-surgery compared to the PEEK cages. Tritanium cages were also said to be the only cages to show a decrease in ROM and an increase in stiffness across all three loading directions (axial rotation, flexion-extension, and lateral bending) between the 8 week and 16 week time points.

Sigurd H Berven, MD, Orthopaedic Surgeon at the University of California, San Francisco, USA, and one of the authors of the study, stated, "The results of this study provide an evidence-based approach to decision-making regarding interbody materials for spinal fusion, as there is significant variability in the materials commonly used for interbody cages in spine surgery. The study showed the potential for bone in-growth into and around the Tritanium cages."

Michael Carter, Vice President and General Manager of Stryker's Spine division, stated, "Stryker's proprietary Tritanium Technology, a novel, highly porous titanium alloy material designed for bone in-growth and biological fixation, is based on Additive Manufacturing techniques for orthopaedic surgery pioneered by Stryker over fifteen years ago. This important study reinforces the value of our growing line of Tritanium interbody cages and demonstrates Stryker's commitment to bringing the latest in advanced technologies to our customers."

The full study, titled 'Bony ingrowth potential of 3D printed porous titanium alloy: a direct comparison of interbody cage materials in an in vivo ovine lumbar fusion model', was published in the July issue of *The Spine Journal*.

www.stryker.com ■■■

Stryker's Tritanium PL cage, built using metal AM (Courtesy Stryker)

Arcast to supply large-scale research gas atomiser to CEIT

Arcast Inc., Oxford, Maine, USA, has reported it will supply a large-scale research inert gas atomiser to the Centro de Estudios e Investigaciones Técnicas de Gipuzkoa (CEIT), San Sebastián, Spain.

The new atomiser will allow the use of various atomising geometries to produce complex alloys in batches of 50–250 kg. These features are said to offer a good capacity and capability to address the growing needs of the metal powder market. Arcast stated that it hopes to work with the team at CEIT to create larger quantities of advanced metal powders in the future.

CEIT is a non-profit research centre and carries out applied industrial research projects under contract, working closely with clients' R&D departments. The Materials and Manufacturing division undertakes Powder Metallurgy research, and is currently expanding its capabilities to develop new alloy powders for metal Additive Manufacturing, Metal Injection Moulding (MIM) and other powder metal markets. It belongs to the IK4 Research Alliance, a collective of seven research institutes from Spain's Basque Country, and also has ties with Spain's Tecnun School of Engineering, Germany's Fraunhofer Society, and other R&D institutions and research centres globally.

www.ceit.es
www.arcastinc.com ■■■

GKN Powder Metallurgy identifies potential of metal AM for production of copper induction coils

GKN Powder Metallurgy has identified a promising application area for metal Additive Manufacturing in the production of copper inductor coils used for induction hardening processes. Induction hardening is used to increase the strength of components by users in the metal-processing industry, at automotive suppliers and in other fields where certain surface areas of components are required to withstand intensive mechanical loads and exposed to wear. The process is used to harden only the surface area of the component and does not have an effect on the internal hardness.

In induction hardening, a coil of highly conductive copper tubes, containing channels through which cooling water runs under high pressure, encloses the component. A high-frequency alternating current then flows through the induction coil, generating a powerful magnetic field which, in turn, induces eddy currents in the boundary layer of the component, giving off frictional heat. These eddy currents heat the component surface very quickly to the temperature required for hardening. Afterwards, it is quenched for sudden cooling.

A copper induction coil produced by metal Additive Manufacturing (Courtesy GKN Powder Metallurgy)

The traditional manufacturing process for inductor coils relies on soldering, which the company explained is a complicated process which can create imperfections in the final product. Using metal AM, inductors can be produced which offer reproducible hardening results, three to four times longer service life, a shorter set-up time when used with hardening machines, and a reduction in operation and investment costs through better machine utilisation. In addition, the closer the shape of an inductor coil is to the shape of the component being hardened, the better the results of the induction hardening process – for this reason, the geometric design freedom offered by AM is a key advantage.

In an article on GKN's Powder Metallurgy blog, the company stated that currently, awareness of the advantages offered by metal AM inductor coils remains low. "We predict that it will take another year before the industry understands this advantage," stated article author Galina Ermakova, GPC Engineer for Additive Manufacturing at GKN Powder Metallurgy.

To help drive awareness and trust of AM inductors among users, Ermakova stated, "Users will have to intensively test and experience 3D printing first, and we need to schedule time for that. Once users gain confidence and realise that 3D printing delivers reproducible results, nothing will ever be the same."

www.gkn.com

Desktop Metal and Markforged reach amicable resolution on trade secret litigation

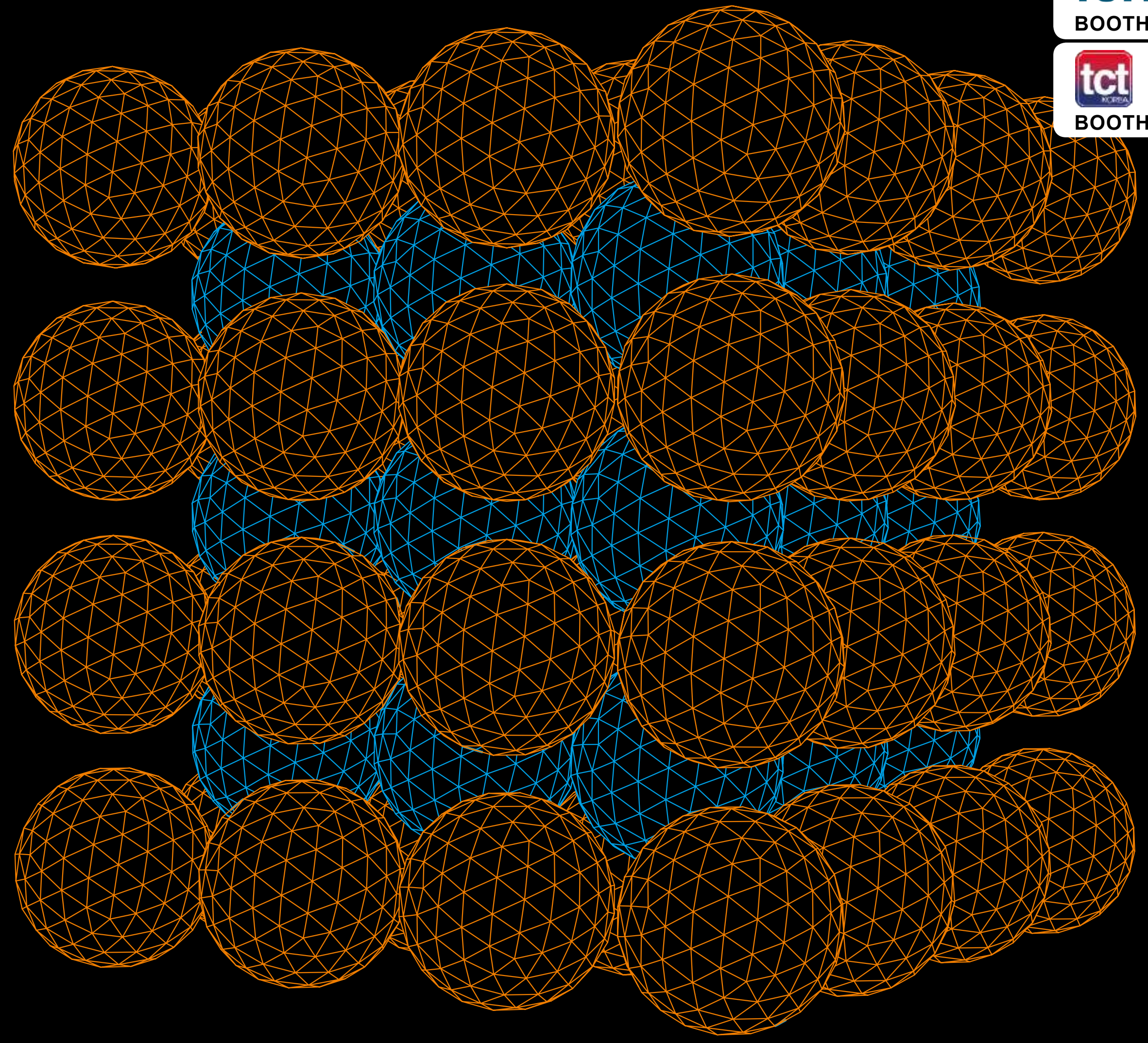
Desktop Metal, based in Burlington, Massachusetts, USA, and Markforged, of Watertown, Massachusetts, USA, have announced an agreement that resolves all outstanding litigation between the two companies.

Desktop Metal's lawsuit was based on U.S. Patent Nos. 9,815,118 and 9,833,839, which were granted to Desktop Metal in 2017 and covered the company's interface layer technology for both its Studio System™ and Production System™. It had alleged that the manner in which the Markforged Metal X Additive Manufacturing system forms ceramic release layers for the separation of parts from the build plate infringed on these patents.

Both Desktop Metal and Markforged now acknowledge that neither company, nor the individuals named in the litigation, misappropriated any trade secret or confidential information belonging to the other. Further terms and conditions of the settlement will remain confidential.

www.markforged.com

www.desktopmetal.com ■■■



AP&C partners with Canada's Research Council on advanced image analysis for metal powders

The National Research Council of Canada (NRC) and AP&C, a GE Additive company based in Montreal, Quebec, Canada, have developed a way to test the quality of powders used in Additive Manufacturing using X-ray micro-computed tomography (micro-CT) and 3D image analysis. According to the partners, this could lead to the production of stronger, cleaner, safer and more reliable additively manufactured parts for aerospace and medical devices.

The testing method developed allows for the detection of very low concentrations of foreign particles in powders. Using X-ray micro-CT and 3D image analysis, each individual foreign particle is visualised and its size, brightness and overall concentration measured. In situations where cross-contamination is a concern, the technique is said to be more sensitive and discriminating than current methods available for chemical analysis.

The testing method was validated using titanium powders intended to be used in aerospace parts, in collaboration with industrial partners. The NRC and AP&C are now said to be expanding its capabilities to cover other materials and metals, such as nickel alloys. The method could be especially useful in the qualification of recycled powders in safety-critical applications.

The partners stated that they are cooperating further on improving and developing metal powder characterisation methods that are better adapted to the specific needs of the metal AM industry. In addition to detecting foreign particles using X-ray micro-computed tomography, the NRC is currently working on analysing the flow of metal powders during the AM process by measuring how spherical and porous particles are.

Louis-Philippe Lefebvre, Powder Forming Team Lead, Medical Devices Research Centre, NRC, stated, "We hope this new method will support the industrial adoption of 3D printing and ease its implementation in highly regulated environments such as the aerospace and medical devices industries. As a leader with over thirty years of experience in Powder Metallurgy and Additive Manufacturing, the National Research Council is pleased to have joined forces with AP&C to improve the reliability of the manufacturing process and metal powder behaviour."

"The competitiveness of 3D printing relies heavily on the capability of machine users to recycle their powders; however, the industry is concerned that foreign particles will be introduced in the feedstock as the powder is recycled," added Frederic Larouche, Executive Vice President & Chief Technology Officer, AP&C. "The method we are developing could help confirm that the feedstock maintains the utmost cleanliness during processing. Leveraging our complementary research and development competencies should help speed the development of 3D printing technologies."

Dr Fabrice Bernier, a researcher at the NRC, analyses powders used in Additive Manufacturing (Courtesy National Research Council of Canada)

AP&C has been collaborating for more than six years with the National Research Council of Canada on developing and characterising titanium and nickel superalloy powders for AM, Metal Injection Moulding and other Powder Metallurgy processes. "Our partnership with the National Research Council, a recognised research organization with deep expertise in Powder Metallurgy and materials characterisation, is supporting Advanced Powders & Coatings' growth and allows us to offer better-integrated solutions to our partners," concluded Larouche.

www.ge.com/additive/additive-manufacturing/materials/apc-homepage

www.nrc-cnrc.gc.ca ■■■

Airbus Helicopters begins series production of A350 passenger aircraft components

Airbus Helicopters, Donauwörth, Germany, which manufactures the doors for all Airbus aircraft programmes, has begun production of latch shafts for the doors of the Airbus A350 passenger aircraft using metal Additive Manufacturing.

The latch shafts are made in titanium on an EOS M 400-4 system in batches of twenty-eight per build. The resulting parts are reported to be 45% lighter and 25% cheaper to produce than traditional latch shafts; as each A350 has sixteen latch shafts, the result is a saving of just over 4 kg per aircraft.

Airbus Helicopters stated that it plans to deliver 2,200 components a year once production is fully operational. Qualification is scheduled to be completed at the end of 2018, with serial production starting in early 2019; the first additively manufactured A350 components are expected to begin service in active aircraft in 2020.

Airbus Helicopters added that it has begun preparations to produce an even larger group of A350 door components using Additive Manufacturing, and also expects to use the technology in the production of future helicopter components. Luis Martin Diaz, Head of Industrial Service Centers, Airbus Helicopters Donauwörth, stated, "Our goal is to get developers making more use of 3D printing."

Metal additively manufactured latch shafts prior to depowdering at Airbus Helicopters (Courtesy Airbus)

"This means that 3D printing should be taken into consideration right from the initial planning stages for new components, which may be able to be manufactured particularly easily and cost-effectively using this method. Weight savings are especially important when it comes to helicopters. Airbus will start preparations for the industrialisation of 3D printed helicopter components this year."

Nikolai Zaepernick, Senior Vice President Central Europe, EOS, commented, "We are proud that Airbus Helicopters relies on EOS Technology for the manufacturing of flight-critical components such as latch shafts. Our systems provide a very high and reproducible quality. With this machine performance and with our know-how, we can significantly support Airbus Helicopters in the certification process for the component."

www.airbus.com | www.eos.info ■■■

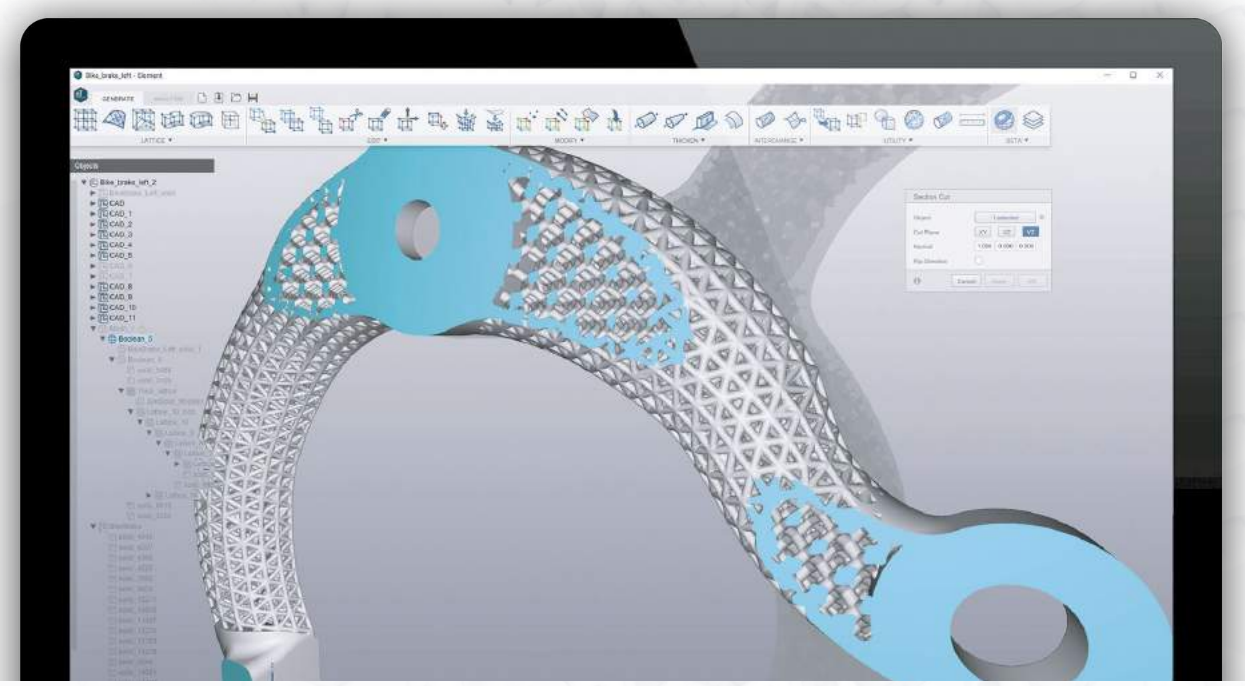
Globe Metal names new COO

Globe Metal Recycling Services Inc., Quebec, Canada, has appointed Douglas (Doug) Veitch as its new Chief Operating Officer. The company specialises in the processing and recycling of all alloys of powder, swarf, turnings and solids generated by the thermal spray, Additive Manufacturing and coating industries.

The appointment was announced by Jeff Solomon, Globe Metal's CEO, who stated, "Doug's new responsibilities will include aiding in long term financial planning, defining sales strategies and defining goals for the sales team. He will make future sales projections based on input from the sales team and act as my representative when I am away from the office."

Veitch holds a BSc degree in Mechanical Engineering from the University of Alberta and joins the company's team following many years in the corporate world, including positions at DuPoint, Materion and IBC Alloys.

www.globemetal.com ■■■



GE Additive launches Manufacturing Partner Network with Burloak, Carpenter and Protolabs first to join

GE Additive has launched a new Manufacturing Partner Network (MPN) with the aim of creating an open, competitive marketplace to accelerate both supply and demand for Additive Manufacturing. The network will consist of manufacturing partners specifically chosen to help customers who are ready to progress into volume production of AM parts. The first three companies to join the network were announced at the 2018 Farnborough International Airshow as Burloak Technologies, Carpenter Technology and Protolabs Inc.

GE Additive believes that as companies become ready to make the move into volume production they are looking for cost-efficient, scalable routes. However, limited access to equipment, funding to invest and expertise often prevents them from taking the next critical steps. Additive Manufacturing suppliers are also seeking demand to build long-term business cases in order to invest, while OEMs need a guaranteed source of capacity, so they can continue to invest with confidence.

"We know first hand that the transition from prototyping to volume production is possibly the biggest step on any company's additive journey and that can be daunting. The MPN is designed to give companies a range of options to help them progress and continue innovating by connecting them with a choice of trusted additive production partners to give them peace of mind, in a cost-efficient way, " stated Jason Oliver, President & CEO, GE Additive.

The MPN will add additional manufacturing partners in all regions, but by design will remain a select group of Additive Manufacturing specialists who all understand the capabilities and future of this technology. Manufacturing partners will also benefit commercially in three areas:

- Direct demand generation through a network of OEMs and revenue opportunities generated by GE Additive's sales teams.
- Knowledge sharing across the network. This includes access to over 150 AddWorksTM consultants and technical support. New GE Additive technologies and innovation will be made available to MPs for testing and feedback shared will be incorporated into future product development.
- Co-marketing support and campaigns, including permission to use the GE monogram on all sales, marketing and promotional materials, communications channels and buildings.

Carpenter Technology Corporation

Carpenter Technology Corporation is a recognised leader in high-performance alloy-based materials and process solutions for critical applications in the aerospace, defence, transportation, energy, industrial, medical and consumer electronics markets.

"We are pleased to further our long-standing relationship with GE by entering into this important AM partnership as we help accelerate the advancement of AM across industries," stated Tony R Thene, Carpenter's Chief Executive Officer. "Partnering with an industry leader such as GE is an excellent opportunity for Carpenter to further advance our AM capabilities and network to bring highly differentiated AM business solutions to its customers and partners."

Burloak Technologies

Burloak Technologies is said to be Canada's leading supplier of highly engineered additive manufactured components for demanding applications.

"Burloak Technologies is proud to be a launch partner for GE's Manufacturing Partner Network," added Peter Adams, Co-founder and President of Burloak Technologies. "We have developed a strategic plan for the industrialisation of Additive Manufacturing. Our participation in GE's MPN strengthens this plan and will allow us to accelerate the the adoption of Additive Manufacturing in the market."

Protolabs

Protolabs is a manufacturer of custom prototypes and on-demand production parts, with manufacturing facilities in five countries. "We take pride in having been in the Additive Manufacturing industry for nearly 20 years, and we are excited to partner with GE Additive to further advance and democratise access to industrial-grade Additive Manufacturing technologies and materials," stated Vicki Holt, President and CEO, Protolabs.

GE Additive's Customer Experience Centers in Munich and Pittsburg will continue to support customers with prototyping and low volume production, but will act as a bridge to the MPN, which is seen as a natural extension for those customers ready to take the next step.

www.burloaktech.com
www.cartech.com
www.protolabs.com
www.ge.com/additive ■■■

Lockheed Martin and Arconic look to develop advanced aerospace materials

Lockheed Martin, headquartered in Bethesda, Maryland, USA, and Arconic, headquartered in Pittsburgh, Pennsylvania, USA, have entered into a Joint Development Agreement (JDA) to develop customised lightweight material systems and advanced manufacturing processes, including metal Additive Manufacturing, for aerospace and defence structures and systems.

This agreement expands the longstanding relationship between Arconic and Lockheed Martin, which currently collaborate on advanced materials and manufacturing projects such as the development of process modelling, simulation tools and lightweight, corrosion resistant alloys. Arconic also supplies Lockheed Martin with a range of multi-material products for the F-35 Joint Strike Fighter aircraft programme – from engine to airframe structures – as well as metal additively manufactured parts for service on NASA's Orion spacecraft.

An optimised aerospace bracket produced by Arconic (Courtesy Arconic)

Rod Makoske, Lockheed Martin SVP of Corporate Engineering, Technology and Operations, stated, "At Lockheed Martin, we are relentlessly finding ways to develop materials that create state-of-the-art advanced capabilities, reduce waste and generate efficiencies in manufacturing practices. Collaborating with Arconic will help us uncover new ideas for materials development where traditional practices aren't suitable, investigate more sustainable material compositions and find ways to produce materials more effectively."

"We have a long history of innovative collaboration with Lockheed Martin across multiple platforms – from single-piece forged bulkheads for the F-35 to 3D printed parts for the Orion spacecraft," added Ray Kilmer, Executive Vice President and Chief Technology Officer, Arconic, "and we are pleased to expand on that relationship with this new agreement. Lockheed is always innovating, and it is a privilege to apply our materials and manufacturing expertise to help them deliver their next generation of cutting-edge products."

www.arconic.com

www.lockheedmartin.com ■■■

Oerlikon and RUAG focus on space components

Oerlikon, Pfäffikon, Switzerland, has signed a Memorandum of Understanding (MoU) with RUAG Space, Zurich, Switzerland, a division of Group RUAG, to qualify and accelerate the series production of metal additively manufactured space components.

Dr Roland Fischer, CEO, Oerlikon Group, stated, "Through our ongoing collaboration with RUAG Space, we have identified opportunities to fine-tune the qualification and certification processes, which are crucial in ensuring consistent quality in production. We are confident that our materials and Additive Manufacturing expertise will further grow this important partnership."

Within the partnership, both companies stated that they intend to co-develop processes and standards for the metal AM of space components, with the intention being to establish standards suitable for the European space community to adopt. In addition, the partnership will explore the refinement of existing alloys for the Additive Manufacturing process and the development of new metallic materials to unlock future design opportunities.

"We see this partnership as an important step in unleashing the full value of Additive Manufacturing in the development of new products that meet the rapidly evolving demands of the space industry," commented Peter Guggenbach, CEO, RUAG Space. "We are working on standardising AM operations for space and are excited to collaborate with Oerlikon AM to further develop industry-leading standards and processes."

www.oerlikon.com/am

www.ruag.com/space ■■■

GE offers improved turbine engine with metal AM parts to the U.S. Army

GE Aviation, Ohio, USA, reports that it has submitted the second and final phase of its proposal to the U.S. Army offering its T901 engines to re-engine the Army's Boeing AH-64 Apache and Sikorsky UH-60 Black Hawk helicopters. The U.S. Army Contracting Command, based at Redstone Arsenal in Huntsville, Alabama, plans to select one engine manufacturer for the project by the end of 2018.

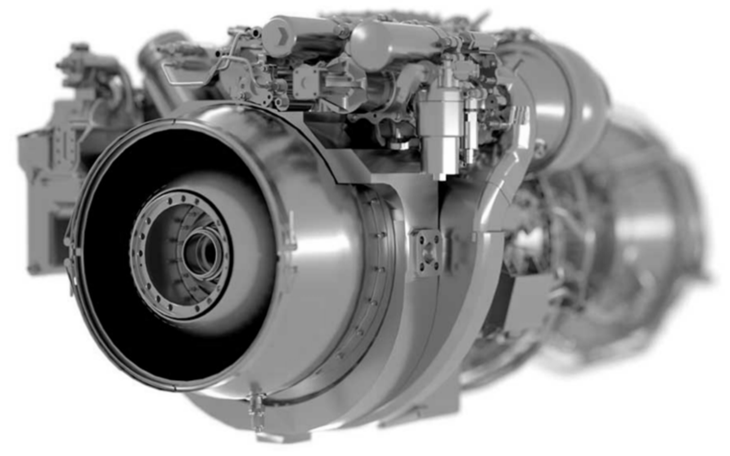
The T901-GE-900 is said to incorporate a number of technologies, among them metal Additive Manufacturing. GE Aviation states that by using metal AM, it has been able to consolidate parts which comprised fifty-one pieces on the former T700 engine to just one integrated part on the new T901, resulting in a 20% reduction in weight.

GE stated that it has invested more than $9 billion in maturing technologies applicable to the T901 and over $300 million on the development and testing of turboshaft-specific technologies. The company has funded and successfully completed testing on a T901 prototype engine, as well as tests on all components of the engine, to prove that it meets or exceeds the Army's Improved Turbine Engine Program (ITEP) requirements.

Ron Hutter, Executive Director of the T901 Programme, stated, "Using GE's industry-leading technologies, rather than mechanical complexity, to meet ITEP requirements enables the use of a single-spool design, making the T901 engine less complex, less expensive and lighter weight. The T901's single-spool core enables full modularity, building on the success of the combat proven T700 and providing the Army superior fix-forward maintainability, reduced life-cycle costs and improved Warfighter readiness."

With fewer parts and a simpler design, the T901 is said to be more reliable and more maintainable. The fully modular design also offers superior growth potential at a lower cost through incremental improvements to engine modules, which could present a significant advantage for meeting FVL requirements as they develop. GE Aviation and the US Army successfully installed a full-scale T901 engine mock-up into an Apache and a Black Hawk in December 2017, demonstrating its ability to integrate into both airframes.

www.geaviation.com ■■■


GE Aviation's T901-GE-900 engine offered to the U.S. Army (Courtesy GE Aviation)

Pratt & Whitney and partners test additively manufactured turbomachinery components

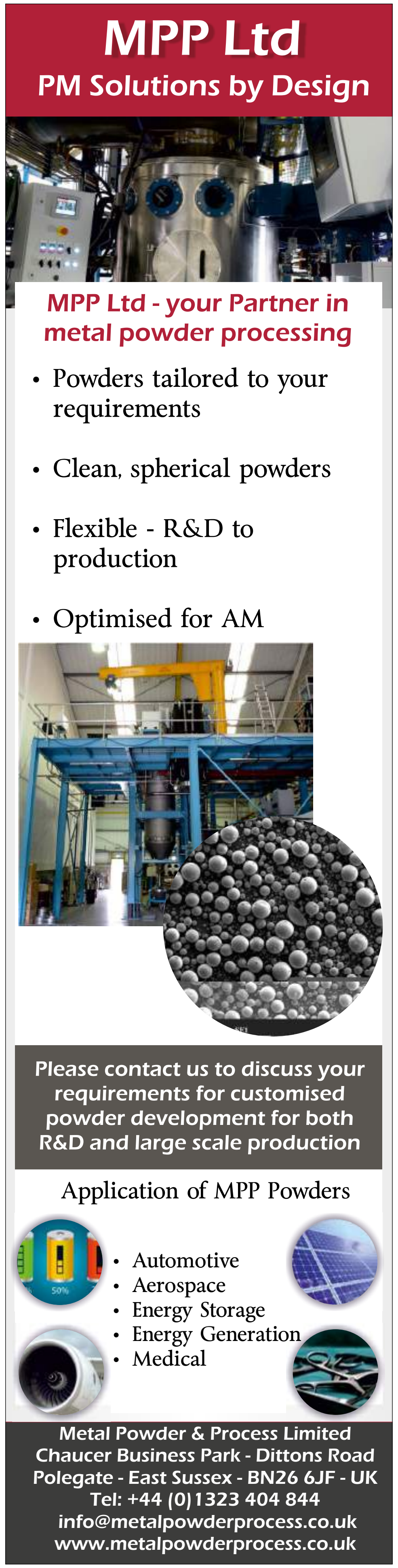
Pratt & Whitney, a division of United Technologies Corp., is partnering with an industry team for the development and testing of additively manufactured turbomachinery components, including the first additively manufactured rotating part for Pratt & Whitney development programmes. The team includes Norsk Titanium, an FAA-approved supplier of aerospace-grade AM structural titanium components, as well as Notre Dame Turbomachinery Laboratory and TURBOCAM International.

Dave Carter, Senior Vice President, Engineering Pratt & Whitney, stated, "We are excited to collaborate on these manufacturing and testing efforts and applications for future engine development. Pratt & Whitney is a 3D printing leader and has been steadily increasing the use of Additive Manufacturing techniques for the past 30 years. Working with Norsk, the Notre Dame Turbomachinery Laboratory and TURBOCAM will accelerate already successful efforts to incorporate additively manufactured parts into our production engines."

The team is currently exploring the applicability of Norsk Titanium's Rapid Plasma Deposition™ material. As part of this, the Notre Dame Turbomachinery Laboratory will test an AM, integrally-bladed rotor produced to meet the applicable quality specifications used in Pratt & Whitney's current turbomachinery products.

Pratt & Whitney will also benefit from United Technologies Corp's recent establishment of a $75 million Additive Manufacturing Center of Expertise near its campus in East Hartford, Connecticut, USA, where the corporation aims to accelerate the implementation of Additive Manufacturing across its product lines.

www.pw.utc.com ■■■



Additive Industries to integrate LPW's powder management in its MetalFAB1 systems

Additive Industries, Eindhoven, the Netherlands, has signed a commercial agreement with LPW Technology, Widnes, Cheshire, UK, to offer LPW's powder management solutions as an integral part of the MetalFAB1 systems and supporting Additive World Platform. The agreement was signed during the Farnborough International Airshow, UK, July 16-22, 2018, by Dr Phil Carroll, LPW Technology CEO, and Jan-Cees Santema, Additive Industries' Sales Director Europe.

The integration of LPW's powder management solutions will reportedly allow Additive Industries customers to automatically load powder into MetalFAB1 systems in inert conditions and record the characteristics of the metal powders throughout their lifecycle, from manufacturing to part production. This closed loop system is thought to be key in reducing the risk of contamination and potential variations in powder performance as a result of exposure to oxygen and humidity; especially important in the series production of qualified parts.

"Viewing Additive Manufacturing from the perspective of the metal powder is what has driven the development of our PowderLife metal powder atomisation, powder transport, delivery and traceability system," explained Dr Carroll. "Our PowderEye sensors ensure that the powder environment is closely monitored during transport and throughout the metal AM process. We are delighted that Additive Industries has chosen to adopt this approach as part of their integrated industrial Additive Manufacturing system."

Commenting on the partnership, Daan Kersten, CEO of Additive Industries, stated, "We have been working with LPW for years and share the vision on full automation and integration. Integrating the LPW Powder Hopper solution and PowderSolve software in our MetalFAB1 systems and software allows our customers to accelerate the manufacturing of industrial quality parts and store all data in one place."

"The integrated supply of powder combined with full traceability closes the loop to produce certified parts in regulated environments like aerospace and healthcare. Moreover, the automated and closed powder loading system cuts manual labour significantly and reduces operator exposure to powder providing a safe and healthy work environment. The long-term relationship between LPW Technology and Additive Industries has resulted in this innovative powder handling system," he concluded.

LPW's PowderLife solutions were reported on in further detail in the Summer 2018 edition of *Metal Additive Manufacturing* magazine, available to read online or download for free.

www.lpwtechnology.com
www.additiveindustries.com
www.metal-am.com ■■■

Dr Phil Carroll, LPW Technology CEO, and Jan-Cees Santema, Additive Industries' Sales Director Europe (Courtesy LPW Technology)

Honda Aircraft Engine R&D Center adopts GE's AddWorks to accelerate aerospace application development

GE Additive has reported its first AddWorks™ additive consulting services engagement in Japan, following an agreement with Honda R&D Co., Ltd, Aircraft Engine R&D Center announced at this year's Farnborough International Airshow. The agreement aims to further Honda Aircraft Engine's additive application development for its future generation aircraft engines.

GE Additive's AddWorks consultants help determine whether AM will benefit the organisation economically, as well as from a performance perspective. The AddWorks team's expertise is rooted in GE's experience with Additive Manufacturing, which has helped produce additive parts for aerospace systems including CFM International's LEAP aircraft engines and the GE Catalyst™ advanced turboprop engine.

GE and Honda's partnership in the aviation industry spans over a decade. Having established GE Honda Aero Engines LLC – a joint venture between GE Aviation and Honda Aero in 2004 – the two companies developed the GE Honda HF120 jet engine used on light business jet aircraft such as HondaJet. GE Additive added that it hopes the AddWorks consulting services will lead to enhancements of the existing partnership between the two companies, and further the adoption of Additive Manufacturing in the aerospace industry.

"We are pleased that Honda Aircraft Engine R&D Center has selected GE Additive to be its vendor in providing AddWorks consulting services to further the use of this transformative technology in its future generation aircraft engines. We are in the best position to share our learnings from our own additive journey, having started from prototyping to successfully applying it to mass production for aviation engine parts," stated Thomas Pang, Japan Director of GE Additive.

GE Additive established its operations in Japan in January 2018 and will sell Concept Laser and Arcam EBM additive machines as well as materials directly and via local resellers to Japan-based customers with a focus on key industries, including aerospace, automotive, heavy industry and others.

https://global.honda
www.ge.com/additive

Johnson & Johnson acquires Emerging Implant Technologies

Johnson & Johnson Medical Devices Companies, through its subsidiary Johnson & Johnson Medical GmbH, Norderstedt, Germany, has acquired Emerging Implant Technologies GmbH (EIT), Wurmlingen, Germany, a privately held company which produces titanium interbody implants for spinal surgery by metal Additive Manufacturing.

EIT's products include proprietary advanced cellular titanium implants, where an open and interconnected porous structure is designed to encourage osseointegration or 'bone in-growth' into the implant. Johnson & Johnson Medical Devices Companies stated that it will leverage its global commercial infrastructure to bring EIT's technologies to patients internationally.

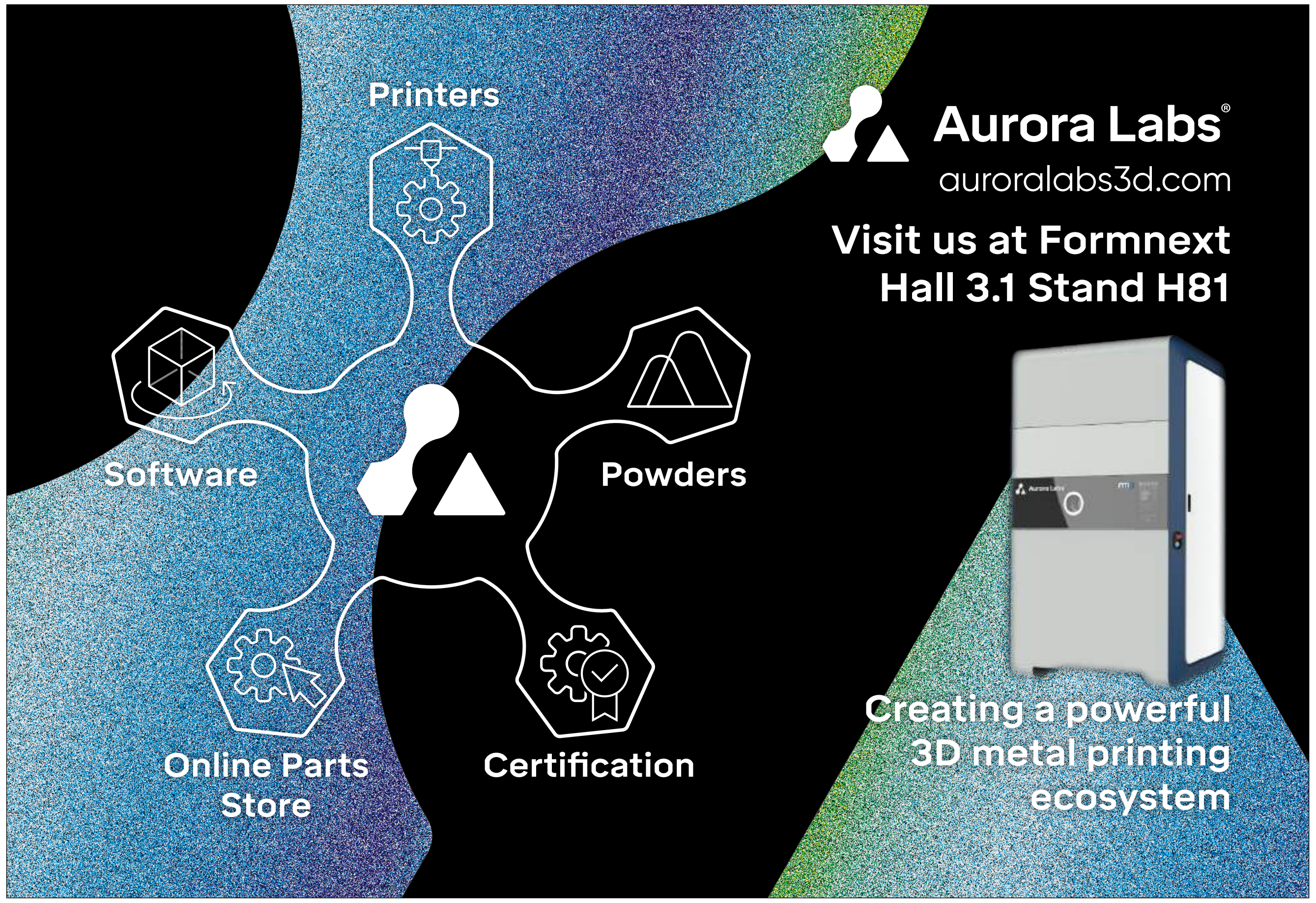
The acquisition is also expected to allow DePuy Synthes, the orthopaedics business of Johnson & Johnson, to enhance its interbody implant portfolio, which already includes expandable interbody devices and titanium-integrated PEEK technology, for both minimally invasive and open spinal surgery.

"Our goal is to offer a complete portfolio of interbody solutions that provides surgeons with even more options for the treatment of their patients," stated Aldo Denti, Company Group Chairman of DePuy Synthes. "We are excited to welcome the skilled team at EIT, and together we aspire to bring to market technologies that allow surgeons to perform spinal fusion procedures reliably and with consistent outcomes."

EIT's additively manufactured titanium implants are offered in a variety of geometries and sizes (Courtesy EIT)

DePuy Synthes stated that this acquisition underscores its commitment to building an innovative portfolio of spine solutions. Moving forward, it will continue to focus on the spinal diseases with the most potential for surgeons and their patients, such as degenerative disc disease, deformity and complex cervical issues.

www.jnjmedicaldevices.com
www.depuysynthes.com
www.eit-spine.de



Dimlaser celebrates ten years of Additive Manufacturing in Portugal

Dimlaser, located in Leiria, Portugal, entered the metal Additive Manufacturing sector some ten years ago. Seeing the potential for the technology in Portugal, the company began supplying the plastic forming industry with a range of conformally cooled mould inserts built using LaserCusing machines from Concept Laser.

Today, the company serves a number of different markets and additively manufactures a wide selection of components. Discussing the company's growth over the years, Fátima Fontes, Dimlaser's commercial manager stated, "Quickly we were able to establish ourselves in the conformal cooling market and start the development of new products for other markets. Then we looked internationally, working directly and indirectly for foreign clients looking to the Portuguese market as their supplier."

The company stated it had invested in both the production technology and human resources required to enable it to respond quickly, and in a qualified manner, to customer demands. "We strive to be partners with our clients, advising and accompanying the projects from the initial idea to the final product," added Fontes.

Dimlaser uses Additive Manufacturing to produce components, prototypes and replacement parts for the automotive industry (Courtesy Dimlaser)

In addition to serving clients in the moulding sector, the company has provided support to and worked with customers in the automotive, jewellery, dental and medical industries. It now offers a range of services and can produce components in many materials including stainless steel, aluminium alloys, titanium and more.

www.dimlaser.com ■■■

Formnext reports exhibition 'full to capacity'

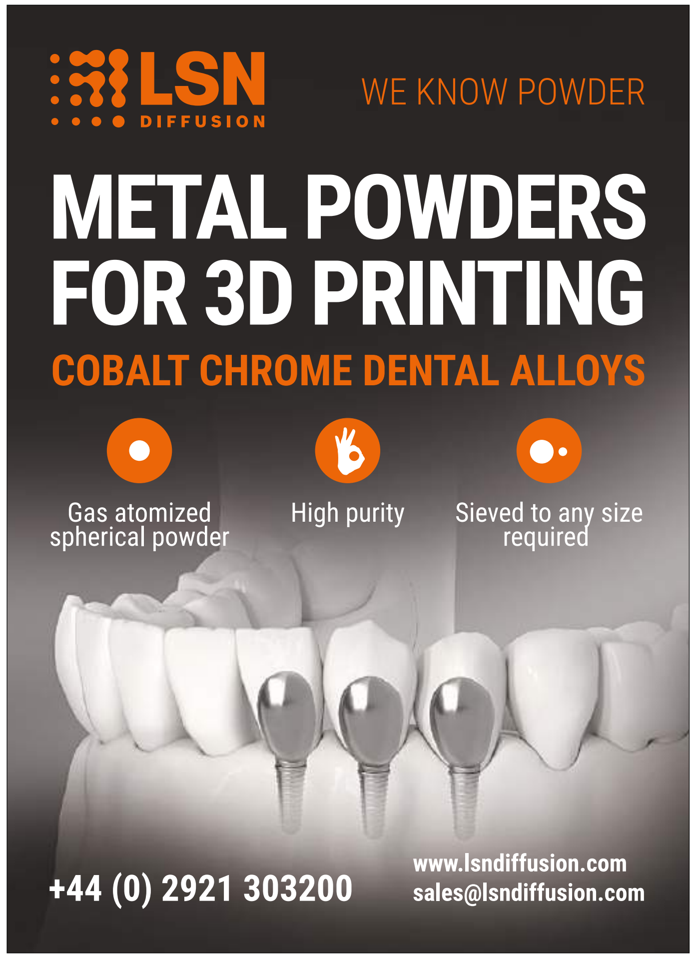
The organiser of formnext 2018, set to run in Frankfurt, Germany, from November 13-16, 2018, has announced that the two levels of the exhibition Hall 3 are now full to capacity. With some 550 exhibitors, formnext 2018 will showcase the latest Additive Manufacturing technologies and solutions across some 36,000m^2 of floor space.

The leading exhibition for AM and cutting-edge production techniques, formnext has recorded significant growth in terms of number of exhibitors and exhibition space. In addition to the exhibition in Hall 3, supporting events will be held in adjacent spaces, such as the TCT Conference @ formnext in Hall 4.

It was stated that this year's event will see an even wider range of topics covered along the relevant process chains, and key areas such as software, material, and pre- and post-processing (for example, for powder removal, surface finishing, and heat treatment) will also receive increased attention. Among the 550 exhibitors, a total of 165 will be showcasing their products at formnext for the first time.

To meet the growing demand, formnext 2019 will relocate to the newly built exhibition Hall 12 of the Frankfurt exhibition ground, which – combined with Hall 11 – will provide an exhibition space of around 58,000 m^2.

www.formnext.de ■■■



Aurora Labs LFT targets metal Additive Manufacturing build speeds

Aurora Labs, Bibra Lake, Western Australia, reports that initial builds using its Large Format Technology (LFT) for metal Additive Manufacturing achieved a build speed equivalent to 662 g/h, or 15.88 kg/day, claiming that this exceeds the ‘market speed’ by a factor of eight. According to the company, this indicates that, once its full-sized Rapid Manufacturing Printer (RMP) is fully built, its targeted build speed of 1000 kg/day could be achievable through scaling.

The initial tests were carried out on the Alpha model, Aurora Labs’ first fully-functioning LFT machine, for the production of a complex metal part including curves and internal structures in commercially pure titanium (Cp-Ti). The system has a build envelope of 200 x 200 x 200 mm and both the envelope and build speed are expected to be scaled up to create the company’s first RMP production units.

Aurora Labs defines ‘market speed’ as the standard speed of metal AM machines which are currently available on the market, are of comparable size to the Alpha model and are able to build parts in Cp-Ti. According to the company, its research has shown the standard market speed to be 81.7 g/h, or 1.96 kg/day.

David Budge, Managing Director, Aurora Labs, stated, “Possibly more than any other step in Aurora Labs’ history, this one is the most important, as it proves out at a fundamental level the potential for this technology to revolutionise the metal manufacturing market. The nature of the Large Format Technology and its ability to be scaled allows us to understand at this stage in the development cycle the potential for this technology to be able to print at our target rate of 1000 kg/day.”

The company expects to have the pre-production model of its RMP ready for sale to an industry partner before the end of 2018. It will now focus on scaling the technology and increasing build speeds further to the targeted 1000 kg/day.

www.auroralabs3d.com ■■■

The first build completed using Aurora Labs’ Large Format Technology (Courtesy Aurora Labs)

Aerospace parts bureau commissions custom Sciaky EBAM system

FAMAero, Fenton, Michigan, USA, a privately-owned bureau specialising in metal additively manufactured parts, has commissioned a custom Electron Beam Additive Manufacturing (EBAM) system from Sciaky, Inc., a subsidiary of Phillips Service Industries, Inc., Chicago, Illinois, USA. The custom system will reportedly be the largest production-scale metal Additive Manufacturing system in the world, with a nominal part envelope of 3708 x 1575 x 1575 mm (146 x 62 x 62 in).

By using a machine with this type of scalability, FAMAero – whose name is an abbreviation for Future Additive Manufacturing in Aerospace – expects that it will be able to produce metal parts and prototypes of over 3.7 m (12 ft) in length for applications in the aerospace, defence, oil & gas, and sea exploration industries. EBAM is one of the fastest deposition processes in the metal AM market, with gross deposition rates ranging from 3.18–11.34 kg (7–25 lbs) of metal per hour.

“FAMAero is well-positioned to be North America’s go-to source for fast and affordable metal 3D printed parts and prototypes,” stated Scott Phillips, President and CEO of Sciaky, Inc. “Based on recent market dynamics, we believe FAMAero is on the cusp of a burgeoning trend in the metal 3D printing marketplace, which will undoubtedly grow globally over time.”

Don Doyle, President of FAMAero, commented, “FAMAero is entering the market as the first private, dedicated parts bureau in North America for large-scale 3D printed metal parts. Our Factory as a Service concept, combined with Sciaky’s industry-leading EBAM technology, will provide manufacturers a new avenue to significantly slash time and cost on the production of critical parts, while offering the largest build platform and selection of exotic metals to choose from in the 3D parts service market.”

www.sciaky.com | www.famaero.com ■■■

The custom EBAM system produced by Sciaky for FAMAero will be used to produce metal parts over 3.7 m in length (Courtesy Sciaky, Inc.)

ATI acquires aerospace and defence additive manufacturer Addaero

Allegheny Technologies Incorporated, headquartered in Pittsburgh, Pennsylvania, USA, has acquired Addaero Manufacturing, New Britain, Connecticut, USA, a leading AM company specialising in the aerospace and defence sectors. Financial terms of the acquisition were not disclosed.

Addaero Manufacturing was established in 2013 by three experienced aerospace and AM technology professionals. The company has extensive in-house capabilities and is AS9100C and ISO 9001:2008 certified.

"This strategic acquisition brings together ATI's deep knowledge and experience in commercial aerospace and our industry-leading powder metal manufacturing capabilities, including our new aerospace-qualified Bakers Powder Operations, and Addaero's technical expertise to produce aerospace quality parts using various Additive Manufacturing technologies," stated Rich Harshman, ATI's Chairman, President and Chief Executive Officer.

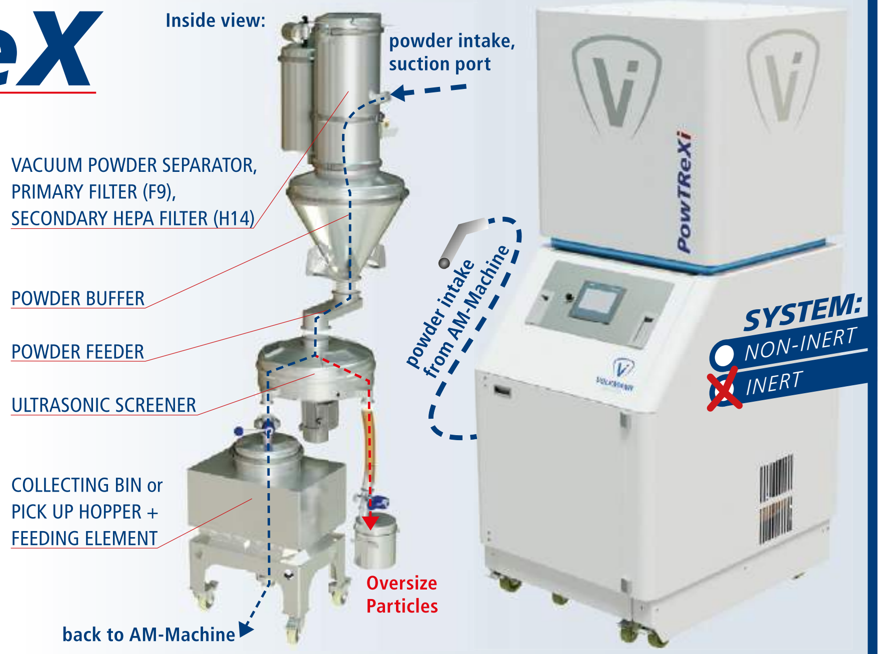
"Addaero's competencies are a natural extension of ATI's metallic powder expertise and will expand our capabilities to provide comprehensive customer solutions ranging from the design of parts for Additive Manufacturing to the production of ready-to-install components. The acquisition of Addaero is another building block in our strategy to enhance ATI's full specialty materials capabilities to provide end customers with finished products," Harshman continued.

"We are excited to have Rich Merlino and the entire Addaero team join ATI," added John Sims, ATI's Executive Vice President, High Performance Materials and Components Segment. "They bring an extraordinary amount of aerospace and defence industry knowledge and real-world Additive Manufacturing experience. The complementary nature of our two businesses will allow for a seamless integration; creating a more capable end-to-end metallic powder component supplier to our key customers."

"The Addaero team is excited to be a part of ATI. The combination of ATI and Addaero will increase the speed to market of new and innovative additively manufactured powder metal solutions for our aerospace and defence customers and beyond," stated Rich Merlino, President, Addaero Manufacturing.

www.atimetals.com

www.addaero-mfg.com ■■■



Link3D launches its Production Planning System for optimisation of Additive Manufacturing workflows

Link3D, New York, New York, USA, has introduced its Link3D Production Planning System (PPS), powered by Advanced Build Simulation and machine connectivity. Link3D PPS is an Additive Manufacturing scheduling solution which is said to enhance the company's AM software, enabling application engineers and shop floor managers to efficiently run their Additive Manufacturing machines. The PPS provides an automated way to:

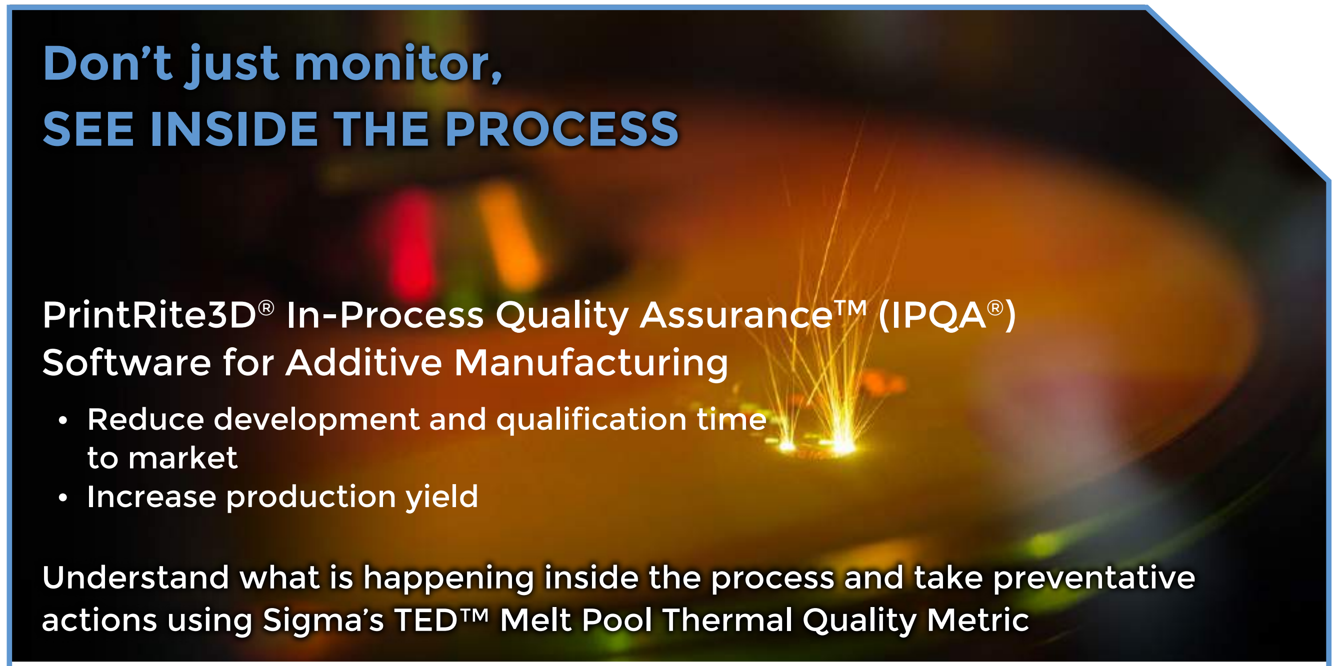
- Plan builds from order submission through to delivery
- Forecast accurate lead times and material usage using advanced build simulation
- Manage finite scheduling, production dispatching and schedule execution with machine connectivity
- Visualise and manage orders and facility capacity
- Trace and track the 'genealogy' of builds

Shane Fox, CEO & Co-Founder of Link3D, explained, "Our comprehensive predictive models are made to forecast AM production and costing outputs by accounting for labour, hardware model, AM technology, post-processing and including material science variables like specific gravity and viscosity. Link3D PPS utilises machine learning algorithms to make recommendations for placing work orders on the correct machines based on machine availability to achieve real-time distributed manufacturing."

Earlier in 2018, Link3D announced the launch of its blockchain technology for AM, designed to provide higher levels of file integrity, security and traceability and thereby help companies move towards mass adoption of AM. Link3D PPS also uses blockchain technology to track and trace all data logged and generated and help organisations validate and certify their processes.

Link3D launched across multiple OEMs and Service Bureaus this year and its Co-founders, Shane Fox and Vishal Singh, stated that they are confident that the company can help customers to achieve on-demand manufacturing across their internal facilities and AM partners. "Blockchain technology powering Link3D PPS is a step forward to enabling organisations to trace, track, validate and certify processes to help organisations move towards achieving 100% repeatability in 3D printing production," stated Singh, CTO of Link3D.

www.link3d.co ■■■



AP&C acquires gas atomisation equipment from Avio Aero

During the Farnborough International Airshow, UK, July 16-22, 2018, GE Additive stated that its materials division, AP&C, Montreal, Canada, has acquired the gas atomiser equipment currently installed at GE Aviation business Avio Aero's plant in Cameri, Italy. This technology is said to be complementary to AP&C's proprietary Advanced Plasma Atomisation (APATM) process.

As the AM industry continues to experience dramatic growth, so does the demand for powder and materials – with titanium and nickel-based alloys for the aerospace industry especially in demand. In anticipation of further increasing demand over the coming years and following a strategic business review, the gas atomiser technology installed in 2014 at Avio Aero's Cameri facility, at which point it was intended for the in-house production of powders of special metal alloys such as Titanium Aluminide (TiAl), is being transferred to AP&C's facility in Montreal.

The move is intended to better position the Additive Manufacturing technologies available within the GE family, allowing both companies to better focus on their respective businesses – AP&C on materials and powder production and Avio Aero on additively manufacturing aero engine components, using Arcam's EBM technology and powders developed by AP&C.

The equipment is expected to be operational by March 2019. As a result, AP&C will become a preferred supplier of TiAl for GE Aviation, as well as extending its technology portfolio and ability to offer a wider range of possibilities to its customers through an extended choice of powder processes. Gas atomisation technology is said to be particularly well-suited to powder recycling for those customers seeking sustainable solutions.

"Without ongoing materials science research and innovation, additive will struggle to advance. So, while this relocation makes sense commercially, it is also a key element of our future materials development strategy. Having this complementary technology in the AP&C portfolio opens up wider possibilities for us as a business and also for our customers, who continue to want to push boundaries," stated Alain Dupont, President & CEO, AP&C.

Giacomo Vessia, Cameri plant leader, Avio Aero, commented, "The equipment moving to Canada means more volume and capabilities at our Cameri plant. And of course more 3D printing machines. In addition to focusing on additive processes, we will also have the time and more space to train and equip our existing and new team members with future manufacturing skills."

www.ge.com/additive ■■■

Avio Aero's facility in Cameri, Italy (Courtesy GE Aviation)

FLIR Systems' new equipment for NDT and stress mapping of advanced materials

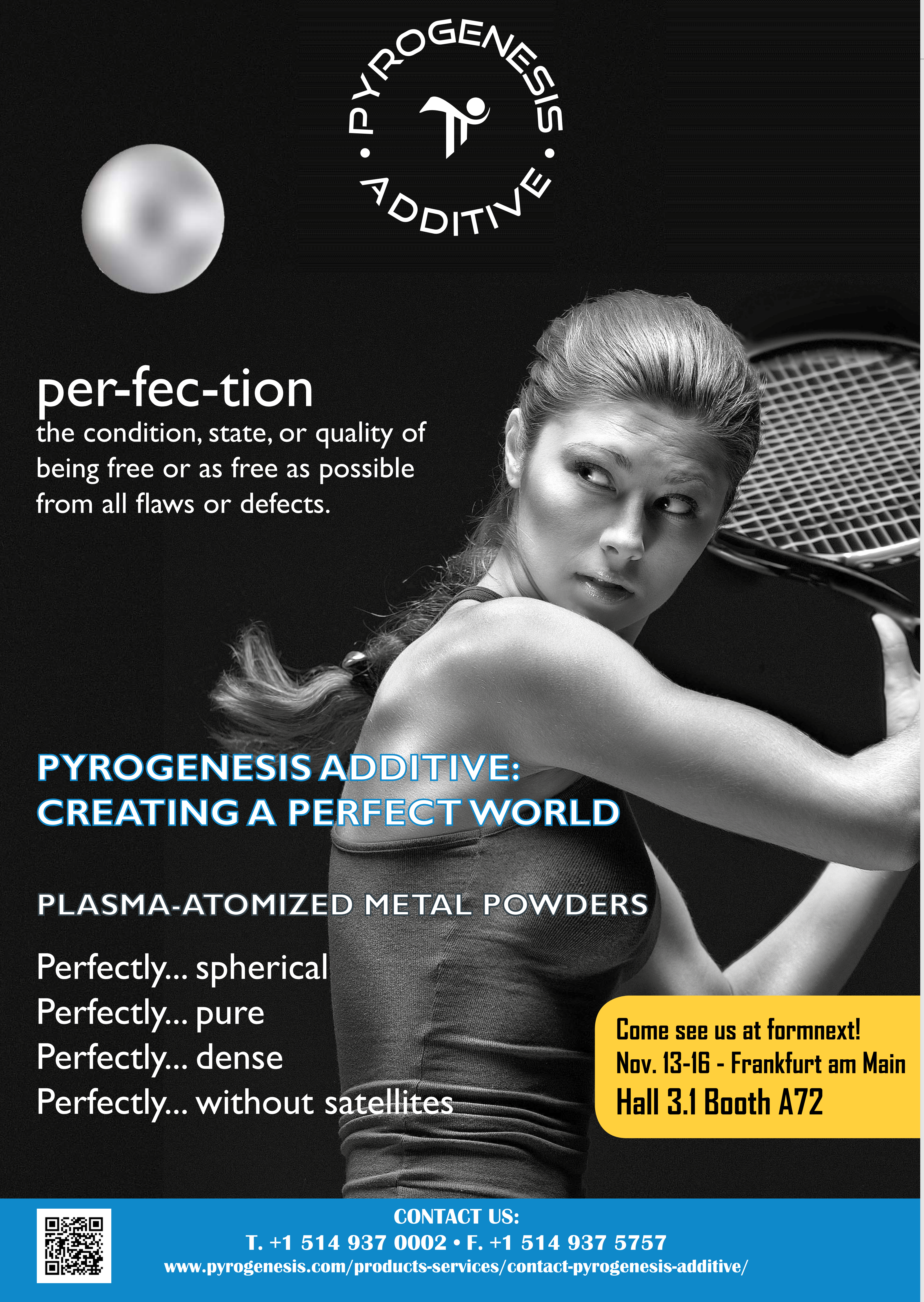
FLIR Systems, headquartered in Wilsonville, Oregon, USA, has launched its FLIR A6750sc SLS thermal imaging camera range for the Non-Destructive Testing (NDT) of advanced materials. The new camera range features lock-in, transient and pulse capabilities for NDT, as well as for stress mapping during materials testing.

NDT is widely used to evaluate the properties of a material, component, or system without causing damage. Thermal imaging cameras can detect internal defects, through target excitation and the observation of thermal differences on a target's surface, and can be used for the detection of defects and points of failure in composites, solar cells, bridges and electronics.

The FLIR A6750sc SLS incorporates a cooled Strained Layer Superlattice detector that is said to operate in the 7.5–10.5 µm waveband and produce 640 x 512 px thermal imagery. It is capable of detecting temperature differences smaller than 20 mK (typically 18 mK). Th company's proprietary 'lock-in' process is said to make it possible to detect temperature differences as small as 1 mK.

The FLIR A6750sc SLS uses a standard GigE Vision® interface to transmit full dynamic range digital video and GenICam for camera control. Additional interfaces include a BNC analog video output. The camera is designed to work seamlessly with FLIR's ResearchIR Max software to enables intuitive viewing, recording and advanced processing of the thermal data provided. A Software Developers Kit is also optionally available.

www.flir.eu ■■■



Siemens metal AM gas turbine burner completes successful first year of operation

The first gas turbine burner to be produced by Siemens using Laser Powder Bed Fusion (LPBF) metal Additive Manufacturing has now been in operation for over 8,000 hours, having completed its first full year of active service in an SGT-700 gas turbine at E.ON's combined cycle power plant in Philippsthal, Germany. To-date, Siemens stated that the burner has no reported issues.

Siemens began additively manufacturing gas turbine burners by LPBF in 2017 with its intelligent burner manufacturing (IBUMA) programme in Finspång, Sweden. Using AM enabled the company to produce each burner head in one piece, compared to conventional methods requiring thirteen individual parts and eighteen welds.

The redesign of the part for AM also enabled improvements to the functionality of the burner, such as incorporation of the pilot-gas feed into the head instead of the outside fuel pipe. This allows the operating temperature to be kept lower and contributes to a longer operational lifespan.

Working side-by-side, Siemens and E.ON became co-creators on this project, realising benefits on both sides of the partnership. Siemens stated that it is accelerating the development of innovative design and manufacturing technologies, while E.ON is benefitting from these innovations at an early stage.

"As an energy service provider, precision and consistency are an absolute requirement for us," explained Niklas Lange, Project Manager at E.ON Energy Projects. "Additive Manufacturing not only delivers this, but in our experience it can even improve performance compared with older models."

"We like to help drive innovation," he continued. "When I saw these burners from Siemens in Sweden, I knew we could benefit from using them in a commercial turbine. It's also important to note that our hands-on collaboration with Siemens has been a key to deliver performance to our customer."

Vladimir Navrotsky, Chief Technology Officer for Siemens Power Generation Services, Distributed Generation, commented, "These early results from the IBUMA burner with E.ON validate our belief that this technology is a game-changer. We appreciate E.ON's active participation and commitment to driving innovation and look forward to our continued close collaboration."


Siemens' metal AM gas burner for the SGT-700 gas turbine operating at E.ON's combined cycle power plant in Philippsthal, Germany (Courtesy Siemens)

Siemens began investing in metal AM in 2008 and has since been developing the technology specifically for power generation. In 2012, it installed its first EOS M280 SLM printer and adapted it for burner repairs. In 2013, the first additively manufactured burner tips and swirlers were installed in commercial gas turbines. In 2016, Siemens acquired UK-based Materials Solutions and in 2017, designed and printed the world's first gas turbine blades and validated them under operating conditions.

www.siemens.com
www.eonenergy.com ■■■

Powder Metallurgy and Additive Manufacturing of Titanium Conference issues Call for Presentations

The 2019 Powder Metallurgy and Additive Manufacturing of Titanium Conference (PMTi2019) has issued a Call for Papers for presentation at its first USA-based event. The conference, which has previously been held in Australia, New Zealand, Germany and China, will be held at the University of Utah, Salt Lake City, Utah, USA, from September 24–27, 2019.

The Metal Powder Industries Federation (MPIF) will sponsor the conference and invites the submission of abstracts on the topics of powder production, compaction and shaping, Metal Injection Moulding (MIM), Additive Manufacturing, sintering, mechanical properties, microstructure vs property relationships, PM Ti alloys including TiAl, PM Bio Ti materials, modelling and applications.

Abstracts are due by April 15, 2019. The MPIF stated that all abstracts will be judged on technical merit and should emphasise results and conclusions in addition to what is new about the work. All manuscripts will be included in the post-conference proceedings.

www.PMTi2019.org ■■■

Canadian AM centre focuses on manufacture of marine certified components

Researchers at Canada's Marine AM Center of Excellence (Courtesy University of New Brunswick)

The University of New Brunswick, Canada, has purchased a GE Additive Concept Laser M2 cusing metal Additive Manufacturing system for use by the Marine Additive Manufacturing Center of Excellence, along with its training partners New Brunswick Community College, the College Communautaire du Nouveau-Brunswick, and Nova Scotia Community College.

The centre, which is being spearheaded by the University of New Brunswick, is said to be the first in Canada to use metal AM for the production of certified parts for the marine industry. Key research and development topics include enhanced corrosion protection, hybrid AM, smart parts and blast resistance.

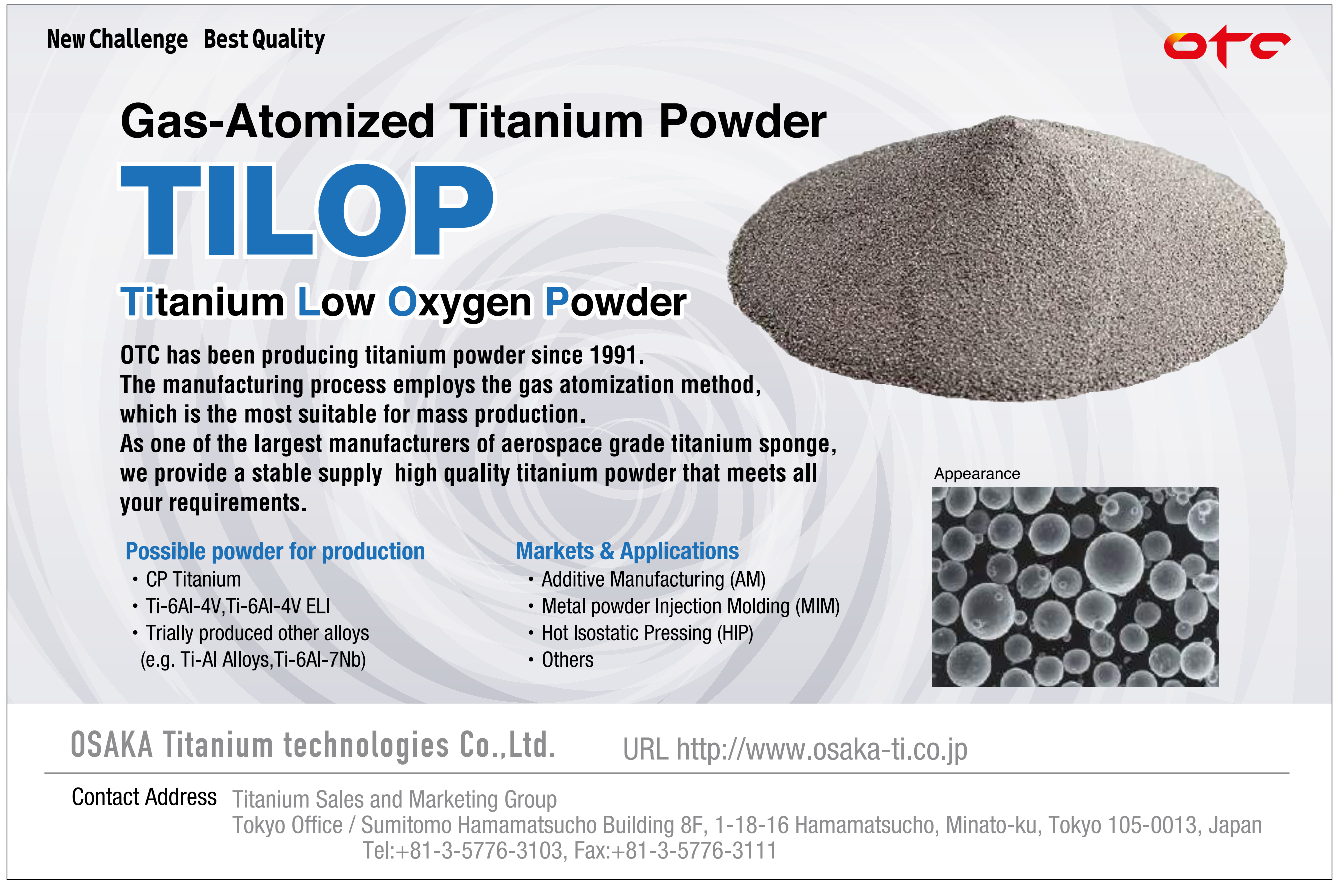
This initiative is the result of a partnership with UNB, Custom Fabricators and Machinists (CFM), and community colleges in New Brunswick and Nova Scotia. As well as being the first in the country to produce certified AM marine parts, the centre is also said to be the first of its kind in Canada to combine research, commercialisation and workforce development and training.

Dr Mohsen Mohammadi, Director of the Marine Additive Manufacturing Centre of Excellence and Assistant Professor of Mechanical Engineering at the University of New Brunswick, stated, "This is the first centre of its kind in Canada and we are doing it right here in New Brunswick. Our technology is greener and more efficient than conventional methods and will create high-value jobs here."

GE Additive refers to its M2 cusing family as the 'workhorse' of its metal Additive Manufacturing product portfolio. According to the university, this machine will be used in a variety of research and development areas by Dr Mohammadi and his team, with metal Additive Manufacturing builds being performed at an industrial fabrication and machine shop in Saint John, New Brunswick.

www.ge.com/additive

www.unb.ca ■■■



Titomic to open Kinetic Fusion R&D facility at new Australian training centre

Titomic, Melbourne, Australia, will launch a Titomic Kinetic Fusion R&D facility as part of a new $4.9 million Australian Research Council (ARC) Training Centre for the Surface Engineering for Advanced Materials (SEAM) with Melbourne's Swinburne University of Technology. The R&D facility will be based at Swinburne and is expected to be capable of incubating multiple Additive Manufacturing projects.

At the facility, Titomic, will work in conjunction with fellow core partner the Australian Nuclear Science and Technology Organisation (ANSTO), Swinburne PhD students and postdoctoral researchers to further the capabilities of its existing Titomic Kinetic Fusion systems. A smart factory designed to make use of advanced automated robotic systems will also be launched at the centre to create cyber-physical systems for the commercial Additive Manufacturing of speciality bespoke metal alloy products using Titomic Kinetic Fusion.

The research grant provided by the ARC is expected to see the training centre integrate industry-university cooperation in applied training and novel research outcomes and applications, with a specific focus on surface engineering. The project team will be trained on those aspects of the Titomic Kinetic Fusion process that are unique to AM.

Jeff Lang, Titomic CTO and named SEAM core partner investigator, stated, "The new ARC Training Centre will allow the creation of the Titomic Kinetic Fusion R&D facility at Swinburne University. This will result in the creation of cutting-edge material advancements and commercial manufacturing systems that are based on Industry 4.0 to enhance the Titomic Kinetic Fusion process as a viable commercial manufacturing integrated system."

"This federal government grant comes at an exciting time for Titomic and the entire metal Additive Manufacturing sector, which is currently experiencing exponential growth worldwide," added Gilbert Michaca, Titomic CEO. "Titomic will invest $250,000 over a five year period as a core partner in the SEAM project to assist the creation of the ARC Training Centre, whilst highlighting Titomic as the global leader of industrial-scale Additive Manufacturing."

www.titomic.com ■■■

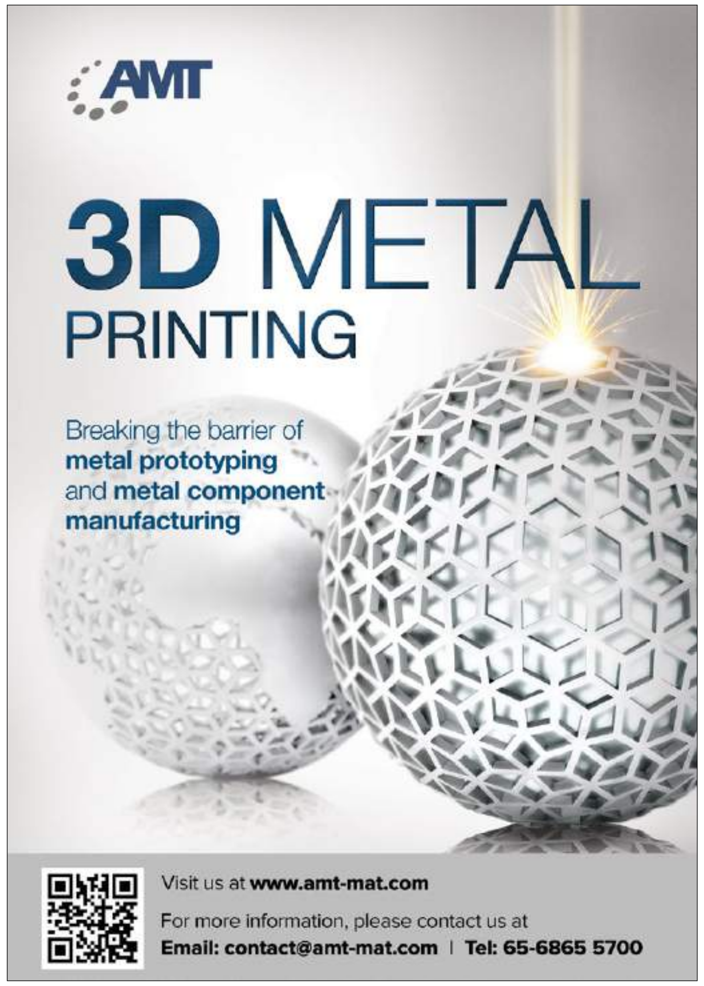
Sintavia announces further expansion

Sintavia, LLC, Davie, Florida, USA, has increased its production capacity with the installation of four new Additive Manufacturing machines. The company has added two new EOS M400-4 large-scale machines, an EOS M290 medium-sized system for volume production and TRUMPF TruPrint 3000, the first machine of its kind in North America.

Sintavia is an independent metal AM component manufacturer for critical industries, including aerospace and defence, oil and gas, automotive and power generation. Serving the international community, the company's operations include precision post-processing equipment, a full complement of mechanical testing equipment, and a full metallurgical and powder laboratory.

It holds NADCAP, AS9100 Rev. D, ISO17025, and ANAB accreditation, as well as being OASIS registered and ITAR compliant. The company expects to more than double its capacity to twenty-five machines in 2019 with the move to its new facility in Hollywood, Florida.

www.sintavia.com ■ ■ ■



Renishaw opens new Additive Manufacturing demonstration centre in California

Renishaw, headquartered in Wotton-under-Edge, Gloucester, UK, has opened its Additive Manufacturing Demonstration Center in Newbury Park, California, USA. Working in collaboration with Ibex Engineering, the new demonstration centre is situated within Ibex's headquarters and allows visitors to explore, interact with and use Renishaw's latest metal Additive Manufacturing systems.

The centre will be equipped to manufacture high-precision titanium (Ti64Al4V) parts on Renishaw's RenAM 500 series of Laser Powder Bed Fusion AM systems. Ideal for industrial production applications, the RenAM 500 series allows for powder sieving and recirculation to be carried out automatically within the compact system, reducing the need for manual handling and exposure to materials.

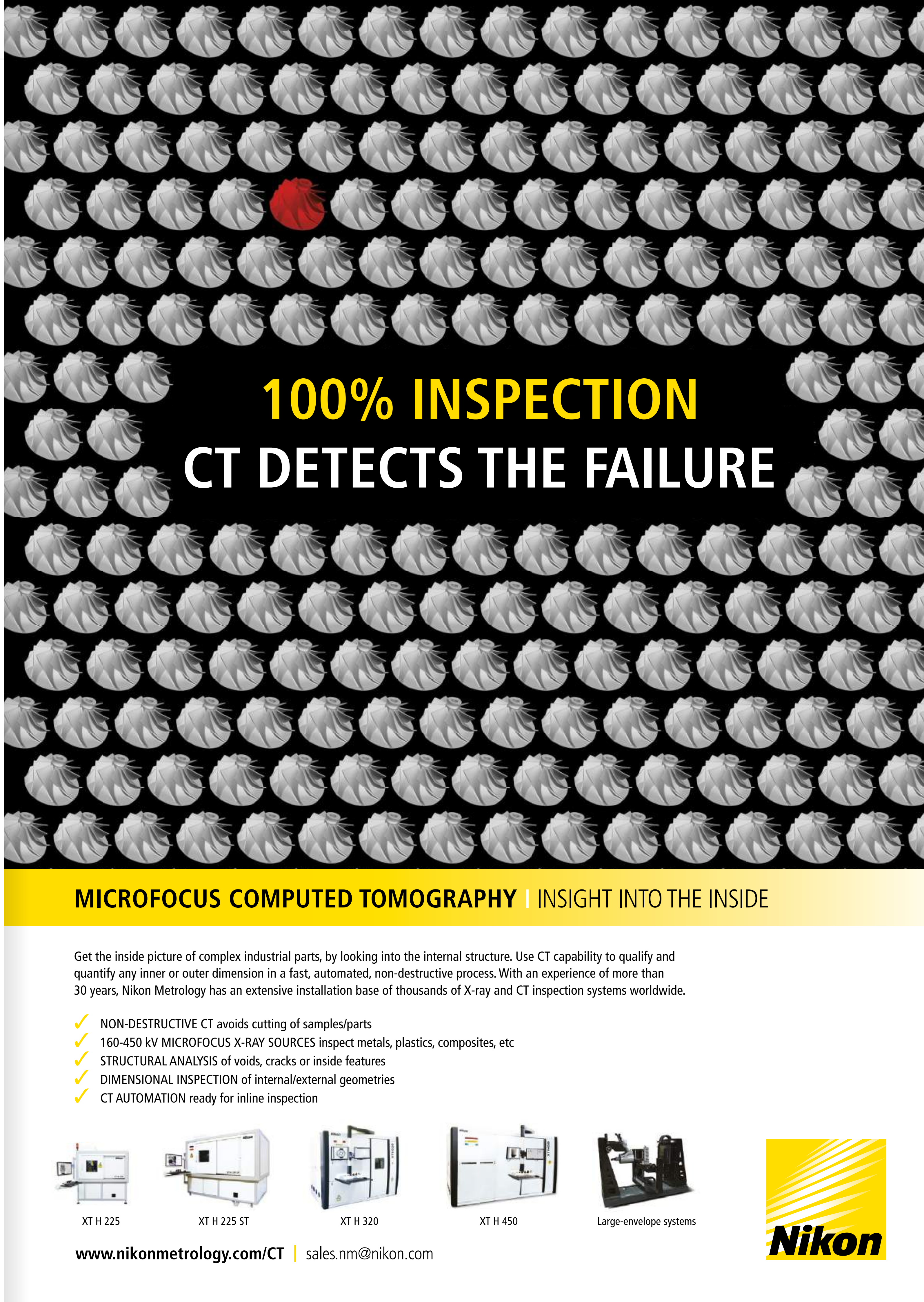
To provide a complete picture of the metal AM process, the centre will also feature ancillary elements such as wet downdraft, heat treatment, support, machining and inspection technology, and part removal equipment. These components work in concert with the AM system to ensure parts are printed and finished to specifications.

Also available at the site are InfiniAM Central software showcasing AM production reporting functionality and QuantAM build preparation software, which allows visitors to work through the development of a AM machine build file, including material parameter development.

Stephen Anderson, AM Business Development Manager at Renishaw USA, stated, "It's fantastic to be able to place a metal Additive Manufacturing production cell within Ibex. Not only does it allow us to showcase our latest technologies, but partnering with Ibex provides us access to an expert manufacturer of precision staging equipment who will utilise the technology to develop innovative products, and drive metal AM into new markets and even wider adoption."

Andre Perrin, Ibex Engineering's CEO, said, "We have been a user of Renishaw's high precision encoder systems in our products for many years and have a close working relationship. They understand manufacturers and manufacturing, the importance of quality, reliability and, most importantly, service. We are very excited about Renishaw's approach to metal Additive Manufacturing and their vision to develop high precision, repeatable machines capable of serial production of parts. We look forward to developing new AM parts for our business and to sharing our knowledge with Renishaw's visitors."

www.renishaw.com
www.ibexeng.com ■ ■ ■



Guyson introduces new ATEX blast cabinet systems

Industrial finishing equipment manufacturer Guyson International, Skipton, UK, showcased its new Euroblast® Ex range of blast systems at TCT Show 2018, Birmingham, UK. Designed for use with potentially explosive powders and certified to the directive ATEX 2014/34/EU, the systems are coded; ATEX II 2/3 D Ex h T135°C Db/Dc.

These systems are particularly relevant in Additive Manufacturing applications where the use of fine powders, such as aluminium, titanium and Inconel powder, can create potentially explosive atmospheres. Mark Viner, Guyson's Managing Director, stated, "As the AM market continues to evolve and encompass more and more mainstream production, it is essential that appropriate legislation and risk awareness keeps pace."

"Guyson is leading the way in the operational health and safety of blast cabinets and have invested heavily in ensuring that our new range of Euroblast Ex blast cabinets are fully compliant and certified to current ATEX legislation," he continued. "Anyone choosing Guyson can rest assured that they have done the best for their operators, minimised all operational risks and purchased a product at the forefront of this technology."

The Euroblast® Ex 8SF ATEX blast cabinet (Courtesy Guyson)

The Euroblast Ex range features four sizes of blast cabinet, a cyclone reclamator and Guyson C600 dust collector. An optional rotating basket is available on select models.

www.guyson.co.uk ■■■

NextGenAM project launches its pilot plant for industrial AM

NextGenAM, a joint project of Premium AEROTEC, Daimler and EOS, has launched its first pilot plant for the development of industrial Additive Manufacturing, at Premium AEROTEC's technology centre in Varel, Germany. The goal of the project is to develop a complete production cell capable of manufacturing aluminium components for the automotive and aerospace industries. Since the project officially began in May 2017, the NextGenAM team is reported to have investigated the entire AM process to assess its potential for automation. The new purpose-built pilot facility in Varel is currently said to consist of various AM machines, as well as solutions for post-processing and quality assurance.

In line with the goals of the project, NextGenAM's partners state that individual steps, and the interaction of all additive and conventional process steps, are fully automated and integrated at the pilot plant, and that manual steps have been eliminated. As a result, complex, lightweight and at the same time robust components can be manufactured and the high level of automation forms the basis for profitable production going forward.

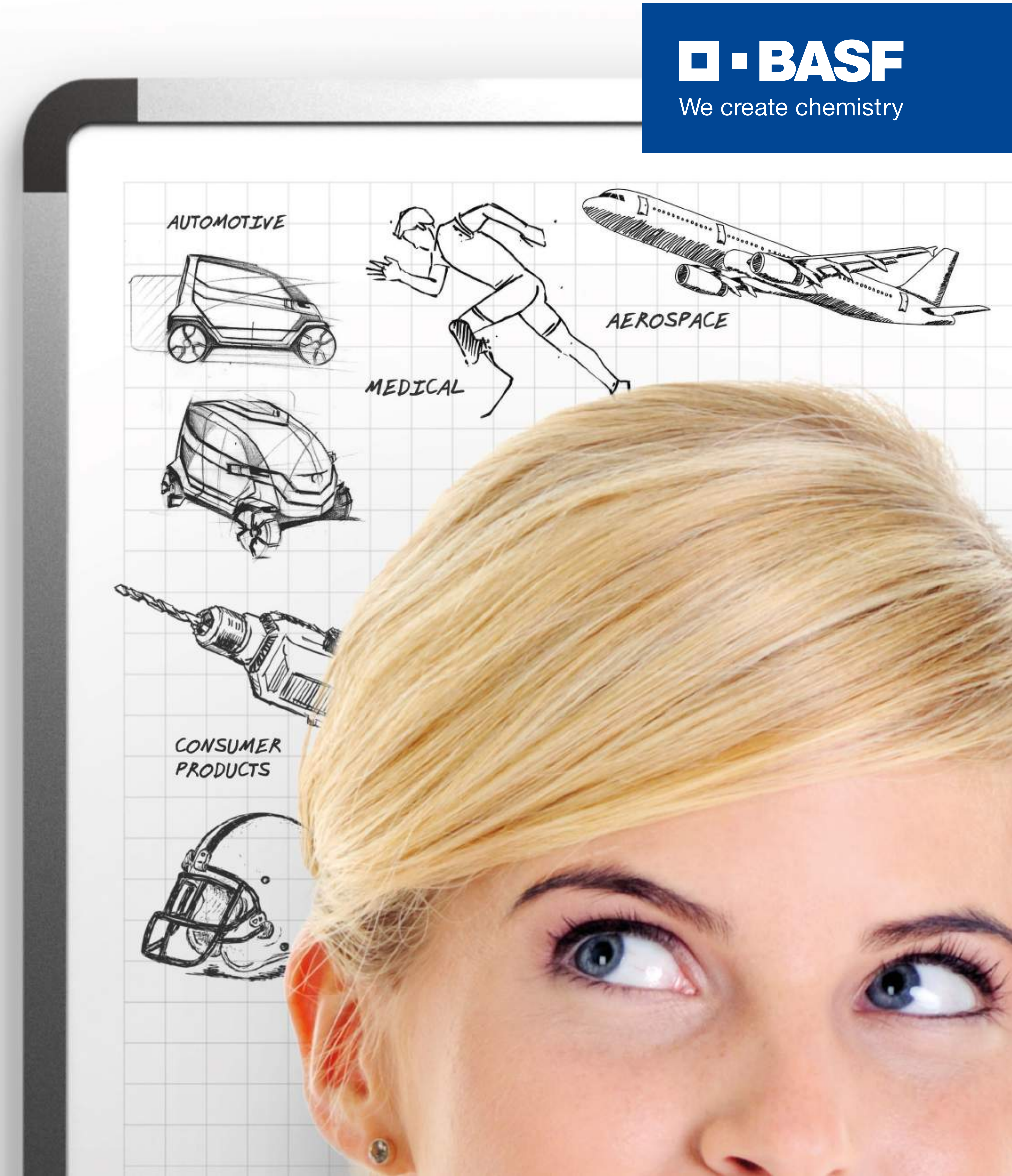
Central to the pilot production chain is an EOS M 400-4 four-laser system for industrial metal Additive Manufacturing. This system is used in combination with the peripheral solutions offered as part of the EOS Shared-Modules concept, and is therefore equipped with a powder station and connected to a stand-alone setup and unpacking station.

Filling and emptying the system with the aluminium material, setting up the system to prepare a new build and unpacking built components from the powder bed can be carried out independently of and parallel to the actual AM build process. This significantly increases productivity. The AM components are transported between the individual stations in a fully automated process and under protective gas, in a container on an automated guided vehicle.

Downstream post-processing has also been extensively automated. Following build completion, a robot removes the build plate with the parts on it from the setup station and places it in a furnace for subsequent heat treatment. The same robot then removes the plate again and transports it to a three-dimensional optical measurement system for quality assurance purposes. Finally, the build plate is conveyed to a saw, which separates the parts from the plate.

Jasmin Eichler, Daimler AG, Head of Research Future Technologies, stated, "3D printing is well on the way to establishing itself in the automotive sector as an additional manufacturing method with great versatility. With this collaborative pre-development project, we are taking a significant step towards achieving cost-effectiveness in metal 3D printing throughout the process chain. The project lays the cornerstone for the future realisation of larger quantities in the automotive series production process– with the same reliability, functionality, longevity, and economy as for components from conventional production."

www.eos.info/nextgenam ■■■



Osseus receives FDA approval for five new additively manufactured titanium spine implants

Osseus Fusion Systems, based in Dallas, Texas, USA, has announced FDA 510(k) clearance for Aries, its family of additively manufactured lumbar interbody fusion devices. The implants are constructed from titanium, optimised for bone fusion and biological fixation using PL3XUS, Osseus' innovative and proprietary AM technology.

PL3XUS titanium technology utilises Laser Powder Bed Fusion to create 80% porous implants with increased bone packability and lower stiffness compared to competitive devices on the market. Aries implants are manufactured in 30 micron layers of titanium powder and sintered in solid, porous parts, in sequential layers. The implants then undergo a rigorous, proprietary post-processing cycle to optimise the device for clinical outcomes.

"We are thrilled to launch the Aries family of 3D-printed lumbar interbodies," stated Eric Hansen, Co-Founder and CEO of Osseus. "The clinical benefits of 3D-printed titanium speak for themselves and Osseus is poised to capture market share in an exponentially growing industry like never before."

"In this industry, you're perpetually considered the underdog if you're a private, self-funded company," added Robert Pace, Co-Founder and CFO of Osseus. "We now have one of the most comprehensive portfolios of 3D printed spine implants. Osseus is unique in our ability to bring surgeon-inspired implants to market quicker than any competitor, and our focus on R&D delivers unparalleled performance and quality to our surgeons and patients."

This is the first FDA 510(k) clearance that Osseus has received for AM spine implants, and the approval effectively doubles the company's product portfolio.

"This is just the first of many 3D printed products that Osseus is working on," stated Asher Breverman, Additive Manufacturing Engineer of Osseus. "We're pushing the boundaries of design with new generative design software packages and surgeon-inspired products with our ability to work with surgeons like never before."

www.osseus.com

The Aries titanium implant has received FDA 510(k) clearance (Courtesy Osseus)

Tethon 3D receives funding to develop metal and ceramic Additive Manufacturing system

Tethon 3D, Omaha, Nebraska, USA, a producer of ceramic powders and photo curable ceramic polymers for Additive Manufacturing, has been awarded a grant by the Nebraska Department of Economic Development to pursue the design and production of a ceramic and metal Additive Manufacturing system. The project, titled 'A Novel DLP 3D Printer Optimized for Ceramics and Metals', will begin immediately and will see Tethon 3D collaborate with engineers at the University of Nebraska on the system's development.

Karen Linder, Tethon 3D CEO, stated, "While there are more than a dozen SLA and DLP 3D printers that work well and are compatible with our UV curable ceramic and metal materials, they are all designed for plastic polymers. By optimising a DLP printer for ceramics and metals and formulating our materials specifically for this enhanced printer, the industry can produce stronger and higher resolution ceramic and metal 3D printed parts with the convenience and lower expenses of desktop DLP technology."

"The Academic Research and Development Program supports partnerships between Nebraska entrepreneurs and academic institutions, and continues to produce incredible results in terms of putting our companies on the leading-edge of innovation and enhancing their industry competitiveness," added Dave Rippe, Nebraska DED Director. "We congratulate Tethon 3D and the University of Nebraska on their new venture, and look forward to their success."

The launch of this collaborative project creates a new hardware division for the Tethon 3D, which has previously produced only AM feedstock. "Our printer will create new opportunities for designers to develop complex ceramic and metal components and will enable higher volume manufacturing of 3D printed ceramics and metals. We are passionate about creating new markets, fabricating designs that were previously impossible and disrupting existing manufacturing approaches."

www.tethon3d.com
www.unl.edu

DNV GL launches approval of manufacturer scheme for maritime Additive Manufacturing

Classification society DNV GL, Oslo, Norway, has released what it states is the first approval of manufacturer (AoM) scheme for companies wishing to supply additively manufactured products for the maritime industry that comply with the DNV GL rules and standards. Companies applying for AoM must firstly undertake a proof of concept to demonstrate that they have feasible technology and products, after which the programme will verify their ability to consistently manufacture materials and products to given specifications.

Knut Ørbeck-Nilssen, CEO of DNV GL - Maritime, explained, "AM is a technology that holds a great deal of promise for the maritime industry. Our responsibility as the world's leading classification society is to give manufacturers a clear path they can take to offer their innovative products, while ensuring that our customers can have the same confidence in an AM product as they do in any other that has undergone approval by class."

"The release of the AoM programme opens up new opportunities for both producers and users of these products, creating potential efficiencies in logistics and supplies chains, as well as in on-board maintenance and repair," he continued. "Above all, however, we must ensure that safety and quality standards are upheld, and this new programme allows producers to demonstrate their fitness to the shipping industry."

DNV GL has been investigating the opportunities and challenges posed by AM since 2014. In December 2017 it partnered with Aurora labs to certify metal AM parts for the oil & gas, renewables and marine industries and develop an AM certification standard to cover the entire value chain from powders to parts. Earlier this year, DNV GL opened its Global Additive Manufacturing Centre of Excellence in Singapore, an incubator and test-bed for the research and development of AM technology for the oil & gas, offshore and marine sector.

www.dnvgl.com


DNV GL has established a scheme for companies wishing to supply AM products to the maritime industry (Courtesy DNV GL)

NIAR is first strategic partner for ASTM International's Additive Manufacturing Center of Excellence

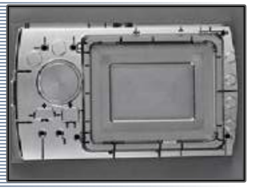
Wichita State University (WSU)'s National Institute for Aviation Research (NIAR), Wichita, Kansas, USA, will join ASTM International's Additive Manufacturing Center of Excellence as its first 'strategic' partner. ASTM International and four founding partners recently launched the centre to support R&D to advance Additive Manufacturing standards, and in turn drive the commercialisation of cutting-edge Additive Manufacturing technologies.

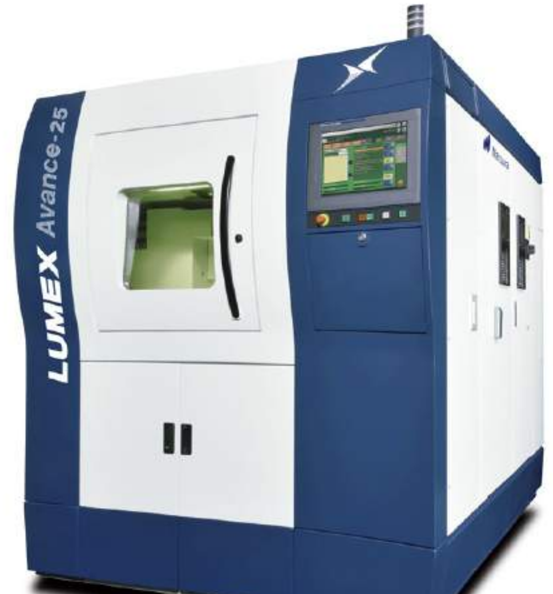
Dr John Tomblin, WSU's Vice President for Research and Technology Transfer, and Dr Mohsen Seifi, ASTM International's Director of Global Additive Manufacturing Programs, made the announcement during a joint workshop focused on the qualification and certification of metal AM parts. "We're proud to be the first strategic partner in this globally-recognised centre of excellence that will help build the technical foundation for the future of Additive Manufacturing," stated Tomblin. "The centre is attracting an array of leading industry players to the table to speak with one voice and make an impact."

Speaking during the workshop, Seifi added, "Building on its strengths, NIAR will lead efforts to qualify additively manufactured materials and to further strengthen relationships with key aerospace regulators worldwide. Leveraging their expertise in R&D, we will develop much-needed standards that will significantly enhance certification in aviation and other industries. We're thrilled to have the NIAR team on board."

NIAR is an industry-focused research institute and, as such, stated that it plans to be engaged in the centre of excellence's R&D, education and workforce development activities, in addition to other functions and programmes. The centre's founding partners are US based Auburn University, NASA and EWI, as well as the UK's Manufacturing Technology Centre.

www.niar.wichita.edu
www.astm.org
www.amcoe.org





Additive Manufacturing on the agenda at the 8th Aviation Forum Hamburg

The 8th Aviation Forum Hamburg will be held at Hamburg Messe, Hamburg, Germany, from November 5–7, 2018. Organised by the Institute for Production Management AG (IPM AG), Hannover, Germany, in partnership with Airbus, Toulouse, France, the forum is a key conference and exhibition for the global supply chain of the aerospace industry.

Since its launch in 2010, the Aviation Forum is said to have become a major annual event for the aerospace industry, connecting a large number of global suppliers and partners to discuss future perspectives and directions. In 2017, the forum attracted more than seven hundred participants from twenty-two countries, with the exhibition hosting ninety exhibitors.

The forum will begin on November 5 with a pre-conference day comprising a series of plant tours, giving attendees the opportunity to tour selected local production facilities for Airbus, Dassault Systemes and ZAL, Lufthansa Technik and Safran Nacelles Integration Center. This will be followed by a networking event in the exhibition area.

Additive Manufacturing and the opportunities it offers to the aerospace industry will be up for discussion on both days of the conference agenda, featuring in a number of presentations. An in-depth look at AM will be offered by a master class on day one of the conference, titled 'Additive Meets Digital' and presented by Bjoern Klass, European VP and Managing Director, Protolabs Europe.

A workshop on Additive Manufacturing will also be held on day one, moderated by Prof Dr Michael Eßig, Bundeswehr Universität München, and presented by Jérôme Rascol, Head of ALM Platform, Airbus, Josef Gropper, Managing Director and COO, Liebherr, Christoph Hauck, Managing Director, MBFZ toolcraft GmbH, Kevin McAlea, Executive Vice President Metals & Healthcare, 3D Systems, and Klaus Müller, Chief Sales Officer, Bionic Production AG.

On day two of the conference, both 'Best Practice Tracks' of the conference will feature an in-depth look at Additive Manufacturing and relevant topics, with Dan Johns, Global Head of R&D at Oerlikon AG, presenting on 'Collaboration in Aerospace to unlock the AM Market', and Dr Simon Merkt-Schippers, Technology Manager Additive Manufacturing for Aerospace and Energy, TRUMPF Laser- und Systemtechnik GmbH, presenting on 'Industrial Additive Technologies'.

Other topics up for discussion during the conference will include supply chain management, global production, the Airbus Bombardier partnership, future supply network, digitalisation, MRO, interior, disrupting business models and automated production.

www.aviationforumhamburg.com ■■■

Norsk Titanium's New York site added to Spirit AeroSystems approved supplier list

Norsk Titanium's Plattsburgh Demonstration & Qualification Center (Courtesy Norsk Titanium)

Norsk Titanium, New York, USA, an FAA-approved supplier of aerospace-grade additively manufactured structural titanium components, has announced that its Plattsburgh Development and Qualification Center (PDQC) site, New York, USA, has been officially added to Spirit AeroSystems' Approved Suppliers List.

Spirit AeroSystems is one of the world's largest independent aerostructures manufacturers and the announcement comes in anticipation of the start of qualified production later this year. Norsk's PDQC was added to Boeing's Qualified Producers List (QPL) list in June and is AS9100D certified. The company believes the new qualification by Spirit is key to furthering the availability of its Rapid Plasma Deposition™ (RPD™) technology in the aerospace market.

Tamara Morytko, Norsk's Chief Operating Officer, stated, "These significant achievements have been made possible by the foresight and commitment made to Norsk by the State of New York and Empire State Development. We are extremely proud of our PDQC quality and operations teams and appreciate the continued confidence our customers have demonstrated in Norsk by granting these qualifications."

The PDQC currently houses nine of Norsk's RPD titanium Additive Manufacturing machines. The RPD process uses titanium wire with plasma torches to additively manufacture titanium structural components. The systems can be used to produce large structural parts weighing over 45 kg (100 lbs) and is said to be 50-100 times faster than powder-based systems, using 25-50% less titanium than forging processes. This technology is applicable to aviation, space, transportation, oil & gas and maritime.

www.norsktitanium.com ■■■

Air Products to relocate its global headquarters

Air Products, Allentown, Pennsylvania, USA, has announced that it will begin construction on its new global headquarters in Lehigh Valley, Pennsylvania, close to its existing location. The new headquarters will be based on a fifty acre site and the company expects to break ground in March 2019, with completion targeted for Summer 2021.

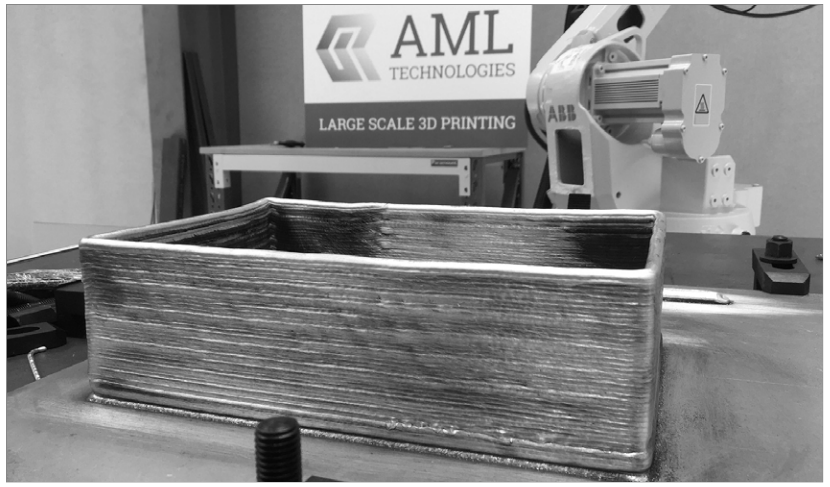
The new headquarters will be occupied by approximately 2,000 employees and includes capacity for future growth. Seifi Ghasemi, Air Products' Chief Executive Officer, stated, "From the beginning of this process to develop a new headquarters facility, we have never wavered in our commitment to remain in the Lehigh Valley. Now, we have made the location decision and we begin our preparations to build facilities that represent our world-class company. This is a very exciting time for Air Products as we evolve our headquarters environment to be more beneficial to our employees and take advantage of sustainable technologies to lessen our footprint and reduce operating costs."

As it continues to focus strongly on Industrial Gases, Air Products has divested a number of non-core businesses over the last two years. These moves, in combination with other operational changes, are said to have resulted in excess building space at Air Products' present location, compounded by annual maintenance costs of approximately $20 million on the sixty-year-old building. A cost estimate for the new site has not been disclosed at this time. It will include the company's new administration offices, a Research and Development (R&D) facility and an enclosed parking structure for employees.

"The decision to leave our current headquarters location, with its rich history, was not one we made lightly," stated Ghasemi. "But we believe our new location will afford us a special opportunity to modernise and optimise our office space and R&D facilities and invest in a work environment that motivates and energises our employees. As a global company operating in more than fifty countries, this new headquarters will reflect the safety, speed, simplicity and self-confidence that move us forward as a world-leading industrial gas company."

www.airproducts.com ■■■

AML is the first wire-arc AM facility certified by Lloyd's Register



An example of a wire-arc additively manufactured metal structure produced by AML (Courtesy AML Technologies)

AML Technologies, Adelaide, Australia, has become the first wire-arc Additive Manufacturing (WAAM) facility to receive Lloyd's Register's AM facility qualification certificate. The company serves as an Additive Manufacturing service bureau, manufacturing parts using its WAAM technology.

Prior to awarding the certification, Lloyd's Register's auditors carried out a full review of AML's systems specific to the WAAM process, as well as a survey of its facility. The facility qualification included a review of such areas as material handling, personnel competence, build process control, health and safety and control of non-conforming items.

"Third-party inspection offers an unbiased advantage to potential customers wishing to build parts using AML's process," stated Andy Sales, AML's Managing Director. "That's core to our values at AML. At the end of the day, the facility certification from Lloyd's Register will help provide awareness and assurance for customers to use AML for their OEM part and component type approval and qualification needs."

Previously, Lloyd's Register's facility certifications for AM have focused on powder-based processes and systems. However, the organisation commented that powder-based AM processes are typically limited by the size of components that can be produced and the available materials.

"These limitations have delayed the adoption of powder-based AM systems for marine and offshore industries," explained Hussain Quraishi, Strategic Projects Lead at Lloyd's Register's Global Technology Centre, Singapore. "Using wire feedstock enables companies to produce larger component sizes with a wider selection of materials. Combined with the lower cost of wire feedstock, this unlocks significant potential for the marine & offshore industries in particular."

"From our humble beginnings, AML had set quality accreditation as a planned key milestone," added Sales. "Our early engagement with LR for facility qualification was a very smooth and efficient process. We gained valuable knowledge and appreciated the solid foundation of LR's highly experienced and enthusiastic surveyors and auditors. We are excited and look forward to working further with LR as our business grows."

www.amltec.com ■■■

Böhler Edelstahl selects Tech-Labs to expand US distribution channel

Böhler Edelstahl, the Austria-based manufacturer of high-quality metal powders for the industrial Additive Manufacturing market, has announced that Technical Laboratory Systems Inc. (Tech-Labs), located in Katy, Texas, USA, will represent Böhler in the Southwestern United States region.

Tech-Labs is a full-service capital equipment and solutions provider for advanced manufacturing, industrial maintenance, renewable energy, and engineering segments also represents Renishaw and Desktop Metal Additive Manufacturing Systems, as well as being a Stratasys Platinum Partner.

"We are pleased to bring Böhler Edelstahl technology to our customers looking to further optimise their 3D printing operations," said Warner Brown, Vice President at Tech-Labs. "We immediately recognised the innovation and impact of Böhler Edelstahl's products and are excited to offer our customers access to the best quality metal powders available."

Böhler's AM facility in Kapfenberg (Courtesy Böhler)

www.tech-labs.com

www.bohler-edelstahl.com ■■■

Betatype demonstrates high-volume metal AM for the automotive industry

Betatype's optimised build enabled 384 LED heatsinks (shown inset) to be stacked on the same build plate (Courtesy Betatype)

Betatype, London, UK, has released a case study demonstrating how the combination of its process optimisation technology and a knowledge of process economics can enable metal Additive Manufacturing to be cost-effectively applied in the automotive industry.

Metal Additive Manufacturing has been considered by some to be incapable of meeting the automotive market's needs, such as the production of high volumes of parts at low costs. While die casting and other traditional manufacturing processes can manufacture millions of components per year, AM processes such as Laser Powder Bed Fusion (LPBF) can add value by delivering geometric complexity, but are perceived as not typically economical at high volumes.

Betatype stated that it has been able to demonstrate that it is possible to combine the geometric capabilities of AM with increased production volumes for cost-effective parts. "With the right part, it is completely possible to break with conventional thinking about what LPBF is capable of, both in terms of what can be built, how and how many," the company stated.

The published case study looks at the use of LPBF to produce heatsinks for LED automotive headlights, an application area which poses new challenges in thermal management. Typically, these components require comparatively large heatsinks which are often actively cooled. Betatype states that the specific geometry for these metal parts makes them ideal for AM production, with its ability to consolidate multiple manufacturing processes into a single production method.

By designing the heatsinks specifically for Additive Manufacturing, Betatype was able to incorporate in-built support features, which allowed multiple headlight parts to be stacked on top of each other on the build plate during manufacturing, without the need for additional supports. Due to the design of the internal support structures, the company reported that it was possible to snap apart the finished parts by hand, without the need for further post-processing.

Stacking can be difficult during Additive Manufacturing due to the thermal stresses involved in the process; however Betatype stated that it was able to achieve this by actively designing the structure to reduce thermal stresses, thereby minimising thermal distortion. This enabled a series of components to be nested together to maximise the build volume, making it possible to additively manufacture 384 parts at once within a single build envelope on an EOS 280M machine.

To enhance the build speed, Betatype used specific control parameters to adjust the LBPF process so that the exposure of the part in each layer to a single toolpath, where the laser effectively melted the part, was reduced significantly, with minimal delays in between. This, coupled with a number of optimisation algorithms and process IP, reduced the build time of each part from one hour to under five minutes.

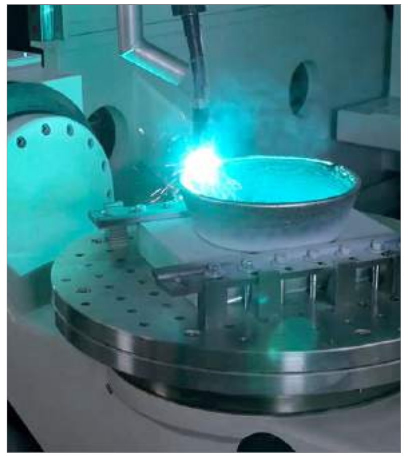
Reducing build times is key to making parts more cost-effective with LPBF. The use of Betatype's optimisation technology and effective part design was said to have brought cost-per-part down from roughly €34 to under €3.

Using single-laser medium frame Additive Manufacturing systems, such as the EOS M280 and Renishaw RenAM500M, Betatype was able to reduce build time from 444 hours to less than 30 hours for the batch of 384 parts. Using multi-laser medium frame systems (SLM Solutions 500, Renishaw RenAM500Q), build time was further reduced to under 19 hours, representing a 19x gain in productivity over a year of production per system, from 7,055 parts per year to 135,168.

With as few as seven machines running this optimised process for a year, Betatype forecast that production volumes could approach 1 million parts, representing a major step toward meeting the automotive industry's demands in terms of both volume and cost-effectiveness. This could in turn allow metal Additive Manufacturing to compete with conventional manufacturing technologies in key markets, marking a major step toward its broader industrialisation.

www.betaty.pe ■■■

Harlow adds Gefertec's wire-based AM for aerospace part production


Gefertec's arc605 is a five axis wire based AM system (Courtesy Gefertec)

Harlow Group Ltd, headquartered in the UK, will install a new arc605 machine from Gefertec GmbH, Berlin, Germany, at its recently-founded US subsidiary, Harlow FastTech LLC. The new facility is set to focus on job shop services for the aerospace industries and will use Gefertec's 3DMP® technology for the production of aerospace parts.

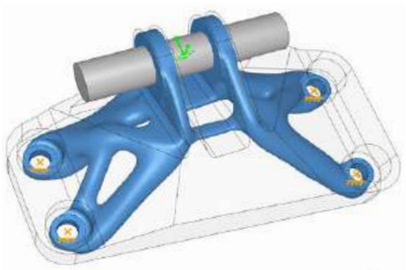
Harlow was established in 1975 and has full aerospace accreditation and approval across a number of industry sectors. The company has until now provided primarily sheet metal fabrication services out of the UK, but stated that it is committed to investing in the latest technology, including metal Additive Manufacturing.

Gefertec's 3DMP technology uses electric arc welding or Wire Arc Additive Manufacturing (WAAM), using wire as the feedstock. Near-net-shaped parts are formed by welding wire layer by layer in a process said to be faster and more cost-effective than powder-based AM technologies. It can be used to produce parts in steel, nickel-based alloys, titanium or aluminium.

The five-axis arc605 is reportedly able to additively manufacture parts up to a volume of 0.8 m^3. The company's 3DMP CAM software calculates data from a CAD model which enables the CNC unit to position the welding head with high precision, producing the part automatically. The machine cost is comparable to that of a small CNC milling centre, significantly lower than many metal AM machines.

www.harlowgroup.co.uk
www.gefertec.de ■■■

Frustum announces Generate® interactive generative design software for Windows OS


Frustum's Generate software will identify the best solution in a matter of minutes (Courtesy Frustum)

Frustum Inc., Boulder, Colorado, USA, has announced a new release of its Generate® software. The company states that Generate represents, "a new paradigm for design, interactive generative design, which fundamentally alters how products are modelled for manufacture by allowing engineers to interact and iterate in real time with generative design models." As a result, engineers can produce multiple, perfectly designed and optimised models to identify the best solution in a matter of minutes versus hours or days.

Generate is a 3D design software that offers interactivity with generative design models. It is said to combine the creativity of the engineer with artificial intelligence, to significantly shorten the time of designing high-performing products – effectively delivering a near real-time interaction with a generative design model, generating designs by functional requirements and producing a result that is ready for manufacture. Parts and products designed through this process are, it is stated, lighter, stronger and use far less materials than those designed using traditional CAD software.

"With Generate, designers and engineers can interactively specify the functional requirements of their design and the design will automatically be modelled to meet those requirements. The design output is functional and does not have to be remodelled in CAD," stated Jesse Coors-Blankenship, CEO, Frustum Inc. "We developed Generate on a multi-threaded architecture that was built from the ground-up to deliver faster design output by leveraging both CPU and GPU computing optionally. Generate will redefine how manufacturers get products to market, reduce materials costs and improve the overall performance of products."

Built on its patented generative engine, TrueSOLID®, Generate couples advanced topology optimisation and simulation algorithms with real-time interaction to quickly produce high-performing, ready to manufacture mechanical designs. It is functionally parametric and facilitates perfect blending of generative geometry to traditional surface-based CAD with engineering precision. The technology is currently being commercially licensed to Siemens PLM software and integrated into Siemens NX and Siemens SolidEdge.

www.frustum.com ■■■

ULT to showcase air and gas purification systems at formnext 2018

ULT AG, Löbau, Germany, will showcase its proven and new solutions for air and gas purification in Additive Manufacturing at formnext 2018, to be held in Frankfurt, Germany, November 13–16, 2018. During the exhibition, the company will demonstrate how air-cleaning systems can support Additive Manufacturing processes.

ULT will introduce its new LAS 200.1 series for laser fume extraction. The system offers a modular design with low noise levels, variable application opportunities for up to four workplaces and a range of accessories. It also offers automatic vacuum stabilisation and selectable pressure ranges, to enable automatic and flexible adaptations of the system to changing pollutant levels.

The new LAS 200.1 series for laser fume extraction (Courtesy ULT AG)

At formnext, ULT will be supported by the Karlsruher Institut für Technologie (KIT), which will be exhibiting a current research system at the same booth.

www.ult.de ■■■

Dutch Prime Minister opens new Additive Industries factory

Dutch Prime Minister Mark Rutte has formally opened Additive Industries' new factory in Eindhoven, The Netherlands. After speeches by the two founders of Additive Industries, Jonas Wintermans and Daan Kersten, Rutte unveiled the spacious, clean and open factory space of the fast growing manufacturer of industrial Additive Manufacturing equipment.

"This new factory allows us to accelerate our growth and has the capacity to assemble and test up to 100-200 systems per year, which aligns well with our worldwide expansion plans to grow to a Top 3 position in our market", stated Daan Kersten, Co-founder and CEO of Additive Industries.

www.additiveindustries.com ■■■

3D Metalforge receives accreditation from Lloyd's Register

Metal additive manufacturer 3D Metalforge Pte Ltd, Singapore, has been accredited for excellent operational and quality assurance by Lloyd's Register, an international provider of classification, compliance and consultancy services to the marine, offshore and other high value industries. The certification was conferred following a successful audit of 3D Metalforge's facility capability, personnel, procedures, systems and equipment in July 2018.

The scope of the audit reportedly reviewed multiple areas of the business, such as the implementation of a Quality Management System (QMS), supplier control, process management, manpower training procedures, HSE (health, safety and environment) and the reception, handling and storage of material within 3D Metalforge's Additive Manufacturing Centre. A critical portion of the audit also involved the certification of the entire metal Additive Manufacturing build process, as well as post-processing techniques that cater specially to the maritime sector.

3D Metalforge stated that it believes this certification will offer existing and potential customers in the marine, shipping and offshore industries assurance on the quality, safety and performance aspects of the final end-use products produced in its metal Additive Manufacturing facilities. Prior to receiving this accreditation from Lloyd's Register, 3D Metalforge received a similar industry certification and successfully implemented the ISO9001:2015 quality framework certified by DNV GL in 2017.

These endorsements are expected to help steer 3D Metalforge's growth as a sector-leading AM service provider focused on continual improvement, customer satisfaction and overall sustainable business performance. Matthew Waterhouse, 3D Metalforge CEO, who also serves as Chairman of the AM Technical Standards Committee set up by Enterprise Singapore, stated, "As a leading additive manufacturer in the maritime sector, we are very pleased to receive this endorsement from Lloyd's Register to bring even more value to our marine and offshore customers and partners."

"At this juncture, large format 3D printing in the maritime industry is developing rapidly," he continued. "Quality and standards can therefore really help by providing a sustainable and practical framework for all partners in the ecosystem to advance AM procedures and technologies in a more structured manner."

www.3dmetalforge.com ■■■

New DryLyte technology enables electropolishing of metal parts without liquids

A comparison of roughness levels; original shown left and the polished sample on right (Courtesy Dlyte)

DLyte, based in Barcelona, Spain, has developed a new patented technology for the automatic grinding and polishing of high-precision metal components. The company's DryLyte® process is said to be the first dry electropolishing system, which uses no liquid as the electrolyte, and is suitable for steel, stainless steel, aluminium and titanium components.

Grinding and polishing of metal parts is an important process step for removing the asperities and defects inherent in components following the initial build process. The removal of peaks, roughness, burs and micro-defects can dramatically improve the corrosion/oxidation resistance, lifespan and friction of a part. This is especially important for high-precision engineering applications such as those within the medical, automotive and aeronautics industries, where surface quality can be critical.

According to DLyte, DryLite was developed in response to problems the company identified in current grinding and polishing solutions, which it states can be highly time-consuming, extremely cost-intensive and may render sub-optimal results failing to meet functional requirements.

DLyte states that its system does not leave micro-scratches on the surface of the workpiece and can achieve small corners –where abrasive polishing, for example, is not able to create enough movement and pressure to polish homogeneously. It is said to offer superior surface results, with Ra under 0.1 µm, without altering the geometry of the workpiece and while assuring excellent mechanical properties and highly-controlled composition.

It was stated that DryLite Technology is currently at a very early stage, but the company believes that it could "revolutionise the finishing industry," given its wide range of applications. DLyte has established partnerships with a number of companies in the Additive Manufacturing industry, among them EOS, Renishaw, SLM Solutions and 3D Systems, as they look to offer a complete solution for customers and develop polishing solutions for the different materials and applications within the metal AM Industry.

www.dlyte.es ■■■

Investment in U.S. Metal Powders supports development of new aluminium alloy powders

U.S. Metal Powders' metal powder production facility Ampal, Inc., Palmerton, Pennsylvania, USA, has received a $10,000 investment from Ben Franklin Technology Partners of Northeastern Pennsylvania (BFTP/NEP). The investment is part of a wave of investments made in the region by BFTP/NEP, amounting to a total of $535,000 across ten companies, aimed at enabling Northeastern Pennsylvania to create a "better economic future by building partnerships that develop and apply technology for competitive advantage."

The investment in U.S. Metal Powders/Ampal is for the completion of R&D work on aluminium alloy powders for new applications, enabling the company to optimise its high-strength alloy powder portfolio to expand its marketability and gain a competitive edge. The research into and development of these new powders will be undertaken in partnership with Lehigh University's Enterprise Systems Center.

U.S. Metal Powders, Inc., markets its aluminium powders worldwide, offering a full-range of coarse to fine aluminium powders. It operates manufacturing facilities in Palmerton and Hermillon, France, and stated that it maintains a dedicated research team. Ampal, Inc. is said to be the largest producer of aluminium powders in North America.

Ben Franklin Technology Partners is an initiative of the Pennsylvania Department of Community and Economic Development and is funded by the Ben Franklin Technology Development Authority. Since beginning operation, the initiative has reportedly helped to start 511 new companies and to develop 1,733 new products and processes. Since 2007, BFTP/NEP clients are said to have generated $1.5 billion in follow-on funding.

www.usmetalpowders.com

www.nep.benfranklin.org ■■■

MELD researches recycling of battlefield scrap metal for on-demand repair and manufacturing

MELD is a solid-state process which can use a wide range of materials as feedstock, including metal powders and rods (Courtesy MELD Manufacturing)

MELD™ Manufacturing Corporation, the University of Alabama and the U.S. Army Research Lab (ARL) have been awarded funding by the USA's Strategic Environmental Research and Development Program (SERDP) to support basic research into the implementation of MELD's metal Additive Manufacturing technology as a method for recycling battlefield scrap metal for repairs and manufacturing in combat theatre.

The research was proposed in response to the Army's published search for methods of manufacturing at the point of need. Throughout the project, MELD will create samples from scrap provided by ARL before sending them to both the University of Alabama and ARL for analysis.

"The capacity to take battlefield scrap and use it at a forward operating base for repairs and other manufacturing processes would be a significant time and cost-saving ability," stated Nanci Hardwick, MELD CEO. "MELD machines are uniquely capable in this area as they can deposit from multiple types of feedstock and require no special chambers or vacuums for operation."

MELD announced earlier this month that it was selected for Phase I of the US Army's xTechSearch for its proposal to create strong, lightweight materials for combat vehicles. The company clarified that while both projects will explore military applications for the company's technology, the SERDP project will research the fundamental characteristics of MELD deposits using feedstock created from scrap, while the xTechSearch-funded project is a demonstration of field-usable equipment to take a waste stream or indigenous materials as raw MELD material.

"It's exciting to be taking part in both the XTechSearch and this SERDP project," added Hardwick. "We're proud of our technology and are eager to continue showing the world more ways that MELD can save time and money while reducing environmental impact."

www.meldmanufacturing.com

Air New Zealand investigating metal AM for aircraft parts

Commercial airline Air New Zealand has partnered with Zenith Tecnica, Auckland, New Zealand, to investigate the production of metal additively manufactured aircraft components and tools. Zenith Tecnica specialises in the design and manufacture of parts from titanium and other metals using Electron Beam Additive Manufacturing (EBAM), using machines from Arcam EBM, a GE Additive company.

Bruce Parton, Air New Zealand's Chief Operations Officer, explained that the airline is committed to innovation though Additive Manufacturing with new materials, stating: "It's fantastic to be able to team up with and support local operator Zenith Tecnica and work with global company GE Additive to learn and collaborate in this space. While we are in the initial stages of working with these companies on 3D printing, so far, we have printed prototype metal framing for our Business Premier cabin, to quickly test new concepts and ideas and we have also made novelty wine aerators."

Parton noted that while these novelty aerators – designed in the shape of aircraft engines – may look frivolous, they represent the genuine possibilities offered by metal AM for cost and space efficiency. "Aircraft interiors are made up of tens of thousands of parts, and the ability to 3D print on demand lightweight parts we only require a small number of, rather than rely on traditional manufacturing methods, is of huge benefit to our business, without compromising safety, strength or durability," he explained.

Martyn Newby, Managing Director, Zenith Tecnica, added, "This is a good project to demonstrate the strength, versatility and utility of titanium 3D printed parts for aircraft applications, and it's very exciting to be working alongside Air New Zealand on this journey. We are in a very good position to support the local adoption of 3D printing for aviation applications and welcome Air New Zealand's enthusiasm to embrace this emerging technology and help take it to the mainstream."

Air New Zealand began investigating Additive Manufacturing in 2016 and has now moved on to the development of items such as improved small parts for IFE screens, as well as working with new partners such as ST Engineering Aerospace on more advanced parts. The airline stated that it is also exploring new processes with Auckland University, Victoria University of Wellington and other technology companies.

www.airnewzealand.com
www.zenithtecnica.com

Open Architecture Additive Manufacturing project investigates DED for aerospace

Independent research and technology organisation TWI Ltd, Cambridge, UK, is leading the Open Architecture Additive Manufacturing (OAAM) project, with partners including Airbus, Autodesk, Cranfield University, Glenalmond Group, University of Bath, University of Manchester and University of Stratchclyde. The aim of the project is to demonstrate the ability to manufacture large metallic components using metal Additive Manufacturing for the benefit of UK aerospace.

The OAAM programme plans to develop Directed Energy Deposition (DED) AM technologies that can be scaled up for the manufacture of components at the multi-metre scale. Working with the project partners, TWI will create three DED AM process platforms to enable aerospace manufacturers and their supply chains to develop advanced AM manufacturing concepts in the following fields:

- Arc-wire / Laser-wire AM – Cranfield University
- Electron Beam wire AM – TWI Cambridge
- Laser-powder / laser-wire AM – TWI Yorkshire Technology Centre

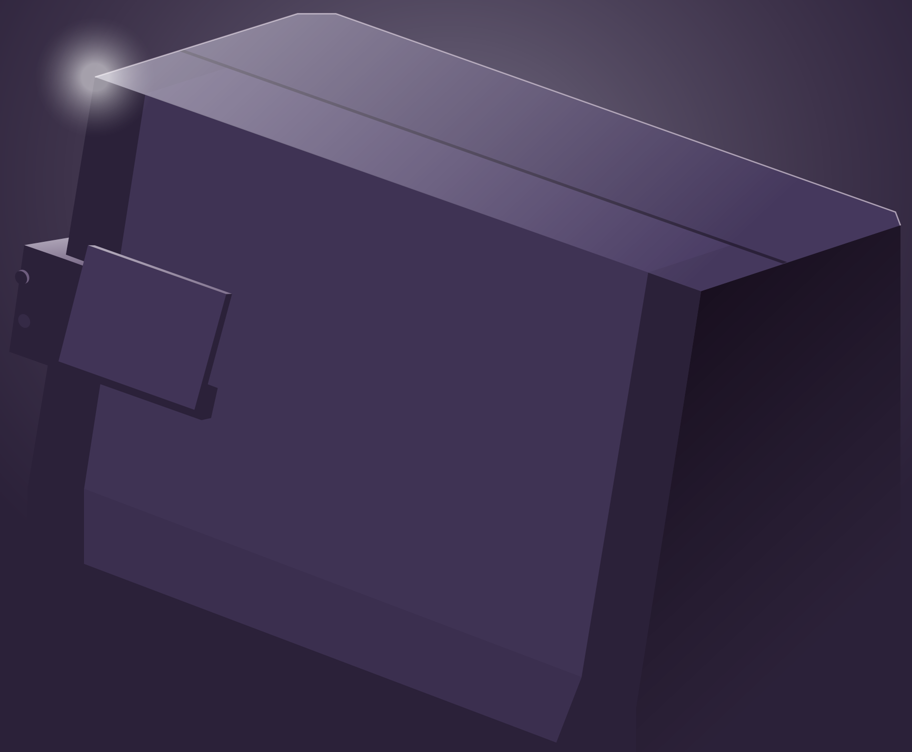
Each of these systems is expected to offer unique AM capabilities and address a number of common needs such as scalable architecture solutions, with common CAD/CAM control interfacing, integrated process steps (NDT, machining, inspection, cold-work, etc.) as necessary for optimum implementation to aerospace requirements, and the ability to additively manufacture aerospace components to TRL 6 or MCRL 4/5. Each system will be made available to UK industry.

TWI commented that this will offer the UK aerospace sector access to next-generation manufacturing with a simplified, lower risk route to support AM's industrialisation and rapidly deploy into aircraft platforms. It also foresees a substantial amount of results overspill into other sectors such as the energy and marine industries.

The project is supported by Innovate UK and began in January 2018. It is expected to run for three years in total.

www.twi-global.com ■■■

Directed Energy Deposition metal Additive Manufacturing in action (Courtesy TWI Ltd)



3D Systems partners with GF Machining Solutions on factory automation for AM

3D Systems, Rock Hill, South Carolina, USA, is partnering with Georg Fischer AG's GF Machining Solutions, Geneva, Switzerland, to deliver a new concept in factory automation that includes software for enhanced part design, Additive Manufacturing machines, materials and automated material handling, electrical discharge machining (EDM), milling equipment and advanced post-processing technologies.

These new design and manufacturing options can enable the improvement of existing products, and the realisation of new designs, new business models, and new markets. The companies reported that they plan to debut the first combined solution to have been developed as a result of their partnership at IMTS 2018, the International Manufacturing Technology Show, September 10-15, 2018, Chicago, Illinois, USA.

Together, 3D Systems and GF Machining Solutions have a presence in more than fifty countries, including production facilities, R&D centres, and sales and service networks encompassing internal teams as well as channel partners. Speaking on the new partnership, Yves Serra, CEO of Georg Fischer, stated, "We are excited about this new partnership of two industrial leaders. With the combined experience and expertise of 3D Systems and GF Machining Solutions, we are well positioned to bring to our customers new manufacturing solutions based on 3D printing."

Vyomesh Joshi, President and CEO of 3D Systems, added, "The 3D Systems and GF Machining Solutions partnership brings together two customer-centric innovators to redefine manufacturing and create the factory of the future. As industry leaders, both companies share the same vision for transforming manufacturing. We are looking forward to delivering integrated technology solutions to provide our customers with significant competitive advantage through reduced production time, faster time to part, and overall lower total cost of operation."

www.3dsystems.com
www.gfms.com ■■■

Eaton Aerospace Group turns to GE Additive to evolve its AM strategy

A bank of GE Additive's AM machines (Courtesy GE Additive)

Eaton's Aerospace Group, Irvine, California, USA, has selected two GE Additive Concept Laser metal Additive Manufacturing machines, as well as AddWorks consultancy services, to direct industrialisation activities as it evolves and executes its long-term Additive Manufacturing strategy. The agreement was announced during the Farnborough International Airshow, UK, July 16-22, at which GE Additive presented the full range of its AM solutions.

One machine will be installed at Eaton's Additive Manufacturing Center of Excellence at its Innovation Center in Southfield, Michigan, USA, while the second will run at the company's R&D lab at its Global Innovation Center in Pune, India. Both machines are expected to be installed by August 2018.

In the aerospace industry, Eaton is one of the leading suppliers of products and technologies for hydraulic systems, fuel and inerting systems, motion control and engine solutions. GE Additive's AddWorks consultants will reportedly consult with Eaton's teams to advise on industrialisation and part certification processes, material characterisation and production readiness selection strategies.

Nanda Kumar, President, Eaton's Aerospace Group, stated, "Additive capabilities provide new business opportunities and a strong competitive advantage. In five to ten years, we see a significant portion of our portfolio being manufactured through additive processes because of the investments we are making today. Additive Manufacturing is an exciting technology that offers many advantages. We look forward to leveraging GE Additive's expertise and experience to accelerate our initiatives in this space."

"We're honoured to have been selected by Eaton to join them at this pivotal stage of their additive journey," commented Jason Oliver, President and CEO, GE Additive. "Our own direct experiences and learnings in mass scale production within the aerospace industry mean that we have an implicit understanding of what they're trying to achieve."

Mike York, Director, Additive Manufacturing, Eaton's Aerospace Group, added, "We were impressed with GE Additive's consultants' focus on strengthening our existing Additive Manufacturing programme in a way that will accelerate our deployment."

www.ge.com/additive
www.eaton.com ■■■

GKN Aerospace wins contract for Additive Manufacturing of rocket engine turbines

GKN Aerospace Sweden AB has been awarded a development and manufacturing contract by ArianeGroup, Issy-les-Moulineaux, France, for the metal Additive Manufacturing of two full-scale turbines for the Prometheus low-cost reusable rocket engine demonstrator on liquid oxygen and methane propellants. It is believed that the turbines will be the first additively manufactured rocket engine turbines produced in Europe.

The turbines will generate power for the methane fuel system, with the first set to be delivered at the end of 2019. Manufacturing will take place in cooperation with partners and at GKN Aerospace's highly-automated Engine Systems Centre of Excellence in Trollhättan, Sweden.

The new turbines must cope with challenging loads including very high pressure, high speed and high temperatures. To produce them, GKN Aerospace will reportedly use the latest Additive Manufacturing technologies to achieve higher performance, lower lead times and significant cost reduction. The company expects this development to support the adoption of AM for future higher loaded critical components in terms of pressure, temperature and rotational speed.

Sébastien Aknouche, Vice President and General Manager, Services and Special Products Engine Systems, GKN Aerospace Sweden AB, added, "With the support of the Swedish National Space Agency, ESA and ArianeGroup we are proud to participate in the Prometheus project and to make a technological contribution to this key European space project. This allows us, together with our suppliers, to work with our customer to develop and demonstrate advanced AM technologies in operation and at full scale. We look forward to demonstrating the benefits and the added value in weight and cost reduction and in faster production rates. These factors, along with our established expertise in space turbines, have resulted in the award of this engine turbine contract."

Prometheus is an ESA funded programme with ArianeGroup as the prime contractor. GKN Aerospace's Space Business Unit in Trollhättan, Sweden, has been active in the Ariane programme from its inception in 1974 until the current Ariane 6 partnership, and has reportedly produced over 1,000 combustion chambers and nozzles as well as over 250 turbines for the Ariane rocket to-date. Today it is the European centre of excellence for turbines and metallic nozzles, having contributed to the programme at every stage from initial research and development through cooperation with academia to serial production.

www.gkn.com/aerospace
www.ariane.group ■■■

GKN will produce two full-scale turbines for the Prometheus low-cost reusable rocket engine demonstrator (Courtesy ArianeGroup)

The Barnes Group Advisors and Purdue University offer online AM Certificate

Purdue University's College of Engineering, West Lafayette, Indiana, USA, will offer an Additive Manufacturing Certificate through its Purdue Online Learning service beginning in early 2019. The programme, developed in collaboration with The Barnes Group Advisors (TBGA), Pittsburgh, Pennsylvania, USA, will give working professionals and students the opportunity to study industry case studies and stay up-to-date with the rapidly industrialising technology.

The course will be tailored to those at the engineer/manager and executive levels, and AM Certificate students will be supported by members of TBGA's ADDvisor^{SM} Services team. Students will gain a basic understanding of Additive Manufacturing, including commonly used terms, key processes, key materials, and key industries using the technology. They will be taught the different AM processes per ASTM F42 specifications, including technology capabilities, limitations, and commercial & technical considerations. In addition, students will see how to develop a business case for AM, including identifying business considerations and key cost drivers.

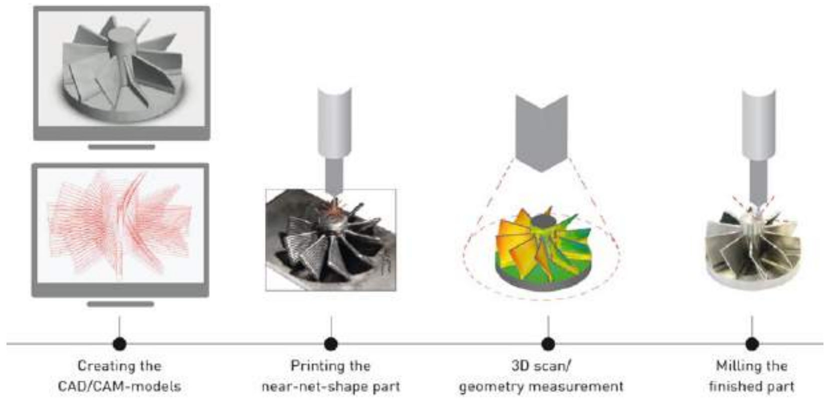
Initially the course will offer Level 1 Certification, Additive Manufacturing Certification for Engineers and Managers, or Level 1 Certification, Additive Manufacturing for Executives. In future, Purdue expects add Level 2 Certification.

www.engineering.purdue.edu/ProEd/certifications/additive-manufacturing
www.thebarnes.group ■■■

Bremer Institut investigates Gefertec's 3DMP arc-based Additive Manufacturing for aerospace

Germany's Bremer Institut für angewandte Strahltechnik GmbH (BIAS), Bremen, and Gefertec, Berlin, are working to qualify Gefertec's patented 3DMP® wire arc based Additive Manufacturing technology for the production of large structural components, particularly for applications in the aerospace industry. The research is being carried out as part of REGIS, a collaborative project bringing together a number of partners from the aerospace industry, machine manufacturers and other research institutions.

Gefertec recently installed an arc403 3DMP machine at BIAS, where work will be undertaken to ensure homogeneous material properties in the production of titanium and aluminium using the 3DMP process. Funded by Germany's Federal Ministry for Economic Affairs and Energy, the project is said to offer an important contribution to the removal of the geometrical constraints when additively manufacturing components.



The 3DMP process chain combines the wire arc welding method with CAD data. The part is produced in a fully automatic, controlled manner, followed by quality control scan and final milling (Courtesy Gefertec)

Using 3DMP electric arc-based technology, near-net-shape parts are formed by welding wire feedstock layer by layer. Compared to powder-based Additive Manufacturing, the advantages of the process are said to include a reduction in process times due to high deposition rates and fewer production steps, the ability to produce large-volume components, and high cost-effectiveness due to the use of inexpensive wire as the base material, high material utilisation and low tooling costs.

In order to be able to guarantee consistently homogeneous material properties in parts produced using 3DMP, one focus of the BIAS's work will be to investigate the influence of heat input and shielding gas concept on the mechanical properties of titanium and aluminium components. Another focus will be on developing an online system for process monitoring of the temperature of the printed material. For this purpose, the emissions-compensated, surface-resolved temperature field measurement developed at the BIAS will be integrated into the machine concept.

www.gefertec.de

www.bias.de ■■■

3D Printing Post-Processing Conference & AM Integrated Factory Conference set for December

The half-day 3D Printing Post-Processing Conference and AM Integrated Factory Conference, organised by Jakajima B.V., will be held at Brightlands Chemelot Campus, Sittard-Geleen, the Netherlands, on December 4, 2018.

3D Printing Post-Processing Conference will encompass primary and secondary post-processing operations, including cleaning and support structure removal, and machining and plating. The conference programme will look at issues, solutions and future trends for the post-processing of additively manufactured components, as well as the impact of the post-processing phase on time, cost, quality, safety, etc. of AM operations.

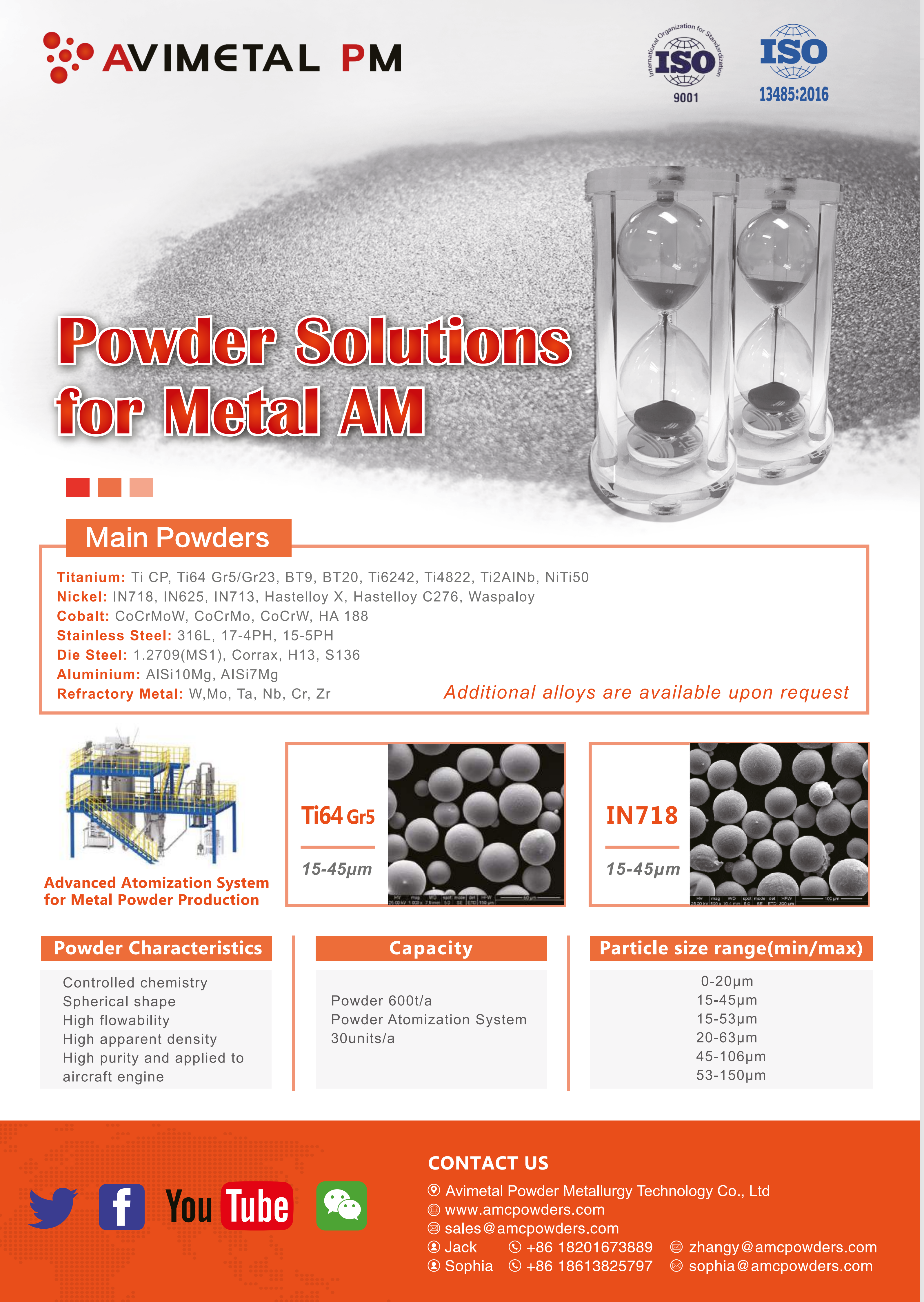
AM Integrated Factory Conference will address the integration of AM into manufacturing processes, looking at key trends such as the use of hybrid manufacturing systems combining additive and subtractive technologies, the implementation of AM systems as part of an end-to-end production workflow, and the implementation of AM systems in traditional production processes (i.e. as part of a production chain with several state-of-the-art production technologies).

The conference programme will also look at the transition this integration requires at software level, with CAD/CAM/CAE software feeding into simulation, manufacturing execution systems and PLM software tools.

Registration for both conferences is currently available at discounted early-bird rates. Attendees can register for the conferences together or separately.

www.3dprintingpostprocessingconference.com

www.amintegratedfactoryconference.com ■■■



Siemens reports successful engine testing of metal AM gas turbine pre-mixer

Siemens reports that it has successfully additively manufactured and engine tested a dry low emission (DLE) pre-mixer for the SGT-A05 aeroderivative gas turbine, with the test results said to show the potential for significant reductions in CO emissions. From concept to engine test, the company stated that the part's development took only seven months, despite requiring very tight tolerances, load resistance and temperature resistance.

To produce the highly complex component using conventional manufacturing methods, over twenty parts would be involved in the casting and assembly process. Siemens stated that, using qualified nickel superalloys and metal Additive Manufacturing, the component design was consolidated into just two parts, representing a reduction in lead time of approximately 70%. Siemens was able to simplify production process complexity, reduce external dependencies in the supply chain and improve the geometry of the component overall to allow a better fuel-air mix.

Vladimir Navrotsky, Chief Technology Officer for Siemens Power Generation Services, Distributed Generation, stated, "This is another excellent example of how Additive Manufacturing is revolutionising our industry, delivering measurable benefits and real value to our customers, particularly as they look to further reduce emissions to meet environmental targets. Our achievements using AM are paving the way for greater agility in the design, manufacturing and maintenance of power generation components."

In engine testing, Siemens reported that the component showed no start issues, all fuel transitions were accomplished successfully without any controls modifications required and there were no combustion dynamics or noise. Measurable CO emissions reductions were realised and full power was achieved.

The DLE solution for the SGT-A05 gas turbine reduces emissions using advanced lean burn combustion technology, eliminating the need for water injection. More than 120 engines using DLE technology are currently said to be in operation, with 3.9 million operating hours accumulated as of February 2018. Speaking on the first successful engine tests on the AM DLE pre-mixer, Douglas Willham, Siemens Director of Engineering for the SGT-A05, commented, "Now, with AM technology we have an opportunity to go even further with emissions reduction for DLE combustion."

In February 2017, Siemens finished its first full-load engine tests for gas turbine blades completely designed and produced using AM technology. In April 2018, it additively manufactured and installed into a customer's equipment its first metal AM replacement part for an industrial steam turbine. The company states that it has accumulated more than 30,000 hours of successful commercial operation for SGT-800 burners repaired with AM technology and for SGT-750 burner swirls manufactured by AM.

www.siemens.com ■■■


Siemens' metal additively manufactured dry low emission (DLE) pre-mixer for the SGT-A05 gas turbine (Courtesy Siemens)

Asiamold 2019 will address needs of China's growing AM industry

The 13th Asiamold – Guangzhou International Mould & Die Exhibition (Asiamold 2019) will take place in Guangzhou, China, March 10–12, 2019. Held concurrently with SPS – Industrial Automation Fair Guangzhou (SIAF), both shows aim to help attendees identify the business opportunities offered by the Chinese government's Made in China 2025 strategic plan.

This year's Asiamold exhibition will feature a '3D Printing Asia Zone' to address the needs of China's rapidly developing AM industry. According to the organisers, this special zone of the exhibition is designed to assist manufacturing industry professionals with their sourcing needs, and to showcase the AM process chain.

Asiamold is organised by Guangzhou Guangya Messe Frankfurt Co Ltd and forms part of a series of international events including formnext and Intermold Japan. The next formnext event will be held from November 13–16, 2018, in Frankfurt, Germany and Intermold Japan will take place from April 17–20, 2019 in Tokyo, Japan.

www.asiamold-china.com ■■■

APWorks' AMXpert offers online part optimisation and ordering of metal AM parts

APWorks, Taufkirchen, Germany, has launched AMXpert, a new online ordering platform for metal AM parts that combines cost analysis, printability checks and real-time feedback. A part screening system, said to be able to identify parts suitable for metal Additive Manufacturing based on various algorithms, includes validated print job data as well as evaluations of the part's optimisation potential.

Based on print job data and machine learning algorithms each uploaded part will be automatically assessed and positioned in the ideal orientation for AM, with customers having the opportunity to choose from various high-performance build materials, including AlSi10Mg, Scalmalloy®, Ti6Al4V, and 1.4404. Post-processing steps may vary between heat treatment, machining and a surface finish. Quality tests available include CT and 3D scanning, and the qualification process involves test series required for qualification certificates such as CoC or EASA Form 1.

Joachim Zettler, Managing Director at APWorks, stated, "Virtual technologies and Additive Manufacturing are enabling the industrial world to achieve more while producing less waste, weight and costs, as well as freeing designers to explore complex shapes that could not be manufactured using traditional processes. AMXpert is fast, intuitive and beneficial. By enabling a fully digital process chain in one tool, from part screening and analysis, to optimisation potential assessment, to price calculation and the online order process, it truly brings Additive Manufacturing to the next level."

Quotes generated by AMXpert cover the costs for the entire metal AM process, including costs for various metal options. Post-processing steps and qualification processes can be added optionally, and it is also possible to specify a requested delivery date for priority production time. Once an order is placed, the system provides customers with real-time updates on the order status of their parts.

www.AMXpert.de ■■■

APWorks new online platform, AMXpert, enables online ordering of optimised metal AM parts (Courtesy APWorks)

Metalysis begins production with first industrial-scale metal powder plant

Metalysis Ltd., Rotheram, South Yorkshire, UK, has established its first commercial metal alloy powder production plant at its facility in Wath-upon-Dearne, South Yorkshire, UK. The Generation 4 (Gen4) project was mechanically completed in Q4 2017 and has since undergone hot commissioning, trial runs and optimisation. The handover from testing to operation follows more than a decade of phased technology development.

Gen4 is the first facility to take Metalysis' solid-state, modular, electrochemical process to industrial scale and is said to be able to produce tens-to-hundreds of tonnes per annum of high value, niche and master alloys. The facility offers a new source of supply for global end-users in advanced manufacturing disciplines including Additive Manufacturing, aerospace, automotive, batteries, light-weighting, magnets and mining.

One of the reported benefits of Metalysis' technology is its multi-metal capability, which enables the company to produce alloy 'recipes' that comparable processing routes cannot. Where conventional technologies are unable to combine elements with melting and density differentials, with the Metalysis process this is said to be possible as it is a solid-state process. It will enable Metalysis to commercially produce a demand-driven product mix of titanium alloys, master alloys including Scandium-Aluminide, compositionally complex alloys including high entropy alloys, magnet materials, high temperature materials and platinum group alloys.

"In powering up and operating our industrial plant, Metalysis is poised to achieve its target to generate significant profits from our new South Yorkshire production facility," stated Dr Dion Vaughan, Chief Executive Officer, Metalysis. "Ours is a true British success story with international implications. Metalysis has grown from the 'lightbulb moment' at Cambridge University in the late-1990s, relocated to South Yorkshire to benefit from regional excellence in operational skillsets in the early-2000s, and now onwards towards a bright commercial future."

In March 2018, the company announced that it had raised £12 million to fund state-of-the-art post-processing facilities, feedstock and provide working capital to support the roll-out of Gen4. Overall, approximately £25 million has been raised to fund the project to completion.

www.metalysis.com ■■■

Carbolite Gero offers updated retort furnace for PM and AM applications

Carbolite Gero has launched an updated GPCMA/174 Retort Furnace, which it states is suitable for a variety of laboratory, pilot-scale and industrial applications requiring heat treatment to 1150°C. The completely revised 174-litre furnace reportedly reduces O2 levels to below 30 ppm and offers uniform temperature distribution and gas tightness, ensuring minimal usage of expensive gases.

Continuous monitoring of inert gas flow volumes and forced cooling for faster cycle times are further features said to ensure safe and efficient operation. Designed with a modified inert atmosphere for annealing and sintering of Powder Metallurgy and metal AM parts, the furnace can be fitted for compliance to AMS 2750E Class 1 (+/-3C) and be equipped with instrumentation type A, B, C or D.

The GPCMA/174 features cascade control for load-temperature sensing, as well as a swing door design for ease of loading and unloading, and is said to be ideal for applications which call for a single platform furnace and small volume requirements for one-off components.

www.carbolite-gero.com ■■■

Two-day medical Additive Manufacturing event set for the Netherlands in 2019

The sixth 3D Medical Printing Conference and Expo will be held at MECC Maastricht, the Netherlands, January 30–31, 2019. Organised by Jakajima in partnership with MECC Maastricht, this two-day event is focused on the latest technological innovations in medical Additive Manufacturing and is co-located with the Health Tech Event, a conference with a wider focus on robotics, the Internet of Things, AI and augmented reality.

The 3D Medical Conference is accredited by the Dutch Association for Technical Medicine (NVTG) and is expected to attract a number of high quality and professional (medical) visitors. The conference programme will feature thirty-six speakers in total (13 speakers Day 1, 23 speakers Day 2), while the Expo will offer attendees the opportunity to view exhibits featuring real-world applications for medical AM, alongside other innovative technologies.

Among the topics on discussion during the conference will be dental AM, AM for the production of medical technology, medical & dental scanning, medical & dental software, medical AM workflow & planning tools and legal and regulatory issues regarding medical AM applications.

www.3dmedicalconference.com ■■■

CECIMO raises concerns regarding recent EU resolution on AM

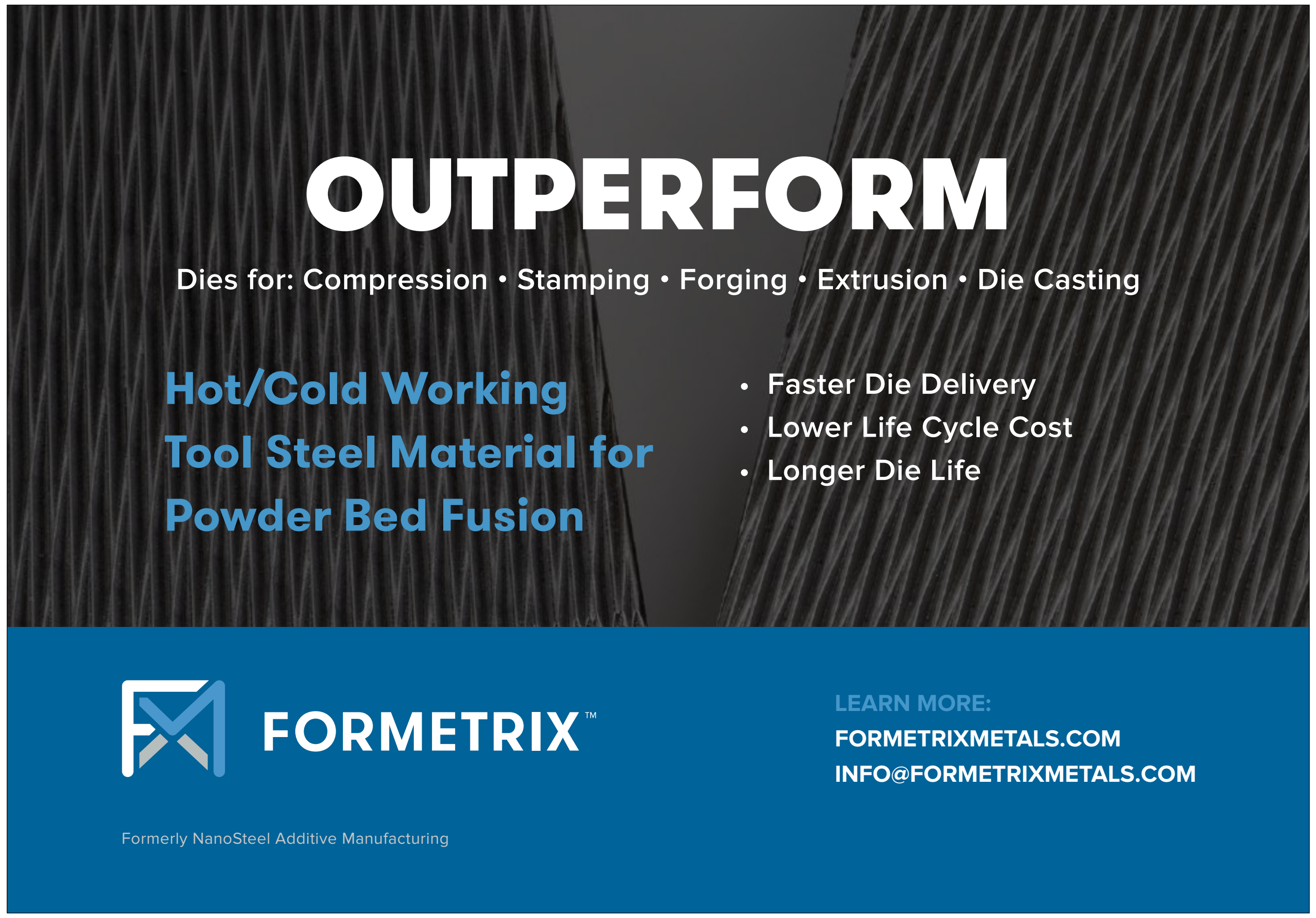
CECIMO, the European Association for the Machine Tool Industries, has raised concerns following a non-binding resolution on Additive Manufacturing released by the European Parliament on July 3, 2018. The resolution, 'Three-dimensional printing: intellectual property rights and civil liability', underlines the advantages of AM for the economy and society, the production status achieved by AM in various sectors and the need for new rules supporting faster certification for parts in the manufacturing process.

However, CECIMO notes that the resolution also calls for the European Commission to consider a potential revision of the Liability and Intellectual Property Rights (IPR) regulatory framework for Additive Manufacturing in the EU, drawing attention to the feasibility of national copyright levy systems for AM. In doing so, the association stated that the European Parliament has disregarded the negative impact such measures can have on innovation, as well as significant economic inefficiencies – including the administrative burden that copyright levy systems impose on the development of AM in Europe.

In an official statement, the association stated, "CECIMO is glad that the European Parliament recognises the added value of 3D printing and its technological, economic and environmental benefits for Europe. We urge the European Institutions, however, to firmly differentiate between business-to-business and business-to-consumer uses of the technology, when approaching 3D printing from a regulatory perspective. 3D printing production methods are already subject to a high level of requirements in the sectors where this production method is applied. Europe has a key position in several segments of the 3D printing market world-wide. For the full adoption of the technology to take place across the continent, it is of the utmost significance to avoid new regulatory actions on liability and IPR, which would stifle innovation and slow down the uptake of 3D printing in EU countries," the statement concluded.

The adoption of the resolution requires a mandatory response from the European Commission, which has been asked to outline its views and intentions on this topic, within three months. CECIMO reported that it will continue to engage closely with European Commission officials to raise the message that the current patchwork of liability and IPR rules is already fit for purpose in the European AM landscape.

www.cecimo.eu



Ingersoll Rand turns to PostProcess for aerodynamic surface finishing


Following surface finishing using PostProcess's Hybrid DECI Duo solution, the impeller consistently passed aerodynamic tests (Courtesy PostProcess Technologies)

In a new case study, PostProcess Technologies, Buffalo, New York, USA, reports that its automated surface finishing technology has delivered excellent surface finish standards and replicable results to exacting requirements for complex additively manufactured titanium and nickel alloy shrouded impellers. The impellers, produced by Ingersoll Rand, Dublin, Ireland, required tight tolerances for aerodynamic testing and a high level of surface finish for aerodynamic performance.

Aerodynamic performance largely depends on the level and consistency of surface finish; Computational Fluid Dynamic (CFD) calculations for boundary layer formation and other flow requirements use surface finish values, and surface roughness and inconsistencies invisible to the eye will compromise the results. Outstanding surface finishes are therefore essential to meet performance thresholds of components such as impellers.

Ingersoll is currently in the process of adopting metal Additive Manufacturing to produce its shrouded impellers due to the quicker lead-times and higher geometric complexity the technology offers. However, due to the nature of AM, the newly developed impellers are produced at an Ra (roughness average) value that does not meet the engineering team's specifications. This problem is further compounded by the existence of long internal channels in the part measuring less than 12.7 mm (0.5 in) wide and 127-177.8 mm (5-7 in) long.

The Ingersoll engineering team stated that it has employed multiple surface enhancement methods including manual sanding, grinding tools, chemical etching and combinations of these, achieving results which lacked the quality and consistency required. Using PostProcess's automated Hybrid DECI Duo solution, Ingersoll obtained consistent and repeatable Ra results for the impellers, with these results being proven through benchmark testing. The technology reportedly delivered parts that consistently passed aerodynamic tests, with an average of 70-80% reduction in Ra for parts run for twenty minutes or less.

Ioannis Hatziprokopiou, Mechanical Engineer, New Product Development, Ingersoll Rand Compression Technologies & Services, stated, "We have chosen the DECI Duo because of its repeatability, minimal setup, processing times and cost of ownership. Photochemical machining, extrude honing and micro-polishing or micro-machining all yield very good results when applied correctly; however extensive tooling and equipment costs, set-up times and required DOEs prior to applying the surface finishing method to obtain a repeatable process have made the DECI Duo a better option."

In addition, some of aforementioned finishing techniques unevenly remove material inside the flow path of the impeller, whereas the DECI Duo uniformly treats the entire surface of the flow path. The final geometry of the flow path must remain as unaltered as possible after post-processing of any kind," he concluded.

www.postprocess.com
www.company.ingersollrand.com

Barnes Group partners with LPW Technology on training for metal Additive Manufacturing

The Barnes Group Advisors, Pittsburgh, Pennsylvania, USA, and LPW Technology, Widnes, Cheshire, UK, have entered into a strategic partnership to offer training and development for metal powder-based Additive Manufacturing. The aim of the partnership is to provide professional development training on a variety of topics specific to AM with metal powders.

"Adequate training increases employee productivity, team performance and end-product quality," stated Alison Wyrick Mendoza, Leader of Training & Services at The Barnes Group Advisors. "Almost everyone who works in our industry understands by now that people are the most important asset. It's necessary to address advanced knowledge of all the processes involved, including those processes associated with AM materials."

Ben Ferrar, Chief Operating Officer, LPW Technology, commented, "We're delighted to partner with The Barnes Group Advisors to provide practical, in-depth powder training for metal AM. We are naturally aligned with The Barnes Group's approach to training."

"Advancing the knowledge-base within our industry of the importance of the metal powder within the AM process results in increased build success and acceptance of metal AM in the production environment," he continued. "The training programme will begin with topics on AM Materials 101, Powder Production Methods, Material Testing Methods and Advanced Specification Writing."

"AM is only as viable as the material parts are made from and increasing the knowledge of these materials is another step forward to drive adoption and technology readiness," added John Barnes, Founder and Managing Director, The Barnes Group Advisors. "LPW puts considerable effort into providing technical information for use by the AM industry, so it is a natural fit for The Barnes Group Training. It's a great match to utilise what LPW already knows with our reach and mission to educate and train AM engineers."

www.lpwtechnology.com ■■■

NanoSteel spin-out Formetrix to accelerate commercialisation of steel alloys for AM

Advanced materials company NanoSteel, Providence, Rhode Island, USA, has announced the spin-out of its Additive Manufacturing business unit into a new corporation, FormetrixTM. Led by NanoSteel and including investors Cycad Group and SPDG, Formetrix aims to accelerate the commercialisation of NanoSteel's steel alloys for metal Additive Manufacturing.

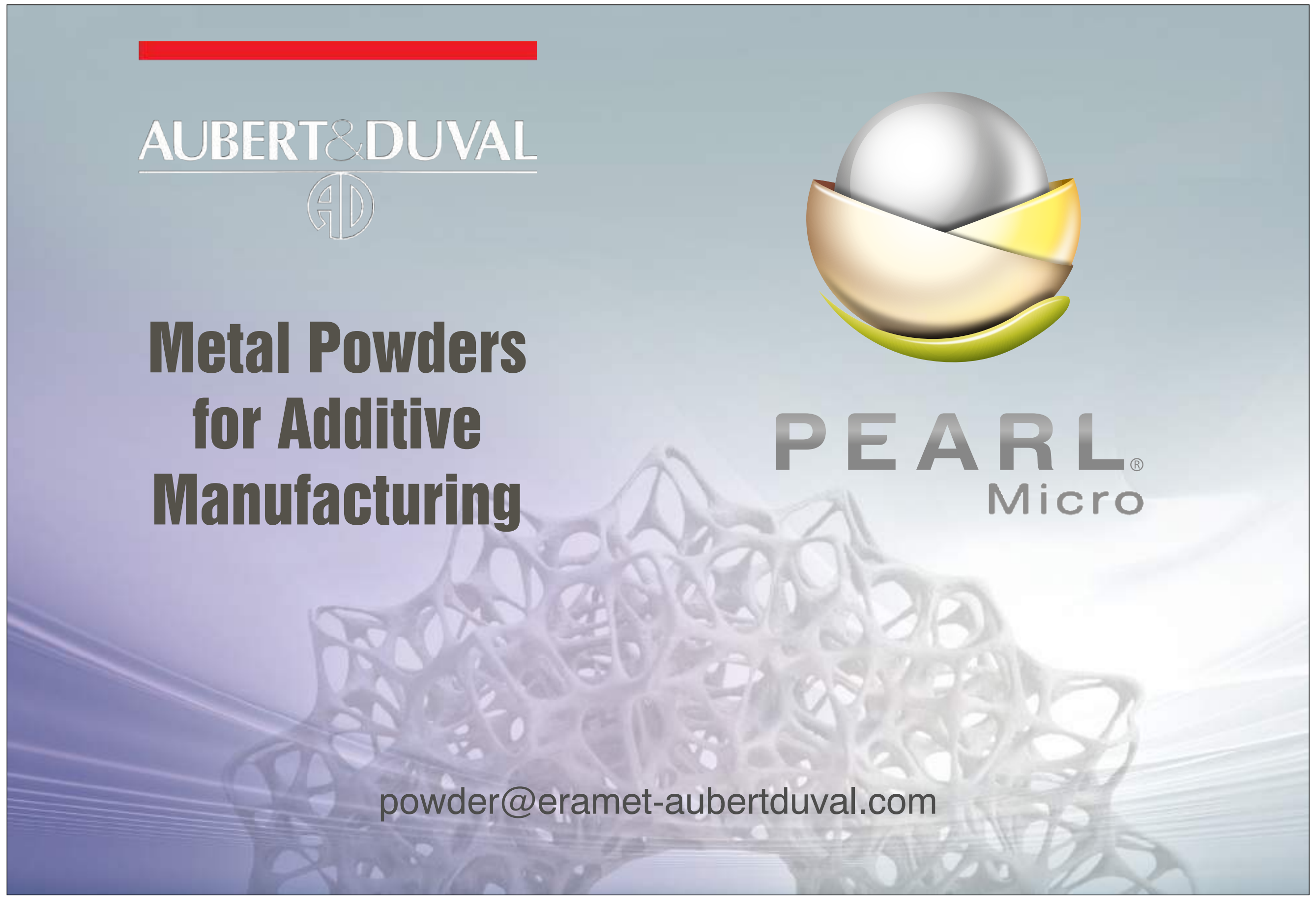
Over the last four years, NanoSteel has developed novel alloys with material properties that current alloys for AM or Metal Injection Moulding (MIM) do not offer. Drawing from NanoSteel's decade-long expertise in patented steel alloy design, Formetrix's metal powder portfolio is said to offer a combination of benefits, such as higher hardness, higher ductility and higher wear resistance, compared to existing alternatives.

David Paratore, President and CEO of NanoSteel, stated, "Formetrix was formed to provide new, high-performance steel alloys to accelerate the adoption of Additive Manufacturing within the tool and die and aluminium die cast industries. Growth in these sectors has been limited, due in part to the lack of suitable materials, and we believe we have developed excellent new options."

In order to support customers' production requests, Formetrix stated that it will install a FormUp 350 AM machine from AddUp at its facility. "Through the precision capability provided by our new industrial AddUp 3D printer, we can support both prototyping and volume customer needs more effectively and efficiently," stated Harald Lemke, Chief Commercial Officer of Formetrix. "Using the initial FormUp 350 along with additional finishing equipment, Formetrix will continue to expand its service center capabilities."

Allegra Kowalewski-Ferreira, Investment Manager, SPDG, commented, "We are driven by the promising value Formetrix offers the Additive Manufacturing industry. The launch of Formetrix is a powerful milestone that we are excited to be a part of and look forward to its growth as an industry leader."

www.nanosteelco.com ■■■



FIT Additive Manufacturing to add SPEE3D's supersonic 3D deposition to its technology offering

FIT Additive Manufacturing Group, Lupburg, Germany, has purchased a supersonic 3D deposition (SP3D) machine produced by SPEE3D, Melbourne, Australia. According to SPEE3D, its machines can manufacture copper and other metal components in record time.

In an SP3D machine, metal powder is not spread over a surface but fired by a nozzle onto a defined spot on a material carrier. The powder particles hit that position at three times the speed of sound, with the corresponding kinetic energy, which binds them without the use of melting or heat.

The first SP3D machine will be installed by FIT late in 2018, initiating an extensive testing phase. Philip Emmerling, Research Engineer at FIT, stated, "We will focus on the functional performance of the components produced by this machine. Our first tests were promising, but much work has to be done."

With its investment in this new type of system from SPEE3D, FIT aims to continue its transition from an additive manufacturer to a global AM research and development partner for industrial clients. "Fifteen years ago, we moved from service bureau to Additive Manufacturing with Electron Beam Melting technology. Five years ago, we started to support our clients with additive design challenges – mostly with powder bed technologies," stated Carl Fruth, Founder and CEO of FIT AG.

"Now, new additive technologies and new players are emerging all the time. These need to be implemented on an industrial scale – independent from machine manufacturers – and we need to constantly scout the AM universe for new developments," he concluded, while Albert Klein, CFO and CSO of FIT AG, added, "With this broad and deep approach we can support our clients in their extremely complex additive design and manufacturing problems. We are rapidly moving to additive technology partnerships rather than Additive Manufacturing."

www.fit.technology

www.spee3d.com ■■■

The SP3D machine fires metal powders onto a defined spot on a material carrier at 'three times the speed of sound' to produce components without melting or heat (Courtesy SPEE3D)

Components produced using SPEE3D's supersonic 3D deposition process (Courtesy SPEE3D)

Carpenter Technology announces plans for Emerging Technology Center

Carpenter Technology Corporation has announced plans for adding an Emerging Technology Center on its Athens, Alabama campus. The facility will initially focus on Additive Manufacturing technology development, with future investments slated for soft magnetics and meltless titanium powder.

Over time, Carpenter expects to invest $52 million in the Emerging Technology Center, which will create approximately 60 jobs over the next five years. This investment is said to be a critical component in executing Carpenter's key growth initiatives and is aligned with its business strategy of becoming a complete end-to-end solutions provider in the AM area.

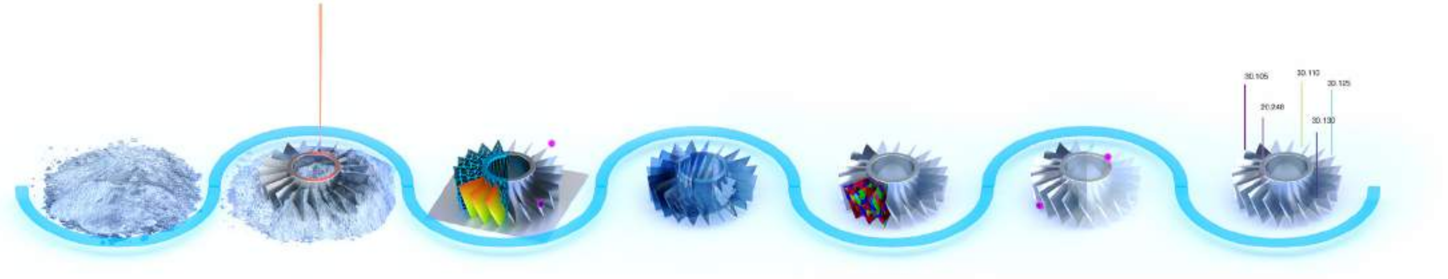
"By utilising our metallurgical and process expertise, the Emerging Technology Center is where we will develop and implement future solutions for our customers ranging from new alloys to revolutionary 3D printed parts," stated Tony R Thene, Carpenter's Chief Executive Officer. "Our recent investments in AM and soft magnetics indicate our ongoing commitment to the rapidly changing landscape of our industry."

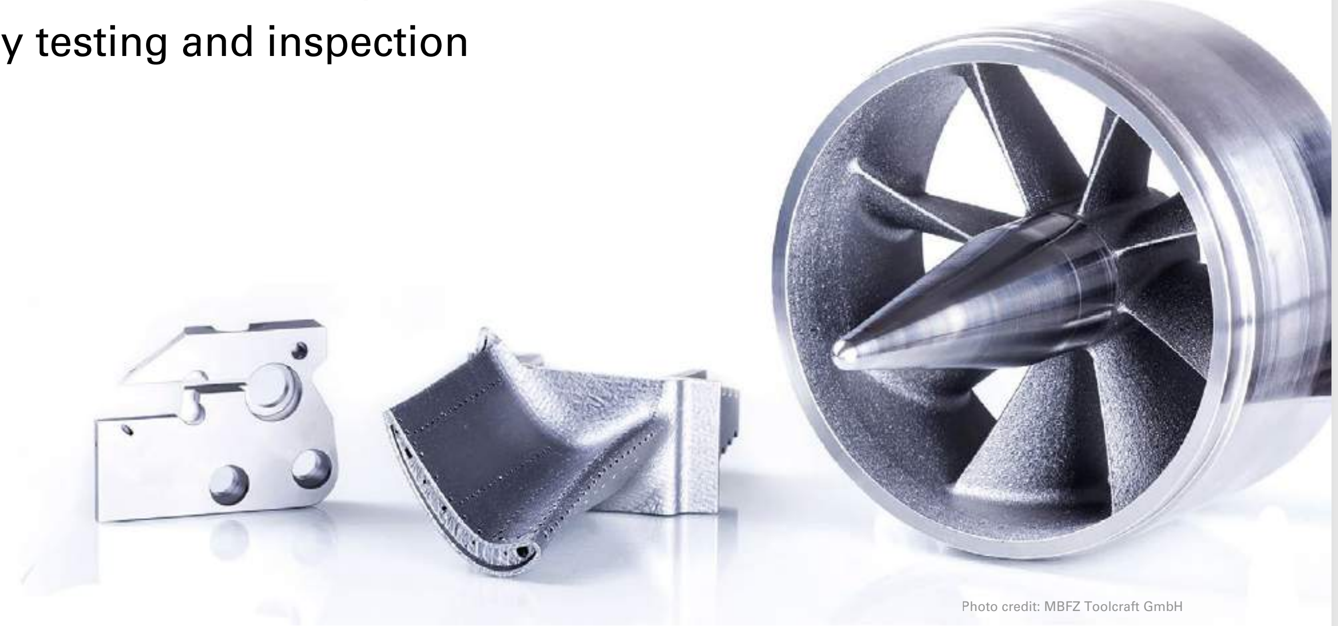
Within the last sixteen months, Carpenter has acquired Puris LLC, a producer of titanium powder for Additive Manufacturing and advanced technology applications; acquired MB CalRAM LLC, a leader in powder-bed fusion AM technologies; announced a $100 million investment in soft magnetics capabilities at its Reading, PA facility; opened an AM Technology Center in Reading, PA; and solidified several AM powder supply agreements with various companies to expand its presence in this rapidly expanding market.

Carpenter's 500,000 ft^2 Alabama manufacturing facility, which began operations in 2014, produces high-end specialty alloy products, primarily for the aerospace and energy markets. The Athens site was later expanded to produce superalloy powders used in applications including jet engine disks and 3D printed aircraft engine components and other products.

The Emerging Technology Center is expected to open in approximately twelve months.

www.cartech.com ■■■





AM cutting blades enable improved medical implant extraction

The endoCupcut developed by Endocon allows for the more accurate extraction of medical implants (Courtesy GE Additive)

Medical devices company Endocon GmbH, Heidelberg, Germany, has developed a new tool which uses metal additively manufactured cutting blades to enable more accurate extraction of used acetabular (hip) cups. The blades are manufactured in 17-4 PH stainless steel on a GE Concept Laser Mlab Cusing 100R machine, which uses Laser Powder Bed Fusion. Traditionally, cutting blades have been manufactured by casting and, especially for multiple sizes and shapes, production time for a single batch of blades could be as long as three and a half months. Including post-processing, the lead time for the new additively manufactured blades is now just three weeks.

The removal of a hip cups from patients following implantation, such as in the event of loosening, abrasion or infection, presents a complex task for surgeons, for whom very few devices are available for the job. The removal process often involves the use of a chisel, which risks damaging bone and tissue and can leave the bone with an uneven surface, making the insertion of a replacement implant more difficult.

Endocon has addressed the need for a better removal technique with the creation of an acetabular cup cutter, the endoCupcut, which allows for more precise cutting along the edge of the acetabular cup and is said to offer surgeons the opportunity to loosen and extract cementless hip cups quickly, without adding additional damage to the surrounding bone. The device is reusable and allows surgeons to implant the same size hip cup that was implanted before. It offers variability in one instrument and can be combined with up to fifteen additively manufactured stainless steel blades, in various shapes and sizes, ranging from 44–72 mm.

Klaus Notarbartolo, General Manager at Endocon, added, "We've also been able to reduce the cost per blade by around forty to forty-five per cent. That means cost savings for us and in turn for our customers. When you combine that with a reduction in product development time, higher efficiency and lower rejection rates, then the business case for additive really becomes attractive."

Local service bureau Weber-KP, a metal AM specialist, manages all stages of the process for Endocon, handling data preparation, build orientation, and the build itself through to high-quality surface finishing, hardening and bead blasting. Depending on the size and orientation in the build envelope between two and six blades can be built on a 90 x 90 mm build platform.

The new blades show excellent corrosion resistance and achieving a consistent hardness level, showing an improvement to 42+-2 HRC, compared to 32 HRC using casting. Harder, stronger, more reliable blades not only perform better in the operating room, Endocon stated, they also address patient safety concerns by reducing the risk of breakage and splinters embedding into the tissue.

Stephan Zeidler, Business Development Manager Medical at GE Additive, added, "Endocon's ability to solve multiple challenges using additive is an impressive example of how it can have a positive impact for smaller companies targeting the orthopaedic industry. What started with the need for a reduced time-to-market in terms of product development and flexible production of various shapes and sizes has resulted in a smart, innovative medical product that enhances patient outcomes. Moving the entire production process from casting to AM was a logical step and that shift continues to provide inspiration for future projects."

Endocon reported that the device has been positively received and is already being used by a number of medical professionals across Germany. This fast and safe procedure has significantly reduced the surgery time from around half an hour to just three minutes. Compared to the previous chisel method, the endoCupcut's precise cutting method preserves the maximum amount of bone substance and supports an accelerated healing process for the patient.

www.ge.com/additive
www.endocon.de ■■■

3D Systems and GF Machining Solutions launch DMP Factory 500

3D Systems, Rock Hill, South Carolina, USA, and Georg Fischer AG's GF Machining Solutions, Schaffhausen, Switzerland, have launched the DMP Factory 500. This joint offering is reported to be a scalable manufacturing system, designed for the building of high quality, seamless metal parts of up to 500 x 500 x 500 mm using simplified workflows.

The DMP Factory 500 is a customisable solution and is comprised of five function-specific modules:

- Printer Module (PTM): designed to withstand the rigors of 24/7 production cycles enabling maximum machine uptime and output
- Removable Print Module (RPM): sealed module for powder and part transport between machine, powder, and transport modules featuring a vacuum chamber to ensure the lowest O_2 content enabling high quality metal AM parts. Powder waste is eliminated, as the vacuum chamber guarantees consistent high material quality, sufficient to be re-used to depletion
- Powder Management Module (PMM): de-powders parts on build platforms, automatically recycles unused powder materials and prepares the RPM for the next build
- Transport Module (TRM): enables efficient movement of the RPMs between machine and powder modules – reducing production time
- Parking Module (PAM): provides interim storage of RPMs in an inert environment until ready for further progression in the workflow (e.g., stores a fully prepared RPM for its next print job while the PTM is finishing the previous print job)

The modular design of the DMP Factory 500 is said to enable continuous function of all metal AM and powder management modules to maximise uptime, throughput and operational value. The ability for a manufacturer to create a custom solution – matching the number and type of modules required for their production workflow – could help maximise their investment, while the integrated automation minimises manual processes to reduce total cost of operation. In addition, the DMP Factory 500 system includes seamless data connectivity with all major ERP systems to facilitate supply chain optimisation.

The AM platform is integrated with GF Machining Solutions' System 3R referencing and clamping system. Zero point clamping is said to enable optimal positioning of the build plate, facilitating a quick transition from the AM machine to the post-processing steps. This integrated feature reduces set-up times and provides enhanced flexibility by quickly transitioning the build plate from the additive process and sending it downstream for post-processing, saving significant time and money.

"This partnership joins two industry leaders in additive and subtractive manufacturing to deliver a solution that will change production manufacturing environments," stated Pascal Boillat, President, GF Machining Solutions. "The blending of GF Machining Solutions' precision machining expertise with 3D Systems' standard-setting AM technologies will ultimately redefine metal parts production."


The DMP Factory 500 is 3D Systems and GF Machining Solutions' first jointly developed solution (Courtesy 3D Systems)

The DMP Factory 500 offers integrated software including 3D Systems' 3DXpert™ for management of the AM workflow from design to manufacture. Additionally, DMP Monitoring facilitates real-time process monitoring. Customers will have access to metals manufacturing applications experts at Customer Innovation Centers in Leuven, Belgium; Denver, Colorado, USA; and Stabio, Switzerland. Customers will be able to collaborate with application engineers in these locations to optimise their DMP Factory 500 system for their business needs.

"The DMP Factory 500 is transforming and redefining how manufacturing gets done," stated Vyomesh Joshi, President and CEO, 3D Systems. "Through our partnership with GF Machining Solutions, manufacturers will have a solution that combines additive and subtractive manufacturing and provides a simplified workflow. As manufacturing continues to advance, customers will start to expect high quality, large part production with significantly reduced total cost of operation, and with the DMP Factory 500, that's exactly what they'll get."

www.3dsystems.com
www.gfms.com ■■■

LLNL investigates machine learning for defect prevention in metal Additive Manufacturing

Researchers at Lawrence Livermore National Laboratory, California, USA, are exploring machine learning to process the data obtained during metal Additive Manufacturing builds in real time to very quickly detect whether a build will be of satisfactory quality. The team reports that it is developing convolutional neural networks (CNNs), a popular type of algorithm primarily used to process images and videos, to predict whether a part will be satisfactory by looking at as little as 10 milliseconds of video from within the build chamber.

Brian Giera, Principal Investigator on the project, stated, "This is a revolutionary way to look at the data that you can label video by video, or better yet, frame by frame. The advantage is that you can collect video while you're printing something and ultimately make conclusions as you're printing it. A lot of people can collect this data, but they don't know what to do with it on the fly, and this work is a step in that direction."

Sensor analysis of metal AM parts carried out post-build can be expensive. Giera stated that CNNs could offer a valuable understanding of the Additive Manufacturing process and the quality of each part, enabling users to correct or adjust the build in real time if necessary.

LLNL researchers developed the neural networks using about 2,000 video clips of melted laser tracks under varying conditions, such as speed or power. They scanned the part surfaces with a tool that generated 3D height maps, using that information to train the algorithms to analyse sections of video frames (each area called a convolution). This process would be too difficult and time-consuming for a human to do manually.

Bodi Yuan, a student at the University of California student and an LLNL researcher, developed algorithms able to automatically label the height maps of each build, and used the same model to predict the width of the build track, whether the track was broken and the standard deviation of width. Using these algorithms, the researchers were able to take video of in-progress builds and determine if the part exhibited acceptable quality.

Researchers reported that the neural networks were able to detect whether a part would be continuous with 93% accuracy, making other strong predictions on part width.

"Because convolutional neural networks show great performance on image and video recognition-related tasks, we chose to use them to address our problem," Yuan explained. "The key to our success is that CNNs can learn lots of useful features of videos during the training by itself. We only need to feed a huge amount of data to train it and make sure it learns well."

Ibo Matthews, a co-author on the paper, leads a group which has for some years been collecting various forms of real-time data on the Laser Powder Bed Fusion (LPBF) metal AM process, including video, optical tomography and acoustic sensors. While working with Matthews and his group to analyse build tracks, Giera concluded it wouldn't be possible to do all the data analysis manually, and turned to neural networks could simplify the work.

"We were collecting video anyway, so we just connected the dots," he stated. "Just like the human brain uses vision and other senses to navigate the world, machine learning algorithms can use all that sensor data to navigate the 3D printing process."

The neural networks described in the paper could theoretically be used in other 3D printing systems, Giera said. Other researchers should be able to follow the same formula, creating parts under different conditions, collecting video and scanning them with a height map to generate a labeled video set that could be used with standard machine-learning techniques.

He added that work is still required to detect voids within parts that can't be predicted with height map scans, but could reportedly be measured using ex situ X-ray radiography. The researchers will also look to create algorithms which incorporate multiple sensing modalities besides image and video.

"Right now, any type of detection is considered a huge win. If we can fix it on the fly, that is the greater end goal," he stated. "Given the volumes of data we're collecting that machine learning algorithms are designed to handle, machine learning is going to play a central role in creating parts right the first time."

The project was funded by the Laboratory Directed Research and Development program. Further co-authors on the paper included LLNL scientists and engineers Gabe Guss, Aaron Wilson, Stefan Hau-Riege, Phillip DePond and Sara McMains.

www.llnl.gov ■■■

EBAM satellite fuel tank domes 'largest additively manufactured parts in space'

Sciaky, Inc., Chicago, Illinois, USA, a subsidiary of Phillips Service Industries, Inc. (PSI), has achieved qualification of its Electron Beam Additive Manufacturing (EBAM) process for the production of titanium domes for satellite fuel tanks through the completion of testing by Lockheed Martin Space, Denver, Colorado, USA. The 116 cm (46 in) diameter vessels will reportedly be 'the largest additively manufactured parts in space', and completed the final round of quality testing this month, ending a multi-year development program to create very large, high-pressure tanks used to carry fuel on board satellites.

Satellite fuel tanks must be both strong and lightweight to withstand the rigours of launch and decade-long missions in the vacuum of space, with even very small flaws or leaks catastrophic for the satellite's operations. These new titanium fuel tanks consist of three parts welded together: two EBAM domes which serve as caps, plus a variable-length, traditionally-manufactured titanium cylinder which forms the body.

A Lockheed Martin engineer inspects one of the additively manufactured dome prototypes at the company's space facility in Denver. The final dome has a diameter of 116 cm (Courtesy Lockheed Martin)

To complete the qualification, Lockheed Martin Space additively manufactured both halves of the titanium fuel tank domes on a Sciaky EBAM 110 machine at its Denver facility. During testing, the tanks are said to have met or exceeded the performance and reliability required by NASA, enabling them to become a standard product option on LM 2100 satellites.

Sciaky's EBAM systems can produce parts ranging from 20 – 580 cm (8 – 228 in) in length, with gross deposition rates ranging from 3.18 – 11.34 kg (7–25 lbs) of metal per hour. Using conventional manufacturing methods, a satellite fuel tank – comprising a four-foot diameter, four-inch thick titanium dome – could take more than a year to deliver, but Lockheed Martin stated that Sciaky's EBAM technology reduced the production time dramatically for the domes as well as reducing material waste during manufacture.

"Our largest 3D printed parts to date show we're committed to a future where we produce satellites twice as fast and at half the cost," stated Rick Ambrose, Lockheed Martin Space Executive Vice President. "And we're pushing forward for even better results. For example, we shaved off 87% of the schedule to build the domes, reducing the total delivery timeline from two years to three months."

"These tanks are part of a total transformation in the way we design and deliver space technology," he continued. "We're making great strides in automation, virtual reality design and commonality across our satellite product line. Our customers want greater speed and value without sacrificing capability in orbit, and we're answering the call."

"Sciaky's EBAM technology is now the world's only large-scale metal 3D printing process that has qualified applications for land, sea, air and space," added Scott Phillips, President and CEO of Sciaky. "We are delighted to work with the innovators at Lockheed Martin Space and will continue to push the boundaries of Additive Manufacturing."

www.sciaky.com | www.lockheedmartin.com ■■■

Fraunhofer demonstrates vibration-eliminating support structures for post-processing of metal AM parts

The Fraunhofer Institutes for Production Technology (IPT) and Laser Technology (ILT), Aachen, Germany, have developed a new design for support structures which is said to eliminate part vibration during post-processing operations such as milling or grinding. Milling operations conducted on thin-walled parts in particular often cause vibrations which can negatively impact both part accuracy and machining time.

As a rule, metallic components manufactured using Powder Bed Fusion (PBF) processes are designed with a larger-than-usual oversize to allow for functional surfaces to be finished in milling operations, since this is the only way of ensuring that all of the surface tolerances and quality requirements can be met. Thin-walled parts are particularly prone to vibration in the course of the machining and material removal operations, and this can result in poor surface quality or even render the components unusable.

Fraunhofer IPT and ILT's new support structures are said to increase the stiffness of susceptible areas of AM parts and thereby reduce vibrations during post-processing. They can also be removed with relatively little effort in the course of the surface finishing operation. Parts stabilised in this way can reportedly be manufactured in higher quality in less time, and with lower level of tool wear.

Fraunhofer IPT and ILT have developed a support structure design which is said to eliminate vibration during post-processing (Courtesy Fraunhofer IPT)

www.ipt.fraunhofer.de
www.ilt.fraunhofer.de ■■■

Conflux Technology appointed as official EOS agent for Australia and New Zealand

Conflux Technology, Geelong, Australia, has been appointed as an Australian and New Zealand agent for EOS Additive Manufacturing solutions. Conflux's Additive Manufacturing and Engineering Centre (AMEC) is located in the heart of the Geelong Innovation Precinct, south-west of Melbourne. It is now complemented by a showroom where an EOS M 290 system for additive manufacturing with metal materials is on display.

"In Australia we currently see the biggest potential for industrial 3D printing in industries such as mining, aerospace, medical and transportation," stated Dr Hans J Langer, CEO & Chairman of the EOS Group.

Conflux's manufacturing operations encompass the design and CFD analysis of parts. Its team has worked with AM for over two decades and possess a deep understanding of designing for AM technology and developing geometry specific parameters for optimal production.

www.confluxtechnology.com | www.eos.info ■■■

MELD Additive Manufacturing technology is finalist in the R&D 100 Awards 2018

MELD™ technology, developed and patented by MELD Manufacturing Corporation, Christiansburg, Virginia, USA, has been selected as a finalist in the R&D 100 Awards. Now in their 56th year, the awards honour the 100 most innovative technologies introduced in the past year.

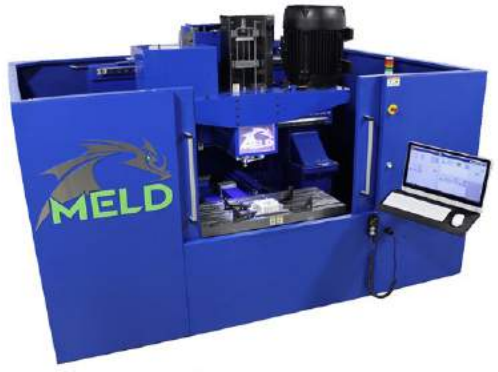
MELD Manufacturing Corporation launched in April 2018, introducing its MELD technology, a no-melt process for metal Additive Manufacturing and for coating, repairing, altering and joining metal parts. Since its launch, the technology has received the Rapid + TCT innovation award, been selected by the US Army as part of its inaugural Army Expeditionary Technology Search, and been awarded funding by the USA's Strategic Environmental Research and Development Programto support research into its use as a method for recycling battlefield scrap metal for repairs and manufacturing in the field.

"Our mission with MELD is to revolutionise manufacturing and enable the design and manufacture of products not previously possible," explained Nanci Hardwick, MELD CEO. "MELD is a whole new category of AM. For example, we're able to work with unweldable materials, operate our equipment in open-atmosphere, produce much larger parts that other additive processes, and avoid the many issues associated with melt-based technologies."

The R&D 100 Awards programme highlights innovations in the categories of Analytical/Test, IT/Electrical, Mechanical Devices/Materials, Process/Prototyping, and Software/Services, while also presenting Special Recognition Awards in the categories of Market Disruptor Services, Market Disruptor Products, Corporate Social Responsibility, and Green Tech. Finalists are selected by more than fifty judges from a range of industries.

Winners for the R&D 100 Awards will be announced in a special ceremony on November 16, 2018, during the annual R&D 100 Conference at the Waldorf Astoria in Orlando, Florida.

www.meldmanufacturing.com ■■■



The B8 Model MELD machine (Courtesy MELD Manufacturing Corporation)

Winners of Formnext Start-up Challenge 2018 revealed

The winners of the Formnext Start-up Challenge 2018 have been revealed as 3DFortify, Aerosint, AMendate, Kumovis and Nanogrande. Now in its fourth year, the award honours companies founded within the last five years who demonstrate significant innovations in Additive Manufacturing.

The official awards ceremony will be held on the opening day of Formnext 2018, where the winners will also have the opportunity to present their technology in the Start-up Area for the duration of the show in Frankfurt, Germany, November 13–16, 2018. Together with other start-ups, the winners will also have the chance to present a short business pitch as part of Formnext's new Pitchnext event. In addition to the opportunities they receive during Formnext 2018, the prize-winning companies will be offered a range of services designed to assist them in achieving further success in the development of their company, including business coaching provided by AM Ventures.

AMendate

AMendate, Paderborn, Germany, is the developer of software for fully-automated topology optimisation in Additive Manufacturing, resulting in efficient and cost-effective production.

AMendate's technology allows structures to be generated rapidly and automatically. Its core element is an intelligent optimisation algorithm that interprets the simulation result automatically and converts it into commonly-used CAD exchange formats.

Thomas Reiher, CEO and Co-Founder of AMendate, stated, "In the field of Additive Manufacturing, Formnext has established itself as a central platform for new products and networking opportunities. As one of the winners of the Start-up Challenge, we are therefore delighted to be part of the industry's must-attend event."

www.amendate.de

Aerosint

Aerosint, Liège, Belgium, has developed a selective powder deposition system to enable multi-material part production. Multiple powder materials are deposited to form a single layer, making it possible to produce parts combining a variety of materials, including metals, polymers and ceramics.

Matthias Hick, CTO Aerosint, stated, "At Aerosint we believe multi-material is the next evolution of 3D printing. Multi-material will enable parts optimisation and functionalisation like no other manufacturing technology is capable of. Replacing the traditional recoater in SLS/SLM printers with our powder deposition recoater can bring multi-material capabilities to a robust and proven technology that exists for more than thirty years."

www.aerosint.com

Nanogrande

Nanogrande, Montréal, Quebec, Canada, has developed what is claimed to be the world's first nano-scale Additive Manufacturing process. The system can assemble highly packed multi-layers of particles as thin as 1 nm using materials such as metals, oxides, waxes and polymers.

The patented technology creates layers using fibres, flakes and unconventional particles, and is also said to be able to combine different materials to form objects with few or no supporting structures. Its high print resolution reportedly enables the Additive Manufacturing of structures in the submicron range, using particles from 1 nm to 1 mm. A build area of up to 200 mm x 200 mm is possible depending on model.

www.nanogrande.com

Kumovis & 3DFortify

Also named as Start-Up Challenge winners are Kumovis, Germany, a producer of plastic medical implants by AM, and 3DFortify, which uses digital composite manufacturing for the AM of carbon fibre, fibreglass and ceramic components.

www.formnext.de ■■■

Initial design (left) and final part design (right) (Courtesy Amendate)

Aerosint's selective powder deposition system (Courtesy Aerosint)

Additive Manufacturing system from Nanogrande (Courtesy Nanogrande)

Siemens: Digitalisation enables the industrialisation of metal Additive Manufacturing at Finspång

As one of the world's largest industrial companies, Siemens has experienced first hand the process of taking metal AM from the R&D laboratory to the series production of critical components for its power generation business. Today, it is supporting the global industrialisation of the technology through its Siemens NX Additive Manufacturing software. In the following report the company's Aaron Frankel and Ashley Eckhoff explain their belief that, whilst the potential of AM is massive, digitalisation will play a critical role in enabling its transition from a prototyping tool to a serial production technology.

The centuries-old city of Finspång, on the banks of Skutbosjön Lake, Sweden, has been a centre of industry since the 16th century, when local factories produced cannon and cannonballs for the country's military. In 2018, Finspång's economy is still driven by industry, and the city is home to a number of metal processing plants and gas turbine production facilities. It is within the gas turbine industry in this small municipality, 180 km southwest of Stockholm, where the future is being additively manufactured. The major employer in this industry, and in this area, is Siemens, which manufactures gas turbines at an innovative, cutting edge production facility in the city (Fig. 1).

To understand why these innovations are occurring in Finspång today, it is important to understand the city's history. Cannon manufacturing spanned nearly four centuries and evolved by the 1890s to become a major industry, with the last cannon being produced in Finspång in 1911. In 1913, the city entered the modern industrial age with the inception of turbine production. By 1955, the gas turbine business had begun and, by the 1980s, the resultant medium-sized gas turbines, capable of generating from fifteen to sixty megawatts, were being used in new and aftermarket applications.

The new millennium brought a rapid succession of changes to the Finspång facility. Beginning in 2008, Siemens started to explore Additive Manufacturing as a means to accelerate gas turbine innovation. As the

Fig. 1 A view of a gas turbine under construction in Siemens' Finspång facility

Fig. 2 A part of the Siemens metal Additive Manufacturing operation in Finspång

technology's development continued, the Finspång facility became a hub of innovation for Additive Manufacturing technology at Siemens.

By 2009, Siemens had begun using metal AM systems from Germany's EOS GmbH. Andreas Graichen, Group Manager for the Additive Manufacturing Centre of Competence at Finspång, stated that the team initially believed it could do everything it wanted with new designs and new materials. "This was only partly true," he said. "The engineers quickly recognised there was much work to do if they wanted to realise AM's full potential." AM has, however, played a critical role since, and the company's engineers soon discovered that this technology could be crucial in spare and new parts production.

Facility engineers knew they were on the cusp of something new in 2012, when they used AM in a new machine designed strictly for burner repair. Two years later, the Centre for Additive Manufacturing Competence Development opened, building upon previous work with the digitalisation of the technology for rapid design, manufacturing and repair. Finally, in 2016, a specialised automated AM facility was opened with eight new machines (Fig. 2).

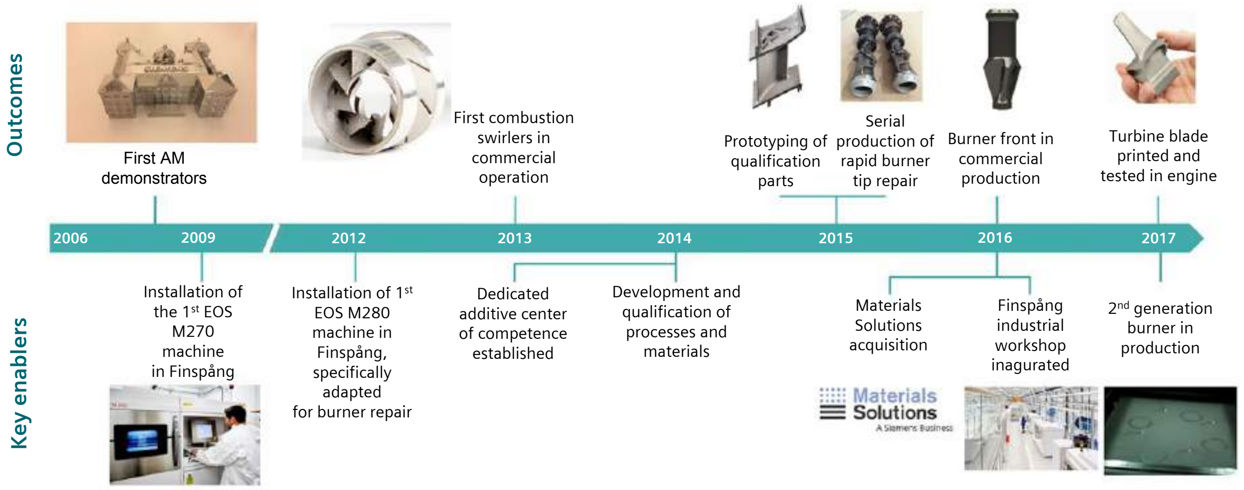


Fig. 3 A timeline of metal AM developments at Siemens' Finspång facility

Today, the facility houses more than 2,600 employees, fifty of whom are dedicated to Additive Manufacturing. It produces world-class, efficient and reliable gas turbines, with 95% of production being exported. "The beauty of the site's setup is that Finspång has everything in one place that is needed for design, production, testing and aftermarket support," stated Vladimir Navrotsky, Technology and Innovation Manager of Siemens Service Distributed Generation and Oil and Gas. The facility is a comprehensive operation that includes a design team for gas turbines, a test facility to test the engines, a state-of-the-art manufacturing facility including serial production, and a service organisation that provides feedback from the operational fleet.

The combustor burner

The combustor burner is a key element in the turbine, where the struggle for efficiency and emissions reduction is won or lost. This dynamic creates the perfect storm for change and disruption by digitalisation (Fig. 6). Developing a gas turbine can include a large number of design changes, but, because of the significant costs associated with these changes, designs are normally limited to two or three iterations. Modifying a turbine design for traditional manufacturing can require costly new castings and moulds, with long lead times using expensive raw materials. The need to minimise lead-time, costs and iterations drove the introduction of digitalisation and the use of Additive Manufacturing technology into the industrial turbine manufacturing process.

Fig. 4 Andreas Graichen, Group Manager for the Additive Manufacturing Centre of Competence at Finspång

Fig. 5 Vladimir Navrotsky, Technology and Innovation Manager of Siemens Service Distributed Generation and Oil and Gas

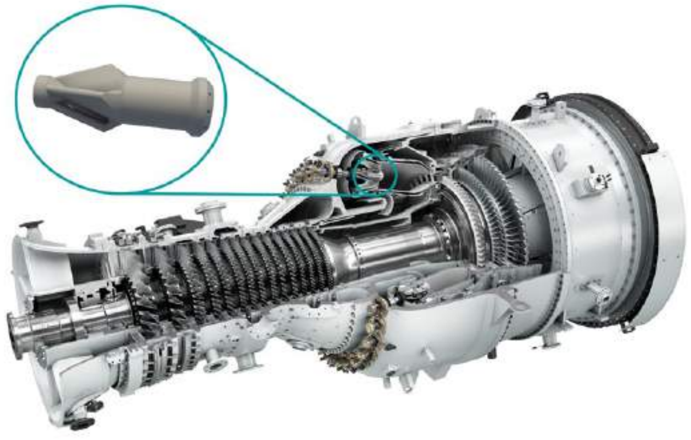


Fig. 6 The combustor burner is a key element in the turbine, where the struggle for efficiency and emissions reduction is won or lost. Shown is a SGT-800 gas turbine with a burner component highlighted

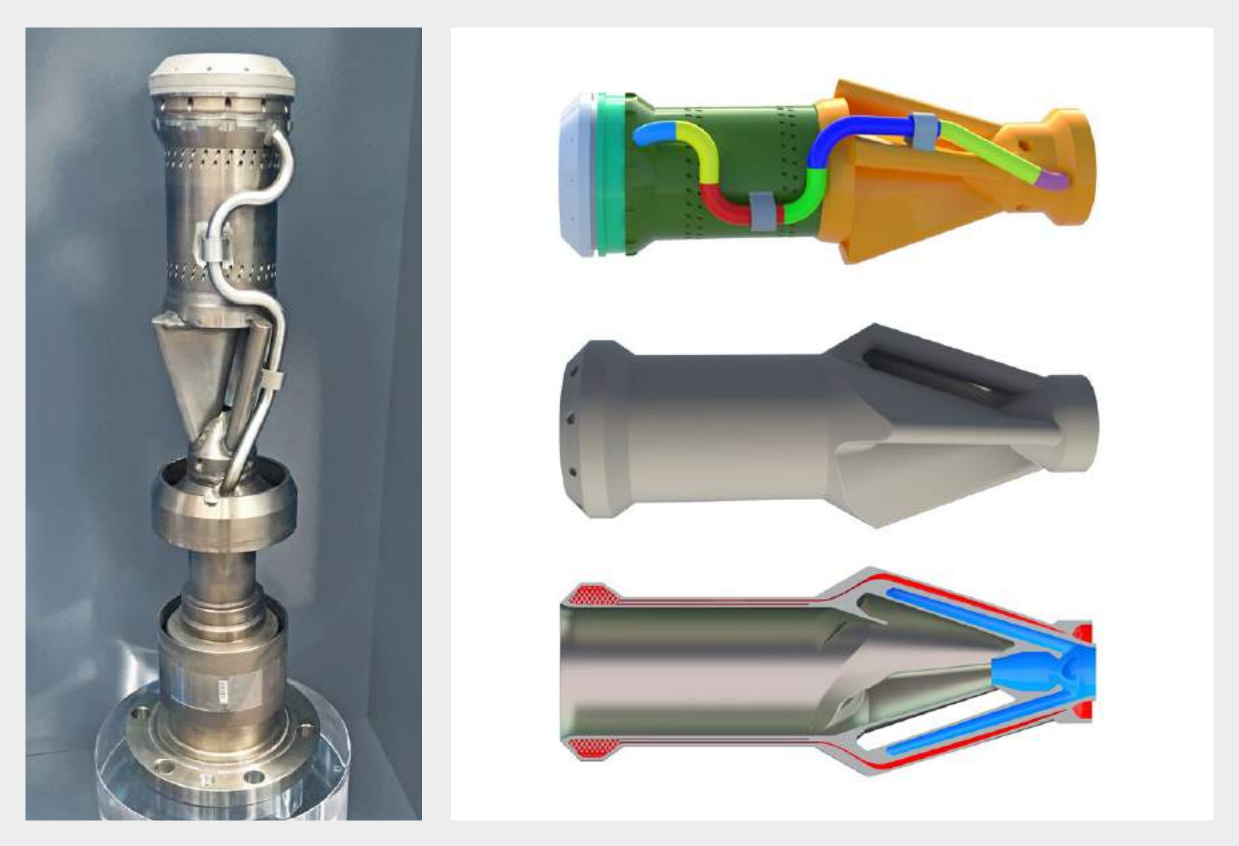


Fig. 7 A conventionally manufactured burner repaired using AM is shown on the left, with the repaired section visible at the top. Top right shows the original complete burner component, middle right shows the new AM design, and lower right shows a cutaway view highlighting the lattice structure

The initial years: From rapid prototyping to spare parts on-demand

Additive Manufacturing is now a standard part of the Siemens product development process, which includes prototyping, the building of components, testing and defining materials for design. "The Finspang facility is the world's largest internal user of Siemens NX AM software solutions, with hundreds of seats.

In the beginning, engineers at the Finspång facility looked to AM for rapid prototyping, allowing for the construction of functional prototypes that could be tested and physically validated. As mentioned, building turbine components and parts using traditional methods is an extremely complicated process, with long lead times. The team saw AM as a way to shorten lead times and allow for more cost-effective part testing and verification of new designs.

At its inception, the facility worked closely with EOS for its AM equipment needs and to this day Finspång primarily uses Laser Powder Bed Fusion (LPBF) technology and EOS machines. The original machines at the facility were EOS M270s, which allowed the facility to rapidly build prototype parts for testing and validation from digital designs.

The beginnings of innovation: Burner tip repair via Additive Manufacturing

When a burner is installed in a gas turbine and runs in the field, the burner tip will erode after a certain number of hours due to the extreme heat from flame and combustion inside the turbine. The cost of new burners can be high, so this was a driver for Siemens' efforts to repair and re-certify burners as a lower-cost alternative.

The long-standing method for repair involved first sending the burners back to Sweden. There, they were loaded into a milling machine where 120 mm of the damaged area– essentially the front section of the burner– was machined away. A new front section was then welded on, completing the refurbished burner assembly. While more cost-effective than assembling a new burner, this process was still lengthy and required several manual steps.

As engineers in the Finspång facility became more familiar with the possibilities of Additive Manufacturing, they wondered if AM could help them to redesign the repair process for these burners. Siemens collaborated with EOS on a process where only 20 mm of the front of the burner was machined away to provide a clean, known surface. A new front section was then additively manufactured directly onto the burner – massively reducing scrap, work and repair time (Fig. 7, left).

To make this process work, the facility worked closely with EOS to design a special version of the M280 AM machine which incorporated a unique fixture system to load and hold the burner, an optical system to orient the print, and a unique process to print a replacement tip on the front of the machined burner base.

This process has been hugely successful, according to Siemens. "We have produced thousands of repairs in this new way of replacing the tip: a fully industrial process," Graichen said. "Moreover, we have reduced turnover time by 70%."

The newly-designed burners were put into service in turbines across the world, but the true test was whether they would last through the required number of duty cycles. After 20,000 hours of operation, the burners were inspected and found to be in good condition, meaning that they were able to continue to run in the field without immediate repair or replacement.

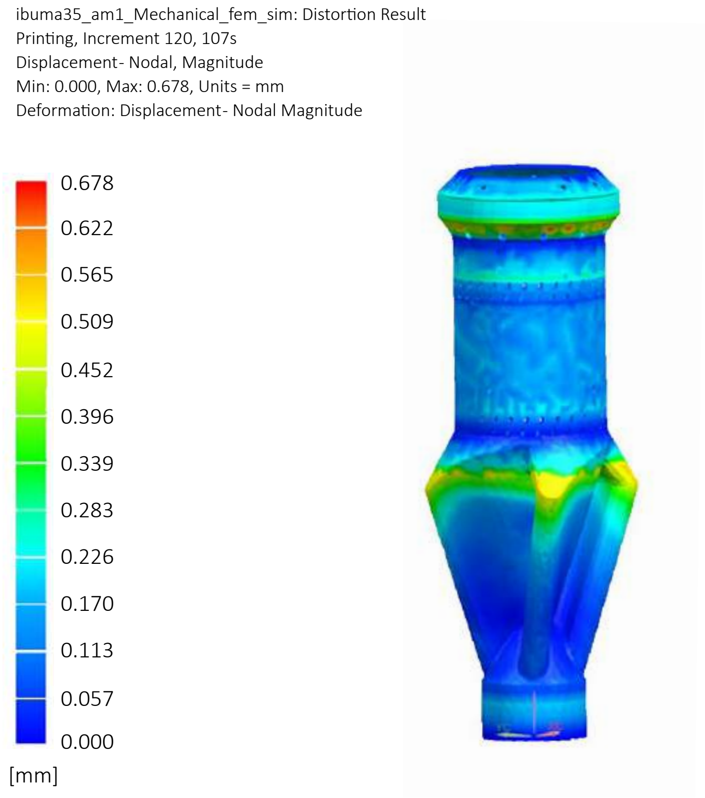


Fig. 8 Screen view from a simulation of the burner build. Siemens states that software was the catalyst that allowed the team to design energy products of the future at the required volume

Design benefits offered by AM

The original turbine burner head design called for thirteen individual pieces to be machined and welded together. The resulting burner was roughly 800 mm in length, and was built using a complicated manual manufacturing process.

As the Siemens team in Finspång gained knowledge about the AM process, it envisioned other uses for the technology. Engineers investigated a complete redesign of the burner head that could consolidate the thirteen individual parts into one single unit, and considered how they might incorporate special features that could only be additively manufactured.

One essential requirement of burner design is a low mass. By designing for AM, the team found that the burner walls could be made slimmer for improved temperature responsiveness, and that lattices could be introduced to make the burner stronger at a lower weight, resulting in less thermal inertia. The lattice structure inside the tip also allows for more effective cooling of the burner tip.

The AM design delivered a stronger, more agile product for the turbine's heating and cooling cycle, enabling a less aggressive heating and cooling routine. This increases the burner's lifetime and lessens the oxidation and crack formation which typically damage burners. The team also achieved a 22% weight reduction, and is working to further refine the design to attain a 50% weight reduction (Fig 7, right).

As the Finspång team's knowledge of AM evolves, its ability to take advantage of the technology's potential continues to grow. "I can compare this technology with a snowball. As you form a snowball, it gets bigger and bigger," Navrotsky said. "There's a positive enhancement with this ball. The same can be said about Additive Manufacturing enabling at the same time enhancement of the components' functionality, design and manufacturing time reduction, materials reduction and component lifecycle cost improvement."

The state of the art: Industrialising Additive Manufacturing

As Additive Manufacturing capabilities at the Finspång facility evolved, it became clear that true industrial production would require more than just adding new machines to boost production volume. The Siemens team quickly discovered that to repeatably produce high-quality parts required a well-defined process, with a strong software foundation. At Finspång, as the AM process moved from prototyping to repair and through production, software was key to industrialising the AM process (Fig. 8).

Fig. 9 Dave Madeley, Senior Strategist and Additive Manufacturing Key Expert for Siemens, discusses the development of the burner

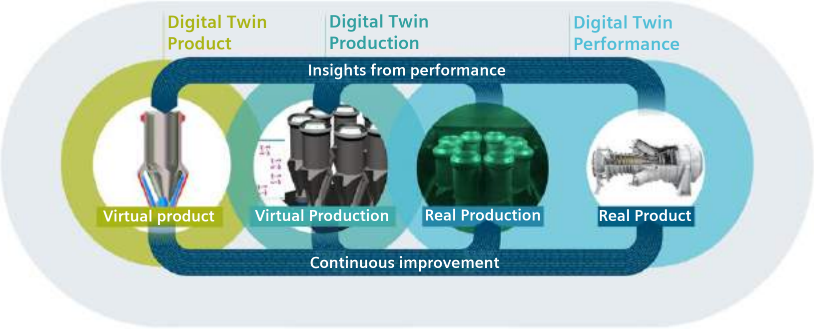


Fig. 10 Siemens believes that without the backing of its integrated NX AM software solution, the evolution from prototyping to serial production would not have been possible

Software was the catalyst that allowed the team to design energy products of the future at the required volume. The use of Siemens NX Additive Manufacturing software, combined with process knowledge from years of prototyping and repairing burners, enabled the team to produce redesigned, quality burner parts at scale.

Moving from prototyping and repair to production required a large investment in new production facilities and hardware, as well as investments in the software required to run those machines and ensure that the production process adapted smoothly to the new demand. Not only were the Siemens NX CAD, CAM, and CAE solutions used in the design and manufacturing process, but Teamcenter managed the part and process data. This helped the process to expand and adjust as the facility's needs grew.

The software's reach extended from the initial design to shop floor management, wherein the Manufacturing Operations Management (MOM) software tracked material usage, ensuring that the right mix of new and recycled materials was used for the process at hand.

These complex software solutions were necessary to run a cost-effective, efficient operation. "At our facility in Finspång, we truly have a real digital thread all the way from upfront design to the manufacturer on the shop floor," said Dave Madeley, Senior Strategist and Additive Manufacturing Key Expert for Siemens.

The integrated NX AM software system allowed the Finspång engineers to reimagine the burner design with an AM mindset and to produce burners with the required quality for such a demanding application. As the volume increased to meet production needs, simulation tools and shop floor execution software became lynchpins in the operation. Without the backing of a proper software solution, the evolution from prototyping to serial production would not have been possible (Fig. 10).

The adoption of AM: lessons learned

With a greater understanding of Additive Manufacturing, Siemens is more empowered to engage with other industries and customers to find solutions based on the revolutionary work at Finspång.

Collaboration was key to developing the AM process and technology to repair gas turbine burners. By removing internal barriers, collaborating through technology and developing trusted partnerships, a path was paved for innovation. Siemens believes that what was done at Finspång can help other industries to advance their Additive Manufacturing operations on an industrial scale.

"With technology as new as this, and that's moving as quickly as it is, it makes sense to form working relationships with other companies that are near the same development stage as you," stated Madeley. "It makes sense to form an ecosystem to connect people."

The work at Finspång continues to prove how revolutionary AM can be. It is now a matter of taking this knowledge and experience into the design of full gas turbine components or subassemblies. The process of moving not just a manufacturing operation, but also a design organisation and shop floor operation, from prototyping to production, is an experience that Siemens believes will pay off throughout the company.

Fig. 11 A selection of metal AM parts manufactured by Siemens, including the burner (left)

AM integration will also provide new delivery methods and solutions to companies. Siemens' work manufacturing products at an industrial scale can help companies to better understand their machines' ability and capacity to print, as well as to understand the knowledge required to ensure the necessary support is available wherever AM systems are operational.

> *"The worst thing a company can do is nothing, because Additive Manufacturing and, in particular, industrial-scale Additive Manufacturing, will make organisations of all sizes more competitive..."*

There are a number of complex problems facing the industrialisation of AM. However, the technology is an important part of the fourth industrial revolution, or Industry 4.0. From a cost perspective, whether it is used as a rapid prototyping tool or as a manufacturing technology on an industrial scale, the potential benefits are monumental, and companies across the world are working to understand the role AM will play in their processes.

"The worst thing a company can do is nothing, because Additive Manufacturing and, in particular, industrial-scale Additive Manufacturing, will make organisations of all sizes more competitive," Graichen stated. "Products will be built and manufactured faster, smarter, stronger and, in some cases, at a lower cost" (Fig 11).

Siemens' vision for AM

The work done at Finspång and the AM software solutions offered by Siemens are just one part of a multi-stage approach to Additive Manufacturing. In 2016, Siemens purchased Materials Solutions, a world-class AM contract manufacturer based in Worcester, UK, that manufactures extremely high-quality metal components for sectors such as aerospace, power generation and motor sports.

Furthermore, Siemens divisions other than the energy and software divisions are working on projects that use Additive Manufacturing. This includes the Mobility division, the Corporate Technology research division and the Consulting division, all of which have ongoing AM projects.

Fig. 12 Finspång has already built a robot arm capable of extracting powder from the current M280 machines where burner repairs are performed, relieving employees of this potentially dangerous task

Another side of this multi-faceted strategy is the recently announced Siemens' Additive Manufacturing Network. This online network links part designers and AM production service providers together, enabling online accessibility to AM knowledge and distributed manufacturing for scaling up global industrial AM.

> *"Without digitalisation or simulation of the process itself, you cannot industrialise on a large scale. Advancements in digital technology, simulation of processes, feedback loops and machine learning will be the core assets to make industrialisation work..."*

In the near term, the Finspång facility will continue its serial production of turbine burners while moving on to the additive production of turbine vanes and blades.

Siemens is eager to assist the industry in its transformation from prototyping into serial production. With research and multiple products having successfully been built, and many more in the pipeline, the company has the capabilities to assist customers and original equipment manufacturers in maturing this technology.

The benefits of AM are massive and digitalisation plays a critical role in ensuring success. "Without digitalisation or simulation of the process itself, you cannot industrialise on a large scale," said Andreas Saar, Vice President of Manufacturing Engineering Solutions and AM Program Lead for Siemens PLM Software. "Advancements in digital technology, simulation of processes, feedback loops and machine learning will be the core assets to make industrialisation work."

Visionaries at Finspång believe that Siemens' turbines will eventually be able to connect to a diagnostic centre where spare parts can be ordered and printed on-demand. Tracking each turbine will provide critical feedback, such as running hours and weather conditions, increasing the turbines' efficiency and longevity while reducing costs. When a gas turbine can analyse its own health and signal in advance when it needs maintenance, components can be additively manufactured to minimise downtime.

Looking to the future

Technology is rapidly evolving and soon the Additive Manufacturing machines and processes of 2018 will be improved. Graichen believes that today's AM machines are similar to the cutting-edge technologies offered during the infancy of computing. "Some may have thought at the time that what had been achieved was enough, but to stop innovation at that point would have eliminated the natural progression of better computers, the internet and the cloud."

Siemens' plan to exploit this potential relies upon new technology as it aims to design a state-of-the-art production facility. Robotics, data security, artificial intelligence and analytics all have a role in the intelligent facility the company envisions. The intention is for Finspång to serve as a model facility, with industry leaders visiting to see what the next generation of industrial production will look like.

Within the context of traditional production facilities, Siemens has already reduced repair times and increased production. But the company now wants to leverage a fully-connected production facility to boost its AM capabilities. By connecting equipment to the digital chain, from design through serial production and quality control, the production process can run smoother and more efficiently, errors can be identified sooner and time-to-market decreased.

Big data analytics and machine learning make this facility a 'learning' facility. Production machines and printers will communicate with each other and use machine learning to capture data for later use. Components and products will be manufactured to exact specifications as build jobs take place on-demand and improvements to the process are made based on the machines' feedback. As complexity grows and more data needs to be scrutinised, the human capacity to monitor changes becomes nearly impossible. These future machines will be able to track, open and print files while providing real-time feedback and adjusting the process 'on the fly'.

Siemens also envisions a facility one level above the learning facility. This will be an 'intelligent' production facility, which brings artificial intelligence and virtual and augmented reality into play.

For example, powders and microparticles used or left over from a part build are unsafe for workers, and the labour-intensive cleaning process involves dressing in safety equipment and manually cleaning the build chamber . As machines take on more dangerous jobs, the work environment will be safer and healthier. The facility will use autonomous robotics and advanced machinery to manage the process and to do this cleaning, ensuring people on-site are not exposed to dangerous materials.

Since its initial investment in this technology, Finspång has already built a robot arm capable of extracting powder from the current M280 machines where burner repairs are performed, relieving employees of this potentially dangerous task (Fig. 12).

Along with human safety, Siemens wants to lead the way with environmental safety. As AM technology evolves, fewer resources are needed to complete production of a component. Using AM can result in reduced final product weight, power consumption and material usage. Costs and environmental impact are minimised as fewer materials are needed for production.

Siemens software solutions for Additive Manufacturing incorporate industrial experience

For Additive Manufacturing to become a reliable industrial manufacturing solution, the right tools and technology need to seamlessly connect design and development to the shop floor. The challenges of doing more with additive manufacturing are designing optimised parts that print first-time-right and repeatedly producing those parts at volume with quality.

Siemens NX CAD/CAM/CAE and PLM solutions provide all of the necessary capabilities to industrialise Additive Manufacturing so that companies can not only prototype, but also design and produce ground-breaking products at scale.

The Siemens software solution integrates tools for DfAM, generative engineering, build process simulation, print preparation, support structures and build processors for driving Additive Manufacturing machines without data translations. This solution automates getting to a first-time-right print by simulating the build process to predict and avoid thermal-mechanical failures.

Siemens' software drives the widest range of Additive Manufacturing equipment for metal and plastic, with machines that deposit material in planar or multi-axis orientations. The software also automates the post-process finishing of production parts with NC and quality inspection programming. Integrating design and additive manufacturing with post-print tools means the entire requirements-to-finished production part process can be executed within a single system.

Siemens' Additive Manufacturing Network connects part designers, production service providers, and experts in an on-line collaborative ecosystem to accelerate adoption of industrial Additive Manufacturing.

Siemens PLM and Manufacturing Operations Management (MOM) software provides the digital backbone to manage the data and process from design to production. MOM solutions orchestrate production, manage material flow across the shop floor and monitor manufacturing processes to repeatedly produce high-quality parts.

Fig. 12 Burners on a build plate at Finspång

The vision at Finspång is to have a semi-autonomous production facility for rapid manufacturing, repair, or prototyping, with service technicians on-hand to manage the factory and capacity. In the field, remote monitoring of gas turbines, for instance, will detect problems, alerting the facility to the need for spare parts and components where they can be ordered automatically via the cloud.

This autonomous, connected factory will need systems such as in-line and off-line monitoring, robotic cleaning of AM machinery, automated 3D scanning and validation, self-healing processes and systems that can handle and react to the data created as the process executes. This vision places Siemens on the cutting edge of advancing AM.

However, in the near term, Siemens anticipates increasing the number of AM production machines in Finspång, creating spare parts on-demand, printing parts for new turbines and harnessing printing and job execution via the cloud and digital twins. Autonomy will allow sensors to monitor work as printing occurs, ensuring the right parameters are met and that the output will be of the required quality.

Looking forward: Designing and producing useful parts at scale

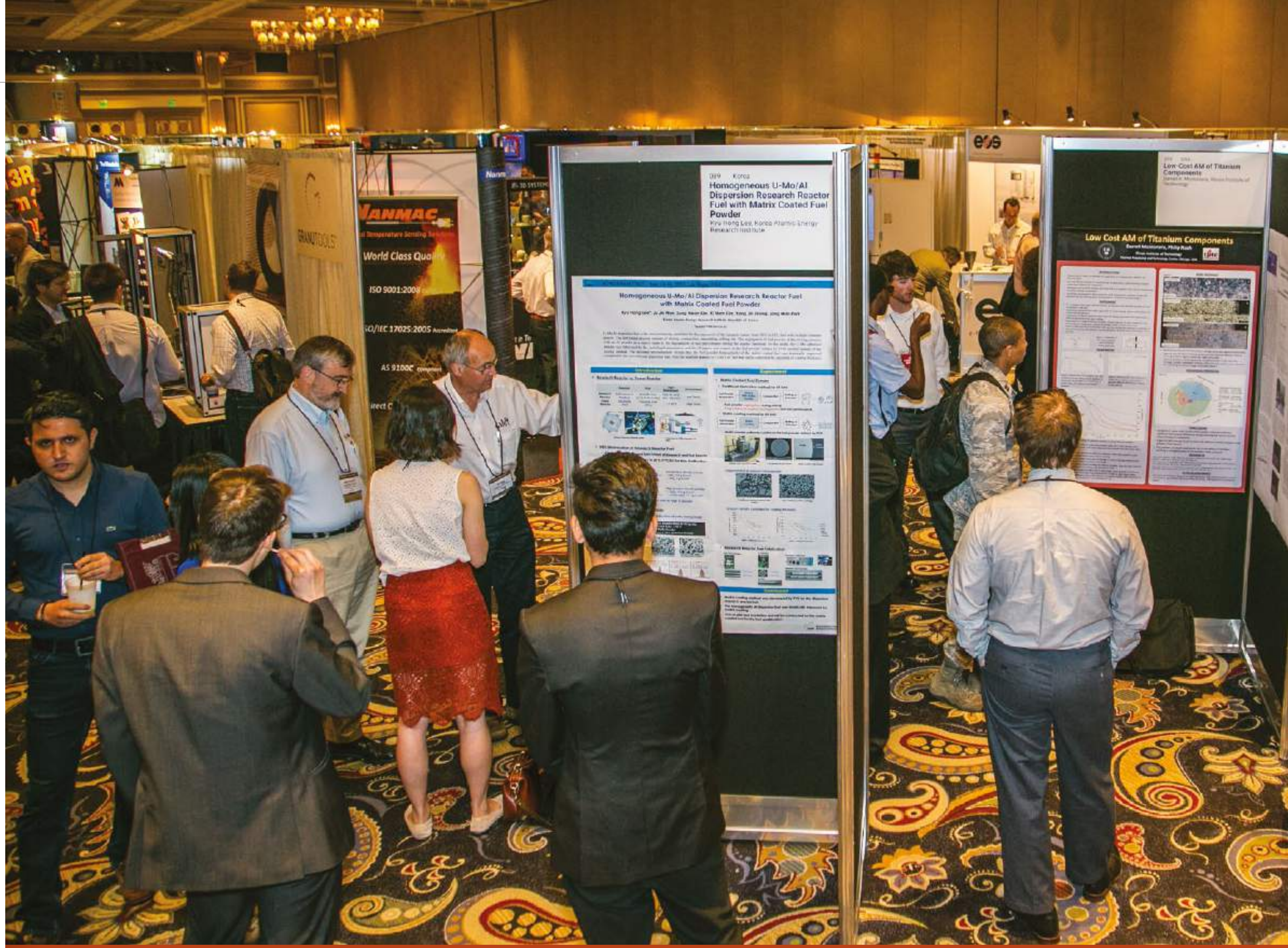
Moving forward often requires a look at the past. Finspång has a long history of manufacturing with metal, and this continues today with Additive Manufacturing at Siemens. This technology presents a tremendous opportunity to look back and see how current products can be improved by making them more cost-effective to produce and less expensive to the end-user. As with the gas burner, what started small as a tool for the prototyping and repair of a legacy design evolved into the consolidation of thirteen components into a single part that is now produced at scale by Additive Manufacturing. However, this is only one application and the potential for further innovation is immense. The people at Siemens are working hard to help industries across the world take advantage of this exponentially growing technology. Their ability to design and produce useful parts at scale with Additive Manufacturing is a proven example for the industry to follow.

Authors

Aaron Frankel
Senior Director Marketing
Manufacturing Engineering Software

Ashley Eckhoff
Marketing Manager
Manufacturing Engineering Software

Siemens PLM Software
5800 Granite Parkway, Suite 600
Plano, TX 75024
USA
www.siemens.com/plm/additive-manufacturing
www.siemens.com/plm/am-network



GKN Powder Metallurgy: Moving metal Additive Manufacturing towards mass production with HP

With the launch of HP's new Metal Jet system, Binder Jetting looks like the technology that will help move metal Additive Manufacturing into the realms of mainstream high-volume manufacturing. GKN Powder Metallurgy is set to be the first global parts manufacturer to move into mass production with this technology and, in the following report, the company outlines the evolution of its AM operations to-date and its expectations for the future.

With metal Additive Manufacturing poised to disrupt a $12 trillion manufacturing market, manufacturers and investors are now wondering what processes, materials and industries they should be watching, and how the seemingly radical processes that comprise metal AM will succeed in entering the manufacturing mainstream.

Firstly, it is important to understand that Additive Manufacturing is only one 'tool in the toolbox' and it will not fully replace conventional manufacturing processes. However, with the speed that metal AM is moving, it is set to transform a wide range of industries and industrial processes to the extent that companies which do not adopt the technology could quickly lose a significant competitive advantage.

A major development in the AM industry has been the recent announcement of HP's Metal Jet system (Fig. 1). Claiming to be up to fifty times more productive than comparable AM methods, the launch could represent a significant change in the market. In addition, it is said to be nearly half the cost of other Binder Jetting systems. However, anyone in manufacturing knows that equipment is only one part of the solution; understanding how to use new technology and having a sustainable and efficient supply chain are other vital parts of the jigsaw that must all come together for success.

In order to bring all of these pieces together, HP collaborated with Volkswagen and GKN Powder Metallurgy. The partnership's broad ambition is to challenge conventional manufacturing, remove design barriers and accelerate the adoption of metal Binder Jetting technology - particularly for automotive and industrial applications.

Fig. 1 The HP Metal Jet system is HP's first metal AM machine and is said to provide up to fifty times higher productivity at a significantly lower cost than other Binder Jet and Powder Bed Fusion technologies (Courtesy HP Inc.)

Fig. 2 Peter Oberparleiter, CEO, GKN Powder Metallurgy

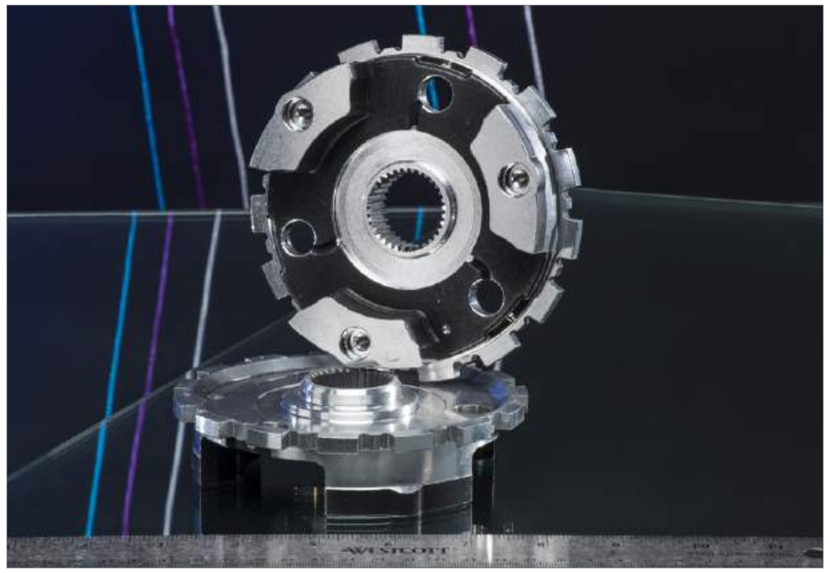


Fig. 3 GKN Powder Metallurgy manufactures 13 million sintered parts per day. These 2018 MPIF award winning aluminium PM planetary reaction carrier components, produced for General Motors, are good examples of the company's PM products (Courtesy MPIF)

During the 2018 International Manufacturing Technology Show (IMTS) in Chicago, Illinois, USA, GKN Powder Metallurgy announced that it will be the first to deploy the newly-launched HP Metal Jet at its factories to produce functional metal parts for companies including Volkswagen and Wilo. GKN stated that its goal with this system's deployment is to drive the global industrialisation of AM, transforming new product development and manufacturing, reducing the time-to-market for mass-produced parts from months to weeks, lowering development costs and providing greater design and manufacturing flexibility.

"Our vision for industrial Additive Manufacturing moves beyond prototypes and small-series production and into mass production. We see a future where every modern digital company will have cutting-edge AM machines in its facilities, enabled by GKN technology, design and support to produce metal parts in twenty-four hours," stated Peter Oberparleiter, CEO of GKN Powder Metallurgy (Fig. 2). "This strategic partnership with HP is the tipping point to accelerate that vision. As we join forces with them, we want our customers to challenge us to break design barriers and accelerate the adoption of Binder Jetting technology as an exciting complement to our existing Additive Manufacturing offerings."

As the world's largest producer of metal powder-based parts, GKN Powder Metallurgy is uniquely positioned to advance the development of the Binder Jetting industry. By integrating the HP Metal Jet system into its plants worldwide, GKN Powder Metallurgy hopes to leverage its metal powder expertise to engineer new powders based on customer needs and help its customers design parts they did not realise were even possible. In this way, the company expects to build on its foundation of manufacturing thirteen million sintered metal parts per day (Fig. 3), continuing on the path to Industry 4.0.

Commenting at the time of the partnership announcement, Stephen Nigro, President of Additive Manufacturing at HP Inc, stated, "HP is proud to partner with GKN Powder Metallurgy to bring the power of 3D mass production to the largest industries on earth, such as the auto and industrial sectors. The combination of HP's breakthrough Metal Jet technology and GKN's engineering and manufacturing leadership promises to enable the production of millions of high-quality, low-cost additively manufactured final parts."

The missing piece of the jigsaw

GKN has been involved in Powder Metallurgy for nearly eighty years. During this time it has amassed experience not just in the science behind the technology, but in working closely with customers and partners to understand the entire process, from raw material to the application and the performance demands of the final product. "Powder production and metal part processing are part of our DNA," stated Oberparleiter, "and we have a long history of collaborating with customers and industrialising solutions that bring great benefits to the entire industry."

With a large footprint in both metal powder and part production, GKN Powder Metallurgy believes that it is its experience and global network that enable new customers to feel comfortable working with innovative technologies. "In order to build the business that we have today its taken very close collaboration with customers to design the best metal powder solutions for their products," explained Christon Franks, President Commercial, GKN Sinter Metals. "For partners such as HP and customers such as Volkswagen, I think that we're the missing piece of the jigsaw. We take the best technology from machine builders, we industrialise it, raising the process to the highest quality standards and, as a result, we are able to give customers and partners full confidence in new technologies." It is these elements, states GKN, that will act as a foundation as it builds its presence in the AM industry.

Fig. 4 A state of the art shop floor at GKN Powder Metallurgy

The move into metal AM

Commenting on how Additive Manufacturing has influenced GKN's go-to-market strategy, Franks told *Metal AM* magazine, "Over the past few years we really started to understand the capabilities of AM and the attractiveness of the marketplace. Initially, we looked at getting into AM to expand our current portfolio of metal powder-related technologies. You need the right combination of application requirements and volume to make products eligible for conventional PM, so we were looking to expand our portfolio to move into lower-volume programmes, products and applications that were simply unsuitable for PM."

"As a starting point, we moved into AM to replicate the same types of shape that we manufacture in PM, but servicing different markets and volumes. However, as we progressed into higher-volume AM, particularly using laser-based AM for external customers, we started seeing designs coming in that weren't 'PM friendly'. As soon as the designer was free of the restrictions of conventional processing, we saw geometries that really surprised us. It was actually the marketplace, and the new creations that designers were asking for, that changed our perspective on how to use AM. It's interesting to see this unexpected shift, but that is how you know something exciting and big is happening," he stated.

Commenting on what GKN's developments in AM mean for its existing customer base, Franks added, "I already mentioned the design flexibility. We already have customers that use powder bed AM to create optimised parts that were originally designed for conventional manufacturing processes. Now, with

Fig. 5 Christon Franks, President Commercial, GKN Sinter Metals

Fig. 6 A high-precision, high-strength metal part produced using HP's Metal Jet system

Binder Jetting, we can offer customers a similar design freedom whilst significantly increasing production volumes."

"Metal Additive Manufacturing offers a fast product development time compared to conventional technologies, and this is a big part of the overall flexibility the process offers. Not only does it offer design flexibility, but manufacturing flexibility; you can move through iterations faster for prototyping, and you don't have to wait on expensive moulds that can take a lot of time and cost. As AM grows, we are seeing it used in higher and higher volumes. Without the need for tooling, we limit any incumbent inertia. This flexibility in design and manufacturing is driving innovation, with powder metal AM leading the charge."

Franks believes that whilst GKN Powder Metallurgy's AM capabilities have allowed it to broaden its customer base, the technology has opened new markets for existing customers. "Whilst we've picked up new customers along the way, the reality is that the customers that are benefiting the most are our established customers. Some of the traditional markets are starting to see major shifts. For example, in the automotive sector, electrification and other industry trends are resulting in a more fragmented market and a move towards fewer global programmes and more regional programmes. When this happens, customers don't necessarily have the same need for industrial scale production, so what we're able to offer is a quick way to introduce products and adopt new, innovative processes."

"As the market moves faster, even becoming more decentralised, the metal-based AM solutions that we deliver give our customers in the automotive and industrial sectors the speed, flexibility, volume and customisation necessary to keep up with the shifts that we have continuously seen in the market for years."

The challenges ahead

Commenting on the challenges to implement such radical shifts, Franks stated, "The first challenge is the market itself. As previously mentioned, it's constantly changing, and you need to have the flexibility to move with it. The second challenge is the customer. We've been spending an incredible amount of time training our customers over the last two years as to what AM, both laser and binder-based, can and cannot do. Once a customer has a deep understanding of what AM can do, you are then able to work with them to push the capabilities of the technology."

GKN believes that companies should consider both prototype and aftermarket volumes together to recognise the full value of AM adoption. "It is important to funnel all low-volume purchases through one door within an organisation, to see what kind of volume collectively, or demands collectively, their company has."

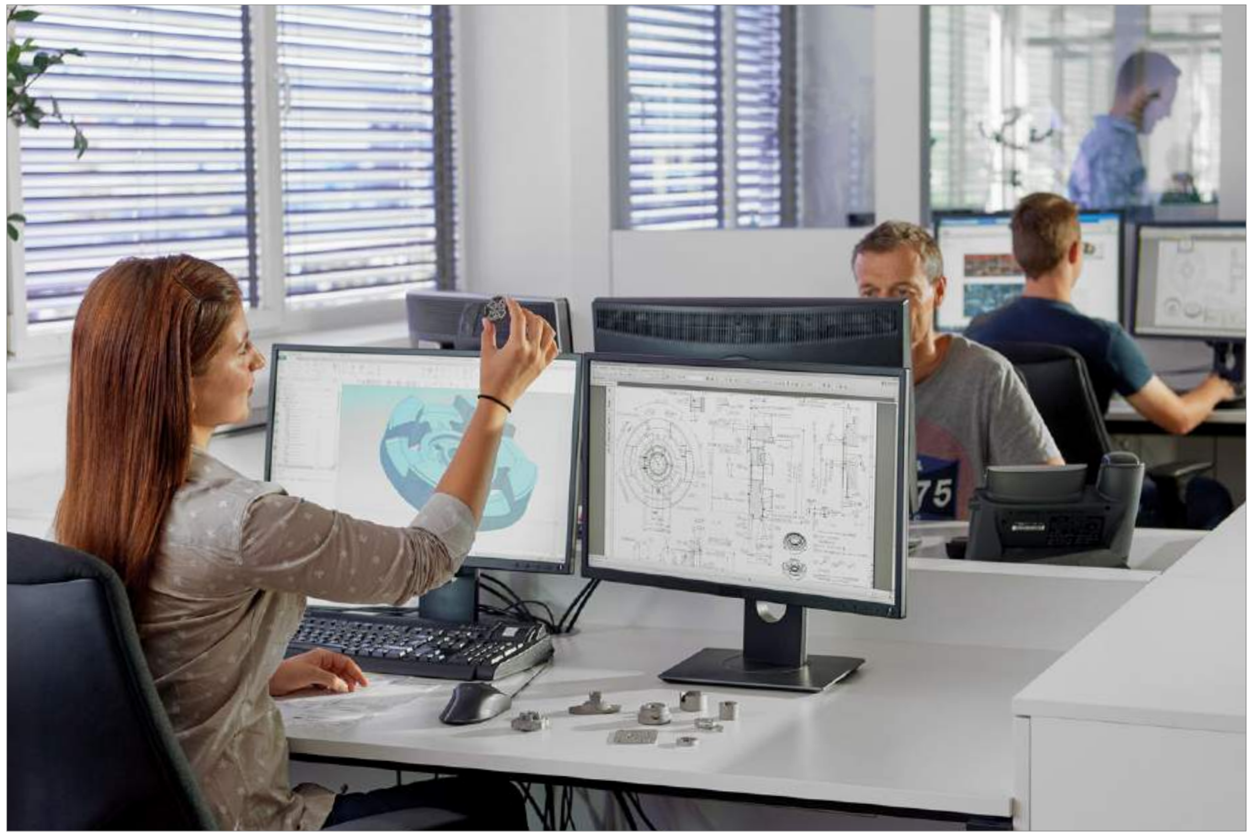


Fig. 7 Designing for metal AM at GKN Powder Metallurgy

A further challenge is that of safety and quality. "When it comes to a new technology, industries are naturally concerned about safety as much as they are about the quality of products produced. We're lucky to work collaboratively with early adopters and can manage expectations. For example, Volkswagen knows it might take a couple of generations to see the full benefit of a new technology, and they understand they are early adopters of a truly innovative AM strategy."

The future of metal Additive Manufacturing

Commenting on the growth potential of metal AM, Franks stated, "In five years, more companies will learn and become comfortable with powder-based AM technology. There is still a large market that hasn't adopted AM for prototyping, for example. Companies will continue to adopt AM for prototyping as the costs reduce, which will expose more designers to the benefits of the technology. GKN believes that this added exposure will push forward the validation of the technology and, as more limitations and benefits are understood, AM will edge further into the mainstream for mass production."

"Factories will combine traditional PM with a growing AM department which will ramp up both Laser Powder Bed Fusion (LPBF) and Binder Jetting. After a period of validation and exploration, the future will become even more exciting; as designers continuously push to do more with less, the design freedom of AM will offer solutions which do not yet exist. When designers have less limitations and are free to optimise a part in any way they see fit, this is when we will see AM change the world."

From a consumer perspective, GKN states that new products will become available with capabilities that simply weren't possible before, and that these products will be introduced much faster than in the past. "This will only create more demand for customisation and decentralisation, which could reduce the overall volume needed from traditional manufacturers. In addition, it will force companies lagging behind to adapt or potentially lose market share," stated Franks.

Imperative to this future will be the development of an integrated supply chain. "About five years ago, manufacturers using metal powders reported that it was difficult to get the right alloys, powder grades, or quantities that they needed. Today, with suppliers such as GKN, a wide range of powders are ready and available for production-sized orders. For example, GKN produces multiple titanium and steel alloys in quantities suitable for high-volume production. In addition, if a customer needs a custom alloy to

Fig. 7 Guido Degen, GKN's Senior Vice President Additive Manufacturing & Business Development

achieve specific material properties, GKN has the knowledge, experience and capability to produce custom batches quickly while meeting or exceeding quality standards," explained Franks.

"But it's not all about what and how much can be produced. Metal AM will also shorten time to market, which means feedstock replacement will have to happen faster too. Partnering with a company such as GKN, with the experience and extensive network to move high-quality powders quickly, will be another key to success in powder-based AM. GKN is already delivering high volumes of powders to customers around the globe in multiple markets."

Moving to mass production

AM systems such as HP's Metal Jet lower the barrier of entry into the AM market and decrease the amount of time before adopters see a return on investment. The range of volumes at which AM is more economical than traditional processes will increase. "This will of course also depend on the part, and if it is fully optimised for the process. Currently, experts are targeting parts produced at around 10,000–50,000 parts per year to be optimised with AM," stated Franks.

"People ask how long it will take to see AM really take off. Depending on who you are, you might say it already has. With every month that goes by I get more bullish about how I answer this question: I see our activity increasing exponentially each month, and I want to move the market for AM mass production closer and closer to today."

GKN has already, from the perspective of laser-based AM, created an industrial footprint to serve customers and is seeing tremendous volume come through for binder jet. However, the true industrialisation of AM, whether using binder or laser-based technology, has not yet been fully accomplished, and this is one of the biggest challenges faced in implementing this technology into an existing supply chain. Guido Degen, Senior Vice President Additive Manufacturing & Business Development, stated, "I'm confident that we're already well-prepared, given our existing digital framework. In addition to that, GKN has a broader vision for Additive Manufacturing becoming a global player in the market."

In addition to an expansion of its Binder Jetting capabilities, GKN will also enhance its relationship with EOS GmbH to develop the Laser Powder Bed Fusion process towards mass production. "The laser process offers huge potential in material, design freedom and productivity. EOS and GKN have the capability and expertise to drive industrialisation within this technology branch. This will be showcased to the public as a joint approach during Formnext 2018," Degen stated.

Outlook

As GKN discovered when it began its exploration of Additive Manufacturing, it will ultimately be the market that steers AM and the early adopters that have the potential to gain the greatest competitive advantage. But how big are the potential wins these companies are targeting? With a manufacturing market valued at some $12 trillion, industry analysts predict rapid growth for the Additive Manufacturing sector. Although metal AM is currently a mere fraction of the total, the industry is following a dramatic growth curve, with metal AM equipment sales growing 875% in the last five years, and 220% in the last two, according to the *Wohlers Report 2018*. Continued rapid growth could represent a bigger shift to come; perhaps, some say, the biggest we have seen since the industrial revolution.

Contact

Markus Josten
Global Sales Director, Disruptive Technologies & Markets
GKN Sinter Metals Engineering GmbH
Dahlienstraße 43
D 42477 Radevormwald
Germany
Tel: +49 2195 609 988
markus.josten@gkn.com
www.gknsintermetals.com

Conformal cooling: How AM is increasing efficiency and quality in the injection moulding industry

Much of the early success for metal Additive Manufacturing came from tool and die applications and this sector continues to offer significant growth potential for the industry. In this report, Jarod Rauch, from tool and die manufacturer B&J Speciality Inc, and David Lindemann, 3D Systems, share their thoughts on the current status and future potential of AM conformal cooling solutions with *Metal AM* magazine's Nick Williams.

Additive Manufacturing has been used to build moulds incorporating conformal cooling channels since the 1990s when the first metal powder-based AM systems came to market. The AM process in those early days used CO_2 lasers and required metal powders coated with polymer binder, which would evaporate out after the part was built. The part would then be infiltrated with a second metal to remove the porosity. Today, the technology has moved on considerably, and the new generation of AM systems uses significantly more precise fibre lasers, high purity metal powders and an oxygen-free manufacturing environment.

Despite the limitations of the early technology, tooling became one of the most important markets for the fledgling metal AM industry and the sector is regarded as one of the first real commercial applications of the technology. Whilst this success continues today, the use of Additive Manufacturing in the mould and die industry remains relatively niche compared to conventional toolmaking technologies.

B&J Specialty, Inc., based in Wawaka, Indiana, USA, offers precision machining, engineering and mould and die services to customers in the US Midwest. With the support of technology from AM technology provider 3D Systems, headquartered in Rock Hill, South Carolina, USA, the company works to offer high performance plastic injection moulding tooling for customers through the implementation of additively manufactured conformal cooling solutions.

Why conformal cooling?

In-mould part cooling is the most time-consuming part of the plastic injection moulding process - reduce the time for part cooling and you will increase production speed whilst achieving higher quality moulded parts with less scrap. A variety of techniques have been used to maintain even temperatures over the years, using methods such as bubblers, heat pipes and complex

Fig. 1 Segments of a conformal cooling system manufactured by B&J Specialty on a 3D Systems ProX® DMP 300 Laser Powder Bed Fusion system

Fig. 2 The ProX® DMP 300 AM metal 3D printer from 3D Systems

Fig. 3 Conformal cooling segments on a build plate at B&J Specialty

drilling operations using laminated blocks. These, however, are cumbersome, time consuming and can limit the useful life of a mould. Drilled cooling channels are also limited to straight lines, no matter what the part geometry.

Conformal cooling moulds have curved cooling channels that conform closely to part geometry and their use for an injection mould can reduce cycle time by anywhere from 10% to 40%. The low range gains are possible with little to no engineering analysis; the higher estimates reflect the use of flow analysis, computational fluid dynamics and finite element analysis.

Whilst conformal cooling solutions can significantly reduce the total cost of production by lowering mould cycle times, they also require sophisticated mould designs. A well-designed conformal cooling mould typically has a wide variety of unconventional curves, twists and shapes that must be precisely placed. Once designed, these complicated moulds must be manufactured to the same standards as any other mould.

Drivers and barriers for the adoption of conformal cooling

According to Jarod Rauch, B&J Specialty's Information Technology and 3D Printing Manager, whilst the demand for tooling with conformal cooling is seeing strong growth, there is also some resistance to such a transformative technology in what can be seen as a very traditional industry.

Rauch stated, "Most customers are eager to listen but very hesitant to make the decision to use AM. Mostly because you are telling them you will be changing both the established processes and the materials used to make the AM parts. Customers like to hear about new technologies but don't seem to like it when they hear they will have to change. My best tools to convince them that this change is for the best are our own case studies, mould flow simulations and CFD analytical tools. These allow us to show things in black and white for them, so they can see first-hand what could be achieved if they decide to go down the path of change. After seeing the results, customers often think it's too good to be true."

"We see the most resistance to AM with customers that know nothing about it. It's a major change and people will normally fear change. I believe they dig their heels in because we are disrupting the status quo. The moulding industry is mostly based around a set of standards that have been in place for decades and now, when you tell a customer we are throwing most of the manufacturing limitations out the window because of what AM brings to the table, they find it very hard to believe. Education is the key. You need to educate your customers on what they can gain through AM - and also help them realise that if you want major improvements things just have to change. Once a customer can accept this, you will then be heading down the path of success with Additive Manufacturing," explained Rauch.

Fig. 4 A flow mixing part with conformal cooling channels. This example highlights why issues such as closed-loop water systems can be such an important factor (Couresty 3D Systems)

Drivers for the use of conformal cooling are often application-specific, he continued, "What we see are production needs relating to the requirements of a specific product driving the decision to use conformal cooling. In some cases, moulds that have AM components with conformal cooling strategies are delivering a 30-50% increase in production at the moulding machine making the plastic parts. This dramatic increase in productivity alone will end up returning 100% or more of the entire mould's cost over the life cycle of the tool."

Unique considerations for conformal cooling

Whilst conformal cooling opens up a world of new possibilties for tool designers and plastic injection moulders, it brings a new level of complexity and its own unique requirements. Rauch explained, "If a designer has good design skills and a good understanding of fluid dynamics, additively manufacturing conformal cooling passages can dramatically improve cycle times and also improve part quality. However, it's not that simple. People tend to have tunnel vision and focus solely on designing an optimised conformal circuit, but one thing that will cause AM tooling with conformal passages to fail – and fail rather quickly – is the quality of water that is circulating inside. Most people don't initially think about this being an issue, but you have to remember that most moulding facilities' water systems consist of open-loop systems, with large cooling towers outside that carry the water through pipes to each moulding machine. Large amounts of debris and deposits build up which end up inside the mould waterlines. Eventually these build-ups cause catastrophic issues during the moulding process and you have to remove deposits."

"Up until now, most waterline passages were machined with some type of a drill bit – as all water circuits travelled in a straight line. So a blocked waterline just meant you had to run a drill bit back through the straight drilled hole to clear it out and everything's good to go. With conformal cooling, it's not so easy. The conforming line that follows the three-dimensional shape of the geometry makes it impossible to clean out in

Fig. 5 An AM metal mould core with conformal cooling lines (Courtesy 3D Systems)

this way. I therefore urge all of our customers to invest in a closed-loop system so you have filtration options and much better control of the quality of water you are using. Once you have water quality in check you can then view conformal cooling as a perfect technological solution for injection moulding."

Strategies to maximise heat removal

As with any technology, conformal cooling can be applied well or applied poorly. Commenting on what sets a great solution apart from a poor solution, Rauch explained, "Not all conformally cooled tooling solutions are created equal. When you are designing a conformal cooling passage you are trying to achieve several different things. The number one goal when wanting to be successful with conformal cooling is figuring out how you can rapidly and uniformly dissipate the heat over the entire surface of the moulding geometry. One of the most important factors that comes into play when achieving this goal is confirming that the conformal circuit itself produces turbulent flow inside the water passage. The best way to achieve this is by using CFD analytical software that simulates the fluid's flow through the line. The Reynolds Scale helps us determine if we are obtaining turbulent flow inside our additively manufactured waterline geometry. The Reynolds number scale is a scientific way to measure flow patterns in different situations. Fluid travels in three different ways; laminar, transitional and turbulent. Laminar flow is when the molecules are following a smooth and steady path in a parallel fashion. An example would be when you open a tap to the slowest flow you can get and the water comes crystal clear."

Rauch continued, "When other forces such as change in direction and obstructions disrupt the flow, it starts to change into what is known as transitional flow. Once the flow has become fully disrupted and a mixing and stirring action happens, turbulent flow has been achieved. This is the goal when I design conformal geometry, because once the fluid travelling inside the conformal passage becomes turbulent I know trapped heat within the steel AM part will start to rapidly dissipate. The mixing action from turbulent flow transfers heat away from the geometry it is travelling through more effectively because you are mixing the warmer fluid near the walls of the cooling passage with the relatively cooler interior fluid. It's just like a hot cup of coffee - if you stir it with a spoon it will cool faster than just letting it sit still. If a designer takes all of these things into his thought process when designing a conformal cooling solution, they will be able to capitalise on the capabilities of what conformal cooling can do in the moulding industry."

Selecting 3D Systems as a technology partner

B&J Specialty uses a portfolio of dedicated software solutions from 3D Systems to develop its conformal cooling solutions, including Geomagic® Design X™, Cimatron® and 3DXpert™. The tool parts are then built on a 3D Systems ProX® DMP 300 Laser Powder Bed Fusion system.

Commenting on what attracted B&J Specialty to 3D Systems' technology offer, Rauch explained, "When we decided to invest in Additive Manufacturing, we looked at several different machine manufacturers, but when we considered what 3D Systems had to offer we were drawn to the fact that they not only focused on the printers themselves but also a complete line of design software that streamlines the conformal cooling development process. Having a good workflow simply makes good business and 3D Systems provides that with its end-to-end solutions for the tooling industry. From the start I can transition from design to build preparation and manufacturing, all from within the same piece of software. This is a huge time saver. We all talk about how AM can affect the supply chain because we can now take a digital design file and, in a matter of hours, have a finished product. 3D Systems seems to understand this, having the same mindset when developing its products. Other companies that we looked at had good machines but fell short when it came to having that smooth flow from the digital to the physical."

Cimatron and 3DXpert

Supporting software is crucial to the successful and efficient development of all AM applications; however, this is especially true when it comes to the design of a conformal cooling mould. Rauch explained, "3D Systems' Cimatron and 3DXpert packages have been phenomenal at giving me the tools needed for quickly navigating the process of designing an entire mould or just a single part for production by AM. I feel that, to be truly successful with additive, a designer has to completely change how they design – it is not a cliché that you have to design for additive. As tool designers we have all been taught to design a certain way. We had to design for how a tool would be manufactured but, with AM, all of the limitations put upon you by subtractive methods of manufacturing are almost completely removed. Cimatron and 3DXpert are very powerful modelling programs that give me the design freedom to quickly make that transition to designing for additive. The complexity of geometry I design with Cimatron and 3DXpert would be inconceivable using anything else. Tailored design tools assist me in the construction of the parts themselves and a complete suite of conformal cooling design tools automates much of the design process, allowing me to focus more on designing a part for its function rather than its ease of manufacturing. 3DXpert then takes it a step further. Once I move into build preparation I again have full freedom to design my support structures with ease because of the huge number of options I have for deciding which type of support structure will work best."

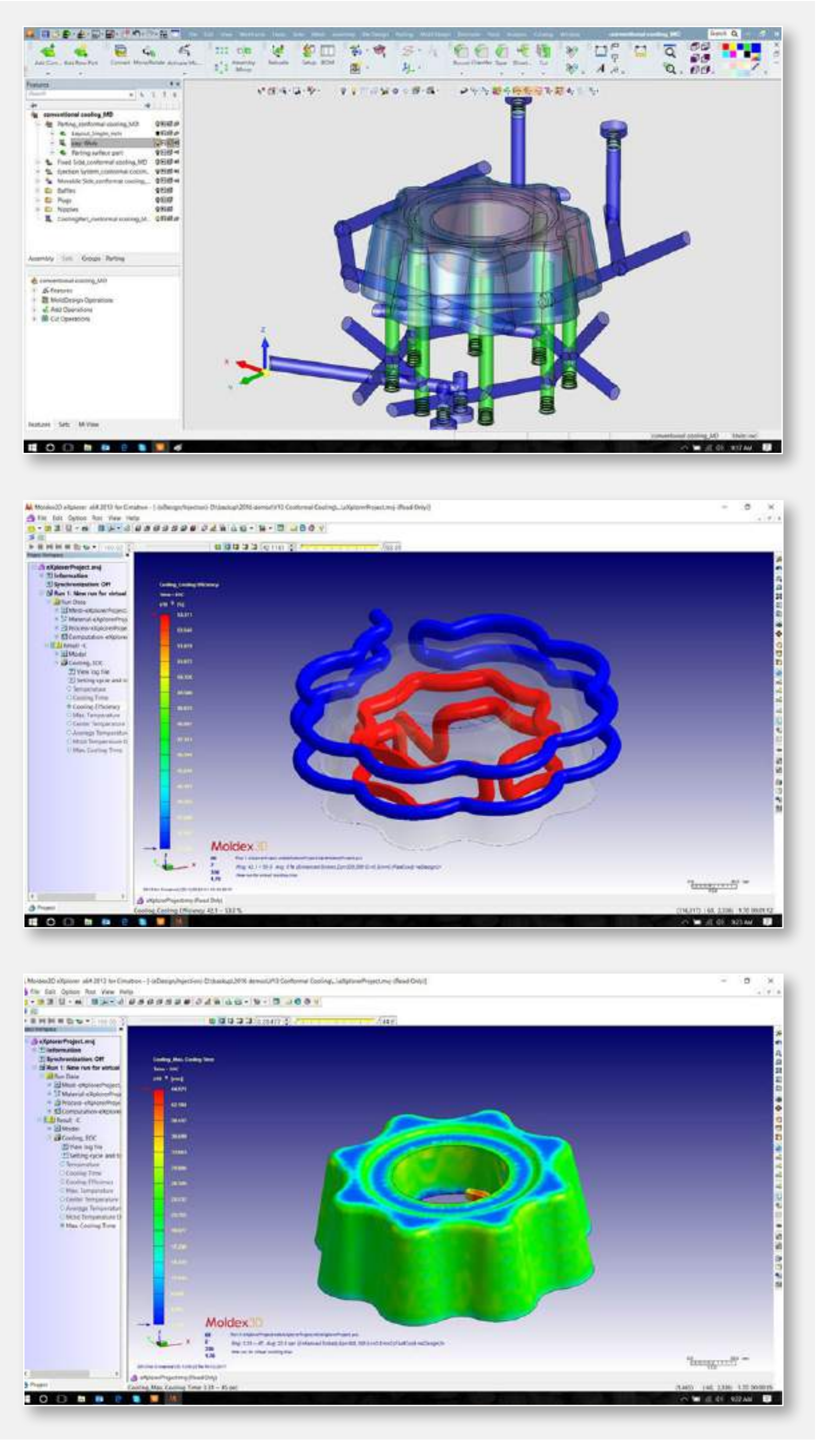


Fig. 6 Top: conventional water lines designed with water baffles; Middle: conformal cooling water lines for core and cavity designed with Cimatron; Bottom: cooling results as shown in a Moldex3D analysis

Growth and opportunities

Commenting on the increasing demand for injection moulding tooling with conformal cooling, and expectations of growth in the near term, Rauch stated, "Seeing the demand increase for AM with conformal cooling in the moulding industry has really been exciting. As with all disruptive technologies it takes some time for a new solution to become the new 'norm' and I believe we are still just scratching the surface of what Additive Manufacturing can do for the moulding world. B&J Specialty has seen the results and we know that conformal cooling is a huge game changer. I would say in the next five years almost all of the moulds we build will have some type of AM components with conformal cooling in them."

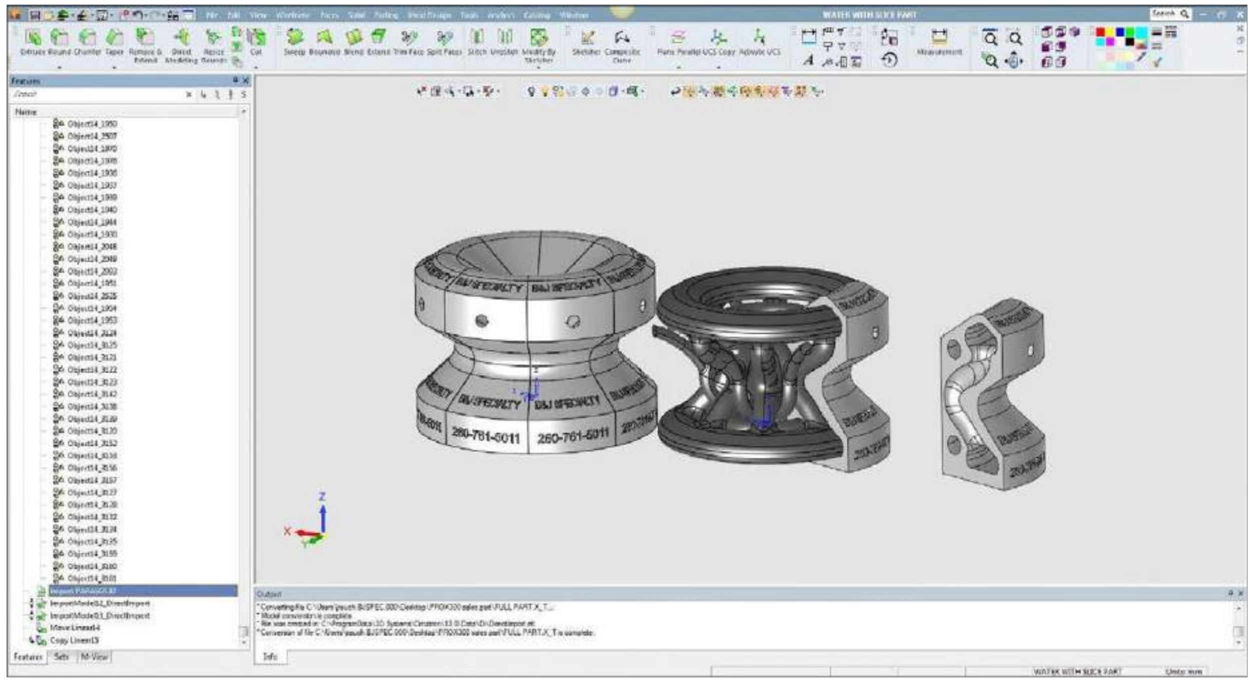


Fig. 7 3D Systems' Cimatron software has been developed specifically for mould design

"Roughly 20% of the tools we are currently producing have some type of AM component. So far, all tooling we make with AM has conformal cooling. The other 80% of our conventionally manufactured moulds would all benefit from the use of conformal cooling in certain areas due to the shape of the geometry and the inability to get a cooling passage into the location needed. AM is slowly gaining traction in the moulding industry and it's just a matter of time before all of the moulds that B&J Specialty builds will have AM parts with conformal cooling passages."

Rauch believes that the sector's growth is coming from both a combination of customers who are demanding faster process times and from innovative toolmakers looking to gain a competitive advantage in terms of their technology offering. "At this point it has been almost a 50/50 split between these drivers, however I am starting to see a change as AM has become a real game changer in the moulding industry. Now I am seeing larger companies wanting to 'go additive' without a company such as ours trying to sell the technology. The door has opened and we are beginning an industry-wide transition."

Conformal cooling: 3D Systems' perspective

Providing 3D Systems' perspective on the broader industrial use of conformal cooling, David Lindemann, Cimatron Application Engineer at 3D Systems, told *Metal AM* magazine, "The driving forces seem to be coming from automotive, aerospace, and medical. The reason is mostly to improve overall part quality and reduce warpage, this in turn improves part fit and functionality. As previously stated, another crucial reason is to reduce the cooling cycle time and thus reduce overall part cost."

Lindemann cautioned, however, that,"there is still a resistance to embracing conformal cooling and this likely will remain for some time. Not all moulded parts are suited for conformal cooling. I once heard an AM representative tell of how he felt mistakes were made at the beginning when metal AM began taking on popularity. He explained about how mould makers especially were being told that this technology would replace them and what they were doing. That has proven far from the case. Good mould making and mould design practice remain essential to the industry and, if anything, AM has proved to be another tool in the tool kit to getting the overall job done well, and not a replacement for everything."

"We have seen some injection moulders and mould makers experiment with conformal cooling in that they will take an existing job that they know well and then create a version for conformal cooled inserts to use as a comparison. In some cases the difference was dramatic and the practice of conformal cooling was adopted. That is not to say it is the best or only solution for every job. It is being investigated on a subjective basis. This trend has grown in recent years and seems to be continuing to grow," added Lindemann.

Managing expectations

Lindemann believes that it is crucial to understand the limits of the technology and to apply it only as appropriate. He stated, "There certainly are many 'upsides' but this is when the conditions are right. There has to be a realistic expectation. Mould builders making extremely large muolds look at the additive process and say that it is not for them. Their moulds are simply to large. There is however a trend in applying additive in a limited degree by creating mould inserts that are of printable size for key areas of the mould where conformal cooling would be beneficial. This requires some creative engineering but many are getting good results."

The correct software, believes Lindemann, is fundamental to achieving success in this sector and the designer needs support in ensuring both functionality and manufacturability. "Not all conformal cooling lines are good waterlines for their intended function or even good to be printed. There are design standards associated with all of this and having the right CAD software that works with these standards is invaluable. We recommend using Cimatron software for the mould design software that has dedicated functionality for conformal cooling that allows for consistent use of 'printable' waterlines and waterlines that are checked for consistent distance from the mould surfaces to hold the conformal effect."

Drivers behind the adoption of conformal cooling

Lindemann concurs with Rauch in that there are two drivers behind the growth of AM for conformal cooling, stating, "Right now the momentum is coming from end-users who want better quality parts at reduced cycle times. The end cost may be such that it is an economical advantage even if the mould with conformal costs more to make initially. In some cases we see mould makers wanting to have the option of offering this technology to their customers, the end-users, as they see a need to be more competitive. With this they can, in some cases, also offer a quicker turnaround time in mould repair. Now they can print replacement cores overnight or in a few days, harden and finish them and have the mould back up and running quicker than with a traditional process. I have to again use the disclaimer 'in some cases' - wisdom dictates that each part or mould be considered on a case by case basis and it is not a fair statement to suggest this is a blanket statement for everything."

Commenting on how 3D Systems is helping toolmakers embrace AM in order to develop their conformal cooling capabilities, Lindemann stated, "We have the software to assist and can work with the customers on a job by job basis and prove out the design. The customer may naturally hesitate to jump in with both feet and buy a metal AM system that he knows little about. We have services where we can print the mould core and prove out its viability and best case situation for printing. Once it is seen as a success, then the customer can move forward using this proven process on their own. They will be trained to use the software and the machine and start manufacturing their own cores per the proven process."

Outlook

Concluding, Lindemann believes that increases in the production speed of AM systems, combined with a move towards increased automation, will accelerate the adoption of AM conformal cooling solutions. He stated, "Right now the direction is to make AM systems capable of manufacturing larger parts, using multiple lasers during the build process, and developing a greater degree of automation. Imagine a production floor environment dedicated just for metal AM. Conformal tooling can certainly benefit from these factors. From there, honestly, who knows where it can go? The future promises to be exciting in the least."

Rauch is also confident that we are just seeing the start of what conformal cooling using AM can do for the plastic injection moulding industry. "Right now, the technology is constantly evolving as new materials and better machines become available. But I think we are still scratching the surface of what AM can truly do for the moulding industry. The big changes won't begin to happen until the people accept change. Designers must learn to think differently and design differently. Applying system level thinking into the engineering process has the power to change everything. Engineers with an open mind will become innovators overnight, and tooling companies willing to use AM in the production environment will become pioneers in what I believe is going to be the next industrial revolution."

Contacts

Jarod Rauch
B&J Specialty Inc.
7919 N 100 E
Wawaka In, 46794
USA
Tel: 1 260 761 5011
jrauch@bjspecialtyinc.com
www.bjspecialtyinc.com

3D Systems
333 Three D Systems Circle
Rock Hill, SC 29730
USA
Tel: 1 919 447 8211
Geomagic.ISS.Americas@3Dsystems.com
www.3dsystems.com

EOS: Developing metal Additive Manufacturing for a truly digital factory

In July 2018, *Metal Additive Manufacturing* magazine's Emily-Jo Hopson attended the company's exclusive EOS Technology Days for an advance preview of its new metal Additive Manufacturing system, the EOS M 300, and a look at its vision for AM and the technology's place in the digital factory of the future. Held at the company's attractive rural headquarters in Krailling, Germany, the event offered attendees insight into areas that are key to EOS's current development strategy.

Founded in 1989, EOS has long been recognised as a global technology leader at the forefront of the industrial Additive Manufacturing of both metals and polymers. The company's portfolio includes a range of Additive Manufacturing systems, materials, global services, applications engineering and consultancy, all designed to give customers crucial competitive advantages in terms of product quality and long-term economic sustainability for the adoption of AM. Fuelled by the belief that Additive Manufacturing has the potential to enhance the industrial value chain, its industrial AM systems are developed with the aim of making it possible for customers to react quickly to changing requirements. Such systems enable applications that weren't possible before, meet increasing demand for customisable end-products and help customers achieve sustainability goals in markets such as aerospace, automotive, medical, tooling and more.

EOS currently has an installed base of more than 3,000 systems around the world. While it took roughly twenty years for the company to bring its first 1,000 systems into the market, it has installed the last 1,000 of its AM systems over the last three years. These numbers emphasise just how fast the industry and the market are growing; the company now has a network of global sales and service offices in fifteen countries, along with six innovation centres and more than 260 service specialists.

The digital factory

In his welcome address, Thomas Weitlaner, Director of Business Development at EOS, used the example of the pace of automotive adoption to demonstrate how quickly he believes the manufacturing industry must be ready to adapt to the changing landscape of 'Industry

Fig. 1 EOS's headquarters in Krailling, Germany, was the venue for the EOS Technology Days 2018

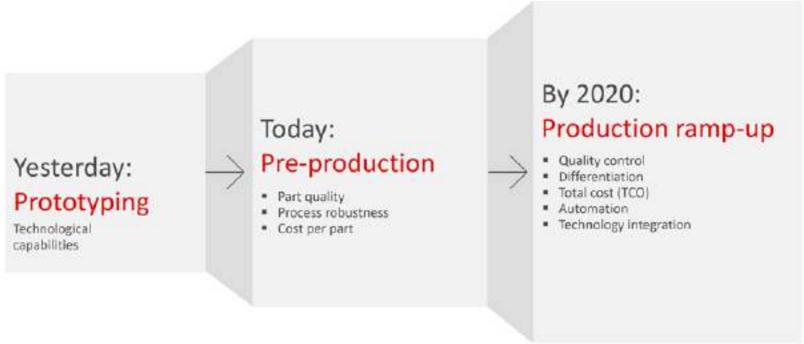


Fig. 2 The evolution of Additive Manufacturing at EOS

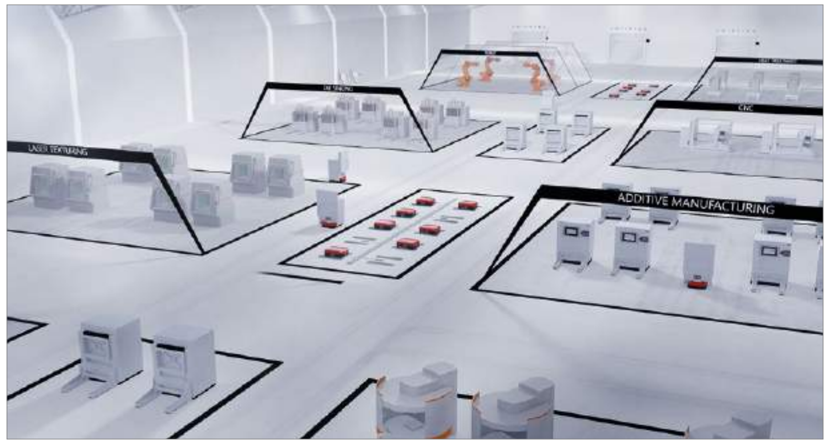


Fig. 3 A primary objective at EOS is to move toward the automation of the entire industrial AM process, focusing on key areas such as the delivery of metal powder and post-processing

4.0'. Using a picture of a New York City street in 1900, Weitlaner asked the audience to spot the car: a single automobile travelling between two horse-drawn vehicles. In the next photograph, taken barely more than a decade later in 1913, the opposite had become the case, and a single horse-drawn carriage travelled amid the flow of automotive traffic, the former technology superseded by the latter. If in the early 20th century this process took just thirteen years, Weitlaner suggested, we can expect things to move much quicker in the 21st century.

In a survey taken at EOS's European Excellence Days, the majority of the company's customers reported that they expected fully integrated digital factories will be standard by 2025; however, Weitlaner stated that the industry can expect this to happen much sooner, with EOS predicting a ramp-up of digital industrial serial production by 2020, including the implementation of suitable quality control, differentiation, total cost optimisation, automation and technology integration (Fig. 2). "The speed of innovation will get faster and faster," he stated, "and it will not stop with B2C, it will affect B2B as well. Here at EOS, we are prepared to support you through this."

Industry 4.0 has become a widely used buzzword in recent years when referring to the 'fourth industrial revolution' which many believe we are living through: a period in which the global manufacturing industry will see the increased adoption of AM and other digital technologies such as robotics, Artificial Intelligence (AI), and an increasing degree of technology convergence – whereby interconnected digital technologies enable new opportunities for both established and new methods of production.

EOS believes that the large-scale digitalisation of industrial production is key not just to the development, but to the future of the manufacturing industry. As product life-cycles shorten, and product variety continues to increase, manufacturing methods based on economies of scale are not in a position to meet these challenges. Economical conventional manufacturing depends on the sale of high volumes of identical products; tool-based manufacturing methods simply are not capable of filling the increased demand for customised products cost-effectively. This is where Additive Manufacturing, as a flexible manufacturing method, comes into its own.

As part of the NextGenAM project launched in May 2017 with industry partners Premium AEROTEC and Daimler, EOS has been accelerating the implementation of metal AM in large-scale serial production and the development of the 'factory of the future'. The primary objective of the project is to move toward the automation of the entire industrial AM process, focusing on key areas such as the delivery of metal powder and post-processing, as well as the development and qualification of other materials, such as aluminium, to enable new applications. At the time of its launch, the project partners stated that they expected to invest several million euros into the planning and construction of an automated production facility. The first pilot plant is located in Varel, Germany, and currently consists of a number of AM machines and solutions for post-processing and quality assurance.

At this pilot plant, the partners have reportedly achieved the full automation of individual steps in the AM workflow, as well as all interactions between additive and conventional process steps, eliminating manual steps entirely. Central to the pilot production chain is an EOS M 400-4 four-laser system, which is being used in combination with the peripheral solutions offered as part of EOS Shared Modules, in which manual or automated peripheral modules and transport logistics will supply several EOS metal AM systems at once. This means that filling and emptying the plant's EOS M 400-4 with metal powders, the preparation of new builds and the unpacking of built components from the powder bed can be carried out independently of, and parallel to, the actual AM build process - significantly increasing productivity.

Fig. 4 The new EOS M 300-4 metal Additive Manufacturing system is described as an 'automation-ready, future-proof platform' that is configurable, scalable and secure

Downstream post-processing has also been extensively automated. AM components are transported between individual stations in a fully automated process. Following build completion, a robot removes the build plate with the parts on it from the set-up station and transports it, under protective gas, to a furnace for subsequent heat treatment. The same robot then removes the build plate from the furnace and transports it to a three-dimensional optical measurement system for quality assurance purposes. Finally, the build plate is conveyed to a saw, which separates the parts from the plate.

The EOS Shared Modules system in Varel is one of the first implemented models currently in operation, with further pilot models installed at some undisclosed partners.

The EOS M 300: Designed with industrialisation in mind

The EOS M 300 series was first previewed during the EOS Technology Days and saw its official launch in September 2018 at the International Manufacturing Technology Show (IMTS) in Chicago, Illinois, USA. The new metal Additive Manufacturing machine expands the portfolio of EOS systems and is described as an 'automation-ready, future-proof platform' that is configurable, scalable and secure (Fig. 4). It is expected to serve customers in a variety of manufacturing fields, including the aerospace, medical, tooling and automotive industries.

During EOS's Technology Days, Dr Tim Rüttermann, Director of Product Management at EOS, explained that the EOS M 300 series is "a response to customer demand for something close to the well-established EOS M 290, but scalable for a high-volume production factory setting." As such, the system comes with a configurable and scalable equipment architecture to enable a degree of user customisation. Employing four lasers, the EOS M 300-4 offers a reported productivity of four to ten times that offered by the EOS M 290. It has a build volume of 300 x 300 x 400 mm, and offers full field overlap with four scanners, meaning that lasers can reach all spots on the build plate and full flexibility is possible with regards to build orientation.

In order to enhance part reliability and quality, Karsten Behrend, EOS Product Management, explained that the new system features a gas flow optimised build chamber. To avoid poor gas flow, the new gas flow

Fig. 5 Earlier this year EOS expanded its production capacity and relocated its system manufacturing facilities to Maisach-Gerlinden, just west of Munich, and closer to its headquarters in Krailling

design is said to ensure a strong flow of gas both through the top and bottom of the build chamber, thus efficiently clearing smoke and debris generated during processing. Also key to the reliability of the system is the incorporation of a permanent filter system, eliminating the need to open the machine up periodically for filter changes. The new recirculating filter system offers automated cleaning, with residue collected in a bin beneath the build chamber for safe and easy removal.

As EOS turns its focus to series production and the development of solutions for the Industry 4.0, key areas of further development across its product range are increased productivity; reliable and repeatable part quality; production flexibility and automation; and efficient process control. As such, the new system has also been designed for compatibility with EOS Shared Modules.

> *"To avoid poor gas flow, the new gas flow design is said to ensure a strong flow of gas both through the top and bottom of the build chamber, thus efficiently clearing smoke and debris generated during processing"*

Software for the digital industrialisation of AM

In addition to its range of AM machines and service offerings, EOS provides four full suites of software developed to support its systems' users from initial CAD integration all the way through to industrial-grade machine connectivity: EOSPRINT, for job and process management, EOSYSTEM, for system and periphery control, EOSCONNECT, for industrial connectivity, and EOSTATE, for process monitoring and quality assurance.

Speaking during the EOS Technology Days, Martin Steuer, Head of Product Management Software & Services, and Heiko Degen, Product Manager Software, introduced EOS's software offerings, and looked in-depth at EOSTATE and EOSCONNECT. Highlighted during this presentation was the company's belief in the importance of a reliable software architecture for quality control, process monitoring and connectivity as a key enabler for the ramp up of digital and additive production at an industrial scale, especially in safety-critical, highly-regulated industries.

"With the technology constantly maturing, manufacturers realise the broad possibilities AM can enable – from new product design to a disruption of their supply chain. As a consequence, AM is entering production. EOS understands its customer requirements and is constantly adjusting its technology to existing production environments," stated Steuer.

EOSTATE makes it possible to monitor and correct errors in the powder bed during Additive Manufacturing, and to monitor the process and automatically analyse signals from the system. It can also offer insights to assist in improving process parameters and ensure repeatable and superior part quality, by collecting data and building feedback loops from quality assurance to production. It is itself composed of four different monitoring tools: System, PowderBed, MeltPool and Exposure OT (optical tomography). Especially key to improved industrial-scale AM is Exposure OT, which provides real-time, camera-ba sed monitoring of the build process, fully mapping each part layer-by-layer, regardless of its geometry or size. Developed in close collaboration with MTU Aero Engines, it aims to enable companies to significantly reduce costs for non-destructive examination in computer tomography after the build process, making it possible for potentially defective parts to be rejected at an earlier stage.

The new EOSCONNECT solution is designed to reduce the cost of AM integration by increasing workflow efficiency. This scalable software enables customers to remotely access reports on the condition of their installed EOS AM machines, automatically generates quality reports, collects data and performs analytics across a number of machines to identify production bottlenecks, and offers industry standard connectivity for access to live and historic process data to fulfil regulatory requirements for strictly-controlled industries such as aerospace. With the new releases of EOSPRINT and EOSCONNECT, print jobs (with their necessary CAM files and meta data) can be automatically passed to available and suitable systems. Job performance and quality-relevant data can be queried and aggregated from the systems, resulting in a simple digital workflow from order to part.

Conclusion

Within conventional manufacturing, the gains offered by a digitalised production workflow are already evident. Following the digitalisation of their operations, conventional manufacturers – according to surveys from Siemens and SEW Eurodrive- reported 75% gains in automation and a 25% increase in output and productivity. They also reported a 20% reduction in factory investment and a 50% reduction in inventory, with total savings amounting to €0.5 million (year/line). Moreover, the overall reported quality rate of products manufactured using a digitalised workflow was 99.9988%.

Now, EOS is exploring how factory digitalisation can enable AM to compete with conventional manufacturing by increasing the speed of production for high volumes. It is enabling the technology to be integrated into the factory in the same way as conventional manufacturing technologies, rather than being seen as a separate, stand-alone process. Key to the ability of AM to complement conventional manufacturing will be a reduction in cost-per-part at high volumes; a further maturing of AM technology to enable the repeatable and reliable production of parts to customer quality requirements; and the development of tools to deliver the kind of traceability necessary for part qualification for strictly-controlled industries such as aerospace and automotive.

While EOS's Additive Manufacturing systems are central to its continued development of an economically viable and effective manufacturing framework for the future, the considerable research and development undertaken by the company into its peripheral technology and software should not be overlooked. As Tim Rutterman explains, "Our mission is to make EOS not just the most attractive platform for metal Additive Manufacturing, but the most attractive ecosystem in which to develop and industrialise applications, materials and processes."

Contact

EOS GmbH
Electro Optical Systems
Robert-Stirling-Ring 1
82152 Krailling/Munich
Germany
Tel: +49 89 893 36 0
Fax +49 89 893 36 285
info@eos.info
www.eos.info

Metal Additive Manufacturing in China: An overview of systems manufacturers

What's happening in metal Additive Manufacturing in China? Quite a lot it seems; however, the extent and nature of this activity, and what can be expected from Chinese systems manufacturers in the coming years, can be unclear to Western observers. In the following report, Joseph Kowen offers a brief look into the current state of the metal AM industry in China. As well as presenting an overview of machine-related activity in this fast growing part of the world, he considers to what extent we can expect to see an increased presence of Chinese suppliers in western countries.

Additive Manufacturing in China is a hive of activity and continues to grow in action and interest from year to year. The first forays into what was then known as rapid prototyping began as early as the first half of the 1990s. Led by a select number of academic institutions, which actively followed technological developments in western countries, the Chinese Additive Manufacturing segment has flourished. Academia's interest in the field was led by Tsinghua University, which began its research on material extrusion and sheet lamination systems.

Wohlers Report, which tracks the status of AM worldwide, lists twenty-four China-based system manufacturers which were either selling or about to begin selling industrial systems as of March 2018. This is out of a total of 135 industrial AM system manufacturers worldwide, or almost 18%.

The Chinese government has been proactive in encouraging the development of Additive Manufacturing. In November 2017, the Chinese government, led by the Ministry of Industry and Information Technology, announced an 'Action Plan for Additive Manufacturing Industry Development (2017–2020)'. The government plans to turn AM in China into a $3 billion industry. Metal AM plays a big part in the plan.

A review of the metal AM industry in China, and conversations with local industry figures, indicate that there are now twenty metal AM systems manufacturers in China. An additional two companies are close to commercialising systems. This report briefly identifies and

Fig. 1 A Ti6Al4V front and rear suspension upright manufactured on a Farsoon FS271 machine (Courtesy Farsoon)

Company	City	Chinese name
Bright Laser Technologies (BLT)	Xi'an	西安铂力特增材技术股份有限公司
Eplus 3D	Beijing	北京易加三维科技有限公司
Farsoon	Changsha	湖南华曙高科技有限责任公司
Hanbang 3D	Zhongshan	广东汉邦激光科技有限公司
Hengtong	Xi'an	陕西恒通智能机器有限公司
Huake 3D	Wuhan	武汉华科三维科技有限公司
Laseradd	Guangzhou	广州雷佳增材科技有限公司
Long Yuan	Beijing	北京隆源自动成型系统有限公司
Quickbeam	Tianjin	天津清研智束科技有限公司
Raycham	Nanjing	安徽煜锐三维科技有限公司（煜宸3D）
Riton	Guangzhou	广州瑞通激光科技有限公司
Syndaya	Foshan	广东信达雅三维科技有限公司
Techgine	Shanghai	上海探真激光技术有限公司
WiiBoox	Nanjing	南京威布三维科技有限公司
Wuhan Binhu	Wuhan	武汉滨湖机电技术产业有限公司
XDM 3D	Suzhou	苏州西帝摩三维打印科技有限公司
Yibo 3D	Beijing	北京易博三维科技有限公司
Yongnian	Kunshan	江苏永年激光成形技术有限公司
Zhuhai CTC	Zhuhai City	珠海西通电子有限公司
ZRapid Tech	Suzhou	中瑞科技

Table 1 Chinese metal AM machine manufacturers

Fig. 2 A map of mainland China showing the locations of metal AM machine manufacturers

introduces these companies. It does not enter deeply into processes, materials and technologies, except to describe the field of activity of each provider. On the materials side, unless otherwise stated, the systems are able to process parts in a relatively standard range of metallic materials. Comparisons of features and quality of parts are beyond the scope of this article, the purpose of which is simply to generate 'a bird's eye view' of the players and offer an understanding of the overall lie of the land. Our hope is that, armed with a map of the terrain, those interested in obtaining further information will have a guide with which to go out and find more details for themselves.

As a broad generalisation, while there is an exceptional growth of activity in China – possibly unequalled in any other single country – the latest innovations and new discoveries in metal AM do not originate there. This is not to diminish in any way the importance of what is happening in the country; there is value in taking ideas invented elsewhere and commercialising them, with all that commercialisation entails. This includes productisation, price and promotion. As we shall see, the sheer extent of the developments in metal AM in China make activities there worthy of interest. As is the norm in most new technological areas, not all of the companies will be equally successful, but the number of metal AM projects in China suggests that the market there has recognised the potential of metal AM and wishes to play a part in exploiting some of that potential. Investors are willing to risk real money to sit at the table and play. There certainly is a buzz emanating from China.

The technologies and the companies

All of the twenty metal AM system providers in China provide systems based on metal Powder Bed Fusion (PBF). Four of them also offer systems using Directed Energy Deposition (DED) technologies. Systems that print

Fig. 3 The BLT-A300 AM machine (Courtesy Bright Laser Technologies)

Fig. 4 A stainless steel mould insert produced on the BLT-A300 (Courtesy Bright Laser Technologies)

sand moulds or polymer/wax patterns used to cast metal parts are also strictly speaking 'metal AM' systems producers. However, due to the fact that a secondary process is required to produce the metal part, these systems are generally not considered true metal AM systems, and are not covered here.

Table 1 lists the companies producing metal AM systems in China and the city in which they are headquartered. The Chinese names of the companies have also been added, because in some cases the English name will differ in translation. Fig. 2 shows the location of the companies in China, giving a good sense of the geographical breadth of the industry.

We will describe in brief each of the metal AM systems providers, which are listed in alphabetical order of the short-form English name:

Bright Laser Technologies (BLT)
Xi'an Bright Laser Technologies Co., Ltd.
BLT was founded in 2011 by Prof Huang Weidong, a researcher in metal AM since 1995. It has a staff of over 300 and the company claims about 40% of them work in R&D. In addition to producing metal machines of their own, BLT is a distributor of metal machines for EOS, the German AM pioneer. The company is also a service provider. It is not clear if the combination of system developer, system distributor and service provider is a viable model for the future and something might have to be adjusted as company and the industry matures. In addition to PBF, the company offers two directed energy deposition models, the largest of which, the BLT-C1000, has a build volume of 1,500 x 1,000 x 1,000 mm (59 x 39.4 x 39.4 in). BLT is a pure metal AM company.

Eplus3D
Beijing Eplus 3D Tech. Co., Ltd.
Eplus is a well-known company with a history of selling polymer AM systems. Its polymer line includes both PBF and Vat Photopolymerisation (VP). Shining 3D, a well-known manufacturer of 3D optical scanning systems, is a leading investor in the company and also serves as a sales channel for Eplus3D machines. In 2017, the company launched a metal PBF system and currently offers three models, the largest being a four-laser system with a build volume of 500 x 500 x 500 mm (19.7 x 19.7 x 19.7 in)

Farsoon Technologies
Hunan Farsoon High-Tech Co., Ltd.
Farsoon is one of the best-known Chinese AM companies, primarily due to its personal and historical connection to the early days of additive technology in the US. Farsoon initially began developing polymer PBF systems in China after its establishment in 2009 and sold its first system in 2011. In 2015, the company launched the FS271M metal system for sale in China and first showcased the product internationally at formnext 2016.

The company currently offers three metal AM systems. The FS421M is its largest system with a

Fig. 5 Farsoon's FS271M machines are targeted at demanding sectors, including aerospace, automotive and medical (Courtesy Farsoon)

build chamber volume of 425 x 425 x 420 mm (16.7 x 16.7 x 16.5 in). In March 2018, Farsoon partnered with major material suppliers to provide it with certified metal powders for sale in China and the US. The company is in the process of expanding its international presence. In May 2017, it opened an integrated demonstration centre in the US, and in April 2018 a subsidiary in Germany. The company is already a fixture at all major international trade shows in Asia-Pacific, the Americas and Europe.

Hanbang 3D
Guangdong Hanbang 3D Tech Co., Ltd.
Hanbang 3D began developing metal AM based on metal PBF in 2007. Its first commercial system was sold in 2013 and second-generation systems were released in 2015. The HBD280 is its largest system, with a build volume of 250 x 250 x 300 mm (9.8 x.9.8 x 11.8 in.). Hanbang 3D is a metal-only AM company.

Hengtong
Shaanxi Hengtong Intelligent Machine Co., Ltd.
Hengtong offers a wide range of systems in a number of product lines. The company is affiliated with Xi'an Jiaotong University. The company has diverse offerings outside the AM area, such as optical scanning and CNC machining. Its products in the Additive Manufacturing space range from material extrusion desktop machines to industrial VP systems. Hengtong does offer a small-volume metal system, but this product does not seem to be well developed. This is an example of a company wishing to enter into the metal AM space, but is not a metal AM company at its core.

Huake 3D
Wuhan Huake 3D Technology Co. Ltd.
Huake 3D was jointly established by Huazhong University of Science and Technology Industry Group and Hexu Holdings. It offers a wide range of industrial industrial polymer, sand and ceramic AM systems. It has two metal PBF system models, the largest of which is the HK M280 with a build volume of 280 x 280 x 300 mm (11 x 11 x 11.8 in.)

Laseradd
Laseradd Technology (Guangzhou) Co., Ltd.
Laseradd specialises in metal AM, although they do also offer one polymer PBF system. The company's Dimetal range consists of three systems, starting at 50 x 50 mm (2 x 2 x 2 in.) up to 250 x 250 x 300 mm (9.8 x 9.8 x 11.8 in.). The company's development team originated from the South China University of Technology, which has been working on metal AM technology for fifteen years. The company debuted its machines in 2018.

Long Yuan
Beijing Long Yuan Automated Fabrication Systems Co., Ltd.
Long Yuan was an early entrant into the Additive Manufacturing world, being established in 1994. It produces a range of polymer and sand PBF machines, and launched a metal PBF system in 2014. The AFS-M260 has a build volume of 260 x 260 x 350 mm (10.2 x 10.2 x 13.8 in.) and is its largest unit. The company also offers a number of DED systems and operates a parts service.

Quickbeam
Tianjin SciTsing QuickBeam Tech.Co., Ltd.
This company spun out of Tsinghua University in 2015. Its Powder Bed Fusion technology is based on an Electron Beam Melting (EBM) technology, similar to that offered by GE Additive's Arcam unit, and called Electron Beam Selective Zone Melting, or EBSM. The QbeamAero has a build volume of 350 x 350 x 400 mm (13.8 x 13.8 x 15.7 in.).

Raycham3D
Raycham Laser Technology Group Co., Ltd.
Raycham was established in 2013 to develop industrial laser applications, including systems for Additive Manufacturing. It offers both PBF and DED systems. The latter is based on the company's laser cladding technology. It offers five DED systems and two metal PBF machines. The company offers a parts service. Its 3D subsidiary also distributes non-metal AM systems.

Riton
Riton Laser Co., Ltd.
Riton produces a variety of cutting and marking machines, primarily for the medical industry. In line with its medical focus, the company launched a metal AM system for the production of dental parts in stainless steel, cobalt-chrome and titanium. The D280 has a build volume with a limited z-axis of 80 mm (3.1 in.) suited primarily to dental applications.

Syndaya
Guangdong Syndaya 3D Technology Co., Ltd.
Syndaya is a wholly owned subsidiary of Foshan Nanhai ZhongNan Machinery. It offers a range of four metal PBF systems. The DiMetal range of machines (not to be confused with the Dimetal line offered by Laseradd) starts with a small build volume machine of 50 x 50 x 50 mm (2 x 2 x 2 in.) and extends up to the DiMetal-400 with a volume of 400 x 400 x 400 mm (15.7 x 15.7 x 15.7 in.). The company also offers a parts service.

Techgine
Shanghai Techgine Laser Technology Co., Ltd.
Techgine is a spin-off from the Shanghai Electric Group, one of China's oldest and largest industrial concerns. The company was founded by the Additive Manufacturing team from Huazhong University of Science and Technology, led by Professor Zeng Xiao Yan. The academic research was formally spun off into a commercial entity in March 2016. The company produces three systems. The largest system offered is the TZ-SLM500A which has a build volume of 500 x 500 x 1000 mm (19.7 x 19.7 x 39.4 in.), and is equipped with up to four 1,000W lasers.

Wiiboox
Nanjing Wiiboox 3D Technology Co., Ltd.
In August 2018, Wiiboox announced the launch of a metal PBF printer called the SLM250. The company offers a very diverse range of 3D printing and AM products, from desktop systems to scanners, and even a food printer. While a metal machine is in its catalogue, Wiiboox is scarcely known in industrial AM, despite having been founded in 2014. It is unclear if the company developed the machine or sells a private label version of another machine.

Wuhan Binhu
Wuhan Binhu Mechanical & Electrical Co. Ltd.
Wuhan Binhu was one of the earliest companies in the AM space in China. It was founded in the first half of the 1990s and for many years developed polymer AM systems. It has introduced a single metal PBF system.

Farsoon Technologies: A Chinese AM systems supplier crossing the international divide

Farsoon Technologies is the most prominent example of an AM system supplier that operates as easily internationally as it does in China. The company moves comfortably between the two worlds – it's in its DNA. It's roots can be traced back to Austin, Texas, USA. The company's founder, Dr Xu Xiaoshu began his career at DTM, a company founded on technology developed at the University of Texas. Dr Xu, a native of China, had moved to the US to complete a PhD in applied mathematics at Colorado Mining University. After a few years in research institutes, he found himself working as technical director at DTM, the developer of a polymer PBF process known as Selective Laser Sintering (SLS). DTM was one of the AM industry's early pioneers and was acquired by 3D Systems in 2001. In 2009, Dr Xu, by this time a worldwide expert on Powder Bed Fusion, moved back to China and established Farsoon, which is based in Hunan province.

In May 2017, Farsoon established a US subsidiary in Round Rock, a suburb of Austin, Texas, more than twenty years after Dr Xu's arrival in the state as a PhD student.

XDM 3D

Suzhou XDM 3D Printing Technology Co. Ltd.

In 2017, XDM3D announced the launch of a large format metal AM machine. At the time of its release, the machine was stated to be the largest of its kind, though larger systems have since become available. The four-laser XDM 750 has a build volume of 750 x 750 x 500 mm (29.5 x 29.5 x 19.7 in.). The company was founded by Professor Zhang Zhengwen of Chongqing University.

Yibo 3D

Beijing Yibo 3D Technology Co., Ltd.

The company was founded in 2008 and is a provider of a range of polymer AM solutions. It recently launched a small frame metal PBF machine.

Yongnian

Jiangsu Yongnian Laser Forming Technology Co., Ltd.

Yongnian was established in 2012. It is located in Jiangsu Kunshan High-Tech Zone Robot Industry Park. It was founded by Professor Yan Yongnian of Tsinghua University. The company produces both metal PBF and DED systems.

Zhuhai CTC

Zhuhai CTC Electronic Co., Ltd.

The company was founded in 2004 and sells a wide range of Additive Manufacturing systems, including non-industrial systems. It entered the metal AM space in 2016 with the introduction of the Walnut PBF systems. The series consists of three models from small-to-medium size. The Walnut 26 is the only model currently available for sale.

ZRapid Tech

ZRapid Technologies Co., Ltd.

ZRapid is an established provider of VP systems, with a full range of eight machines. It also sells polymer PBF machines. The company joined the ranks of metal AM providers with two machines, the largest of which is the iSLM280 with a build volume of 300 x 250 x 350 mm (11.8 x 9.8 x 13.8 in.). ZRapid is planning to expand its activities outside of China. It has appeared in the last two major AM events in Europe (formnext) and the US (RAPID+TCT).

TSC Laser and Sailong Metal are another two companies that are in the process of commercializing metal AM systems.

Models of expansion into metal AM

As already noted, a large number of companies have signalled their intention to address the metal AM market. However, the models of how they go about this task differ from what we see elsewhere. There are a number of paths in western countries. The first and most obvious is a pure-play start up development of metal AM. Examples would be SLM Solutions and Arcam, to name just two. Acquisition is another route, albeit not that common. An example would be 3D Systems' acquisition of Layerwise. A third route is organic growth into metal AM based on experience gained in polymer AM. The prime example of this would be EOS, which moved into metals only after acquiring knowledge and experience in polymers.

In China, there have been no apparent acquisitions by larger AM companies of metal AM start-ups. The dominant path to metal AM has been to leverage knowledge in polymer PBF and use it as a springboard into metal. The most prominent example of this is Farsoon. Eplus3D developed a full range of polymer PBF machines before adding metal, and Huake also developed a full line of polymer systems before addressing metal PBF. Long Yuan followed a similar path, first developing polymer and sand PBF systems before advancing to metal. Wuhan Binhu, Yibo 3D and ZRapid also follow this model.

There are a number of companies that have developed metal AM systems from the ground up: BLT, Hanbang, Laseradd, Quickbeam, Syndaya and XDM 3D. One company, Raycham, has leveraged technological know-how from the laser area to develop metal AM systems.

A number of companies have added metal PBF machines to their catalogues seemingly as a way of meeting a commercial need to be in metal AM, though without any apparent technological underpinnings. In this category we find Hengtong, which was originally a VP system manufacturer, although with some experience developing one system for sand mould printing. Riton has no background in Additive Manufacturing, but was drawn into the space because of its dental focus. Wiiboox creates the appearance of a marketplace for a wide variety of AM technologies. Similarly, Zhuhai CTC lacks roots in PBF, despite launching three systems.

Finally, it is important to note the role that academia plays not only in developing the technology, but in commercialising it. While some key industry technologies originated on campuses, the commercialisation process was generally a separate activity. The examples that come to mind are binder jetting from MIT and SLS from the University of Texas. In the case of Chinese metal AM, many of the companies commercialising systems are still closely connected to the academic institutions that incubated them. Examples of this are: BLT (Northwestern Polytechnical University); Hengtong (Xi'an Jiaotong University); Huake 3D (Huazhong University of Science and Technology); Laseradd (South China University of Technology); Quickbeam (Tsinghua University); Techgine (Huazhong University of Science and Technology); Yongnian (Tsinghua University); XDM 3D (Chongqing University).

International expansion

A number of the leading companies have indicated their intention to expand internationally. Some, such as Farsoon, have made significant progress. One way to measure international intentions is to examine which international events Chinese companies have recently attended. Of the twenty companies on the Chinese metal AM listing, the following companies attended formnext in Frankfurt in November 2017 in one capacity or another: Bright Laser Technologies, Farsoon, and ZRapid had their own booths, and Hanbang and Quickbeam were represented as co-exhibitors.

Only Farsoon has taken practical steps to establish a permanent presence internationally. Non-metal AM companies from China have also taken this route, most notably Shanghai Uniontech, a pioneer in vat photopolymerisation systems since the late 1990s.

Conclusions

Can we expect a flood of Chinese companies in Western markets? Not so quickly. For one thing, quality and reliability have to be proven in most cases. For another, in high-tech systems, price alone is not going to be reason enough to buy a less recognisable brand. The price is amortised over the lifetime of the machine in any event, so the effect on the cost of each printed part is marginal.

Finally, many of these companies' entries into metal AM are very recent developments. There may be IP issues on some aspects of a system. As observers of the AM market are quick to point out, small details are often the difference between successful and less successful machines. While development cycles for new machines have shortened considerably, and although some Chinese companies might be inspired by what they see in more mature metal platforms developed primarily in Europe, it is still not a straight and quick line to market for less-mature brands.

The wealth of activity in China should be viewed as confirmation of the mid- to long-term potential of metal AM, with manufacturing being the operative word. China prides itself on being a global industrial engine and the embrace of metal AM as a manufacturing modality is noteworthy. This is especially true in a country where lower costs, inexpensive labour and mass-production are generally the differentiators. The fact that so many companies have taken the plunge into metal should be particularly encouraging. Established international AM brands are still in demand in China. The largest single systems sale in the history of AM was disclosed by Germany's SLM Solutions in 2017 and involved the procurement of fifty SLM 280 machines valued at €28–43 million. The purchaser of these systems was an organisation in China.

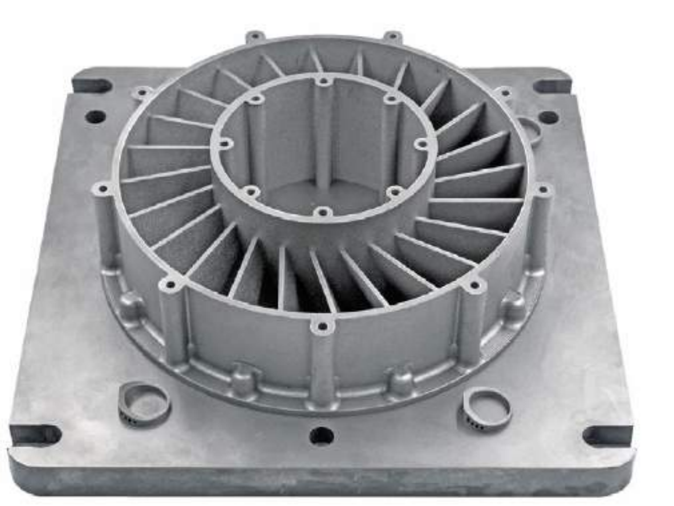


Fig. 6 Ti6Al4V fuel cell cartridge guide manufactured on a FS271M laser PBF system (Courtesy Farsoon)

Finally, we cannot ignore new technologies in the metal AM space. At the IMTS show in Chicago in September 2018, HP revealed a new metal binder jetting technology. Other companies, including Desktop Metal and Stratasys, have launched or announced new metal printing technologies. It is too soon to tell how they compare to proven metal PBF or DED systems and how this might affect the commercialisation of older technology in China. New technologies must inevitably give some pause for thought, even among Chinese entrepreneurs and managers who are perhaps less risk averse than their Western counterparts. Since the IP of new technologies will be protected, even in China, this will present a significant hurdle for Chinese companies, as it no doubt will for metal PBF systems in the west.

The Chinese market is exciting, but also an enigma. Even colleagues on the ground are sometimes unaware of all of the advances and identities of participants, such as the extent and pace of development there. Many companies are not likely to make it, or will consolidate, as is the way of things. One way or the other, we expect a lot of news from China.

Acknowledgements

Special thanks to Jack Cheng of Farsoon Technologies and Jin Tianshi of voxeljet China for help in the preparation of this article. Thanks also to Michael Kowen, a PhD candidate at the University of California, Berkeley, specialising in comparative corporate technology culture in China and the US.

Author

Joseph Kowen is an industry analyst and consultant who has been involved in rapid prototyping and AM since 1999. He is a principal of Intelligent AM, a consultancy specialising in the business of Additive Manufacturing.

Joseph Kowen,
Intelligent AM
Tel: +972 54 531 1547
Joseph.Kowen@intelligent-AM.com
www.Intelligent-AM.com

Binder Jetting and FDM: A comparison with Laser Powder Bed Fusion and Metal Injection Moulding

In recent years there has been a surge in interest in the use of Binder Jetting and Fused Deposition Modelling for the production of low to medium volumes of metal additively manufactured parts. In the following report, Maximilian Munsch, Matthias Schmidt-Lehr and Eric Wycisk of Ampower GmbH & Co KG, Hamburg, Germany, review how the success of Metal Injection Moulding has enabled these technological innovations. They also compare some of key properties and costs to enable designers to better understand the readiness of these technologies for commercial production.

As a technology, Additive Manufacturing can look back on a history of over thirty years. Beginning primarily as a prototyping technology, it has over the last five years gained tremendous momentum for the production of functional parts in a wide range of industrial applications. For many highly demanding applications, Laser Powder Bed Fusion (LB-PBF) has become the dominant Additive Manufacturing technology. However, with the development of metal AM technologies that rely on a sintering process as a final production step, this may be about to change. The technology of fundamental importance to the development of these new processes is Metal Injection Moulding (MIM), hence frequent references to 'MIM-like' AM processes.

Together with a number of industry partners, Ampower is currently evaluating whether these sinter-based metal AM technologies can live up to expectations and become a serious competitor to LB-PBF. The industrial partners for this investigation are Alliance MIM, DB Fahrzeuginstandhaltung GmbH, C. Illies & Co. Handelsgesellschaft mbH, Lufthansa Technik AG, citim GmbH, Porsche AG, SLM Solutions Group AG and Yxlon International GmbH.

The aim of the investigation has been to determine the technology readiness level of Binder Jetting and metal Fusion Deposition Modelling (FDM), as well as identify the potential and limitations of these technologies when compared to Metal Injection Moulding and LB-PBF. Whilst the complete report based on the investigation will give a more detailed look into these new metal AM technologies, this article presents key findings that will help guide prospective users to identify the right technology for a specific application.

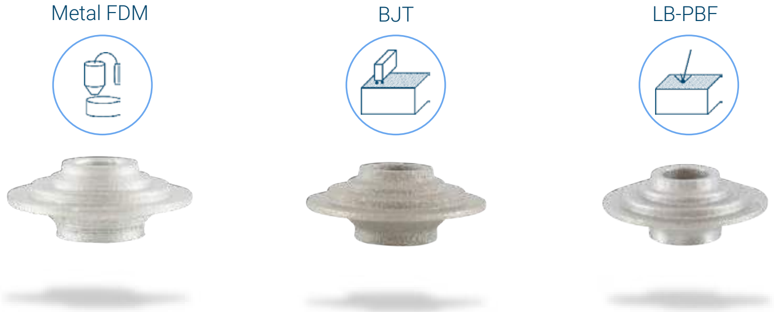


Fig. 1 The three major metal AM technologies for small-to medium size parts (Courtesy Ampower)

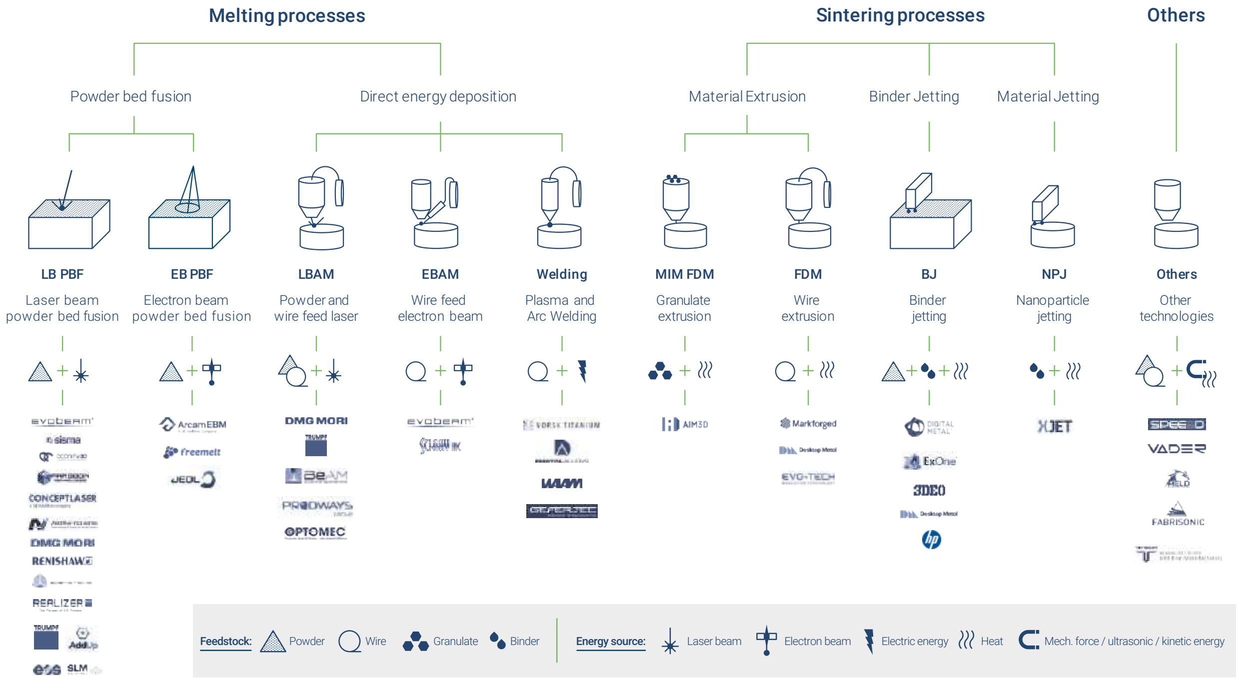


Fig. 2 Map of metal Additive Manufacturing technologies (Courtesy Ampower)

A diverse range of metal AM technologies

As of today, there are at least eleven major metal Additive Manufacturing technologies. Each technology has its specific advantages and limitations regarding part design, mechanical properties and costs. This leads to ever more complex decisions when it comes to the choice of technology for a given application.

The technology map shown in Fig. 2 aims to classify these different metal AM technologies whilst taking the ISO/ASTM 52900 standard into account. Most of the processes can be classified into melting or binder-based sintering technologies. While sintering always comes with a binder component and a two-step manufacturing process, melting technologies use powder or wire in a single-step process to directly produce the part.

Classification of the different melting/fusion technologies can be accomplished by distinguishing the material deposition method (direct or powder bed) and the energy source:

- Laser beam
- Electron beam
- Electric energy

Sinter-based AM processes require a debinding and sintering step and therefore all have heat in common as the main energy source. They are also classified by the material deposition method and further distinguished by the type of feedstock:

- Conventional MIM feedstock (granules or rods)
- Wire made of polymer binder and metal powder
- Metal powder plus fluid binder
- Binder dispersion with nano metal particles

The evolution of an eighty-year-old technology

Conventional Powder Injection Moulding (PIM) technologies, incorporating the use of a metal or ceramic powder, mixed with a polymer binder and then a debinding and sintering step, are firmly established in today's manufacturing environments and have a far longer history in industrial applications than Additive Manufacturing. Dating back to the late 1930s and early 1940s, the precursor to what we now know as Ceramic Injection Moulding (CIM) used ceramic powder and a binder to manufacture products such as spark plug bodies. In the 1970s the technology was significantly enhanced with new, more capable binders, and the use of metal powders was investigated. This work led to the birth of Metal Injection Moulding, for which the first patent was filed in 1976. The early cost of MIM parts, however, was extremely high and the process more complex in comparison to competing casting technologies. The subsequent development of more sophisticated binder materials and debinding processes brought improved process stability and easier access to the technology, leading to strong global growth. Today, total global sales of metal injection moulded parts are valued at over €2 billion, with a compound annual growth rate of between 10 and 20%. MIM applications are dominated by complex components for consumer electronics, medical devices, orthodontic applications, firearms, automotive components, watches, jewellery and power tools. Part sizes typically vary between 5–50 mm, however some are in the micro size range and weigh just 0.02 g, whilst others can weigh more than 500 g. The MIM process is based on three steps (Fig. 3):

1. The forming of a green part by injection moulding with a premixed feedstock (metal powder compounded with a polymer binder)
2. The removal of the main binder by a thermal, acid or solvent process to create brown part
3. The removal of the 'backbone' binder and the sintering of the 'brown' part at high temperature

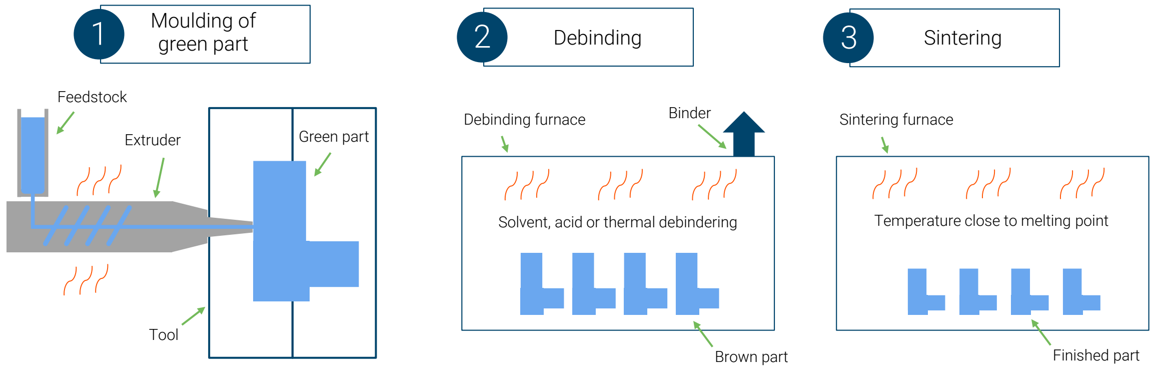


Fig. 3 The Metal Injection Moulding process (Courtesy Ampower)

Two recent award winning MIM parts that demonstrate the technology's capabilities for net-shape high-volume production are shown in Figs. 4-5. Based on the recent success of sintering technologies in general, and MIM in particular, several companies have developed sinter-based metal AM technologies. These new AM technologies share steps 2 and 3 with Metal Injection Moulding. However, the forming of the green part uses the layer-on-layer manufacturing principle of Additive Manufacturing instead of injection into a mould. Nevertheless, the actual material deposition method used to create the green part can vary greatly from company to company.

Technology principles

Sinter-based metal AM technologies can be classified into metal FDM and Binder Jetting processes. Both

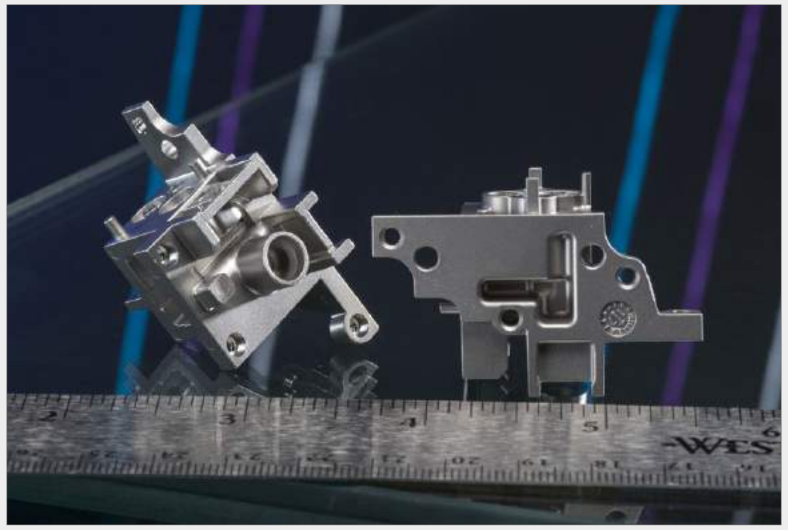


Fig. 4 AMT Pte, Ltd's 'EPR flow block' won a Grand Prize in the Hardware/Appliance category of the Metal Powder Industry Federation's (MPIF) design awards. Manufactured from a stainless steel, it features complex internal channels (Courtesy MPIF)

Fig. 5 ARC Group Worldwide's stainless steel 'shaft grounding guide' won an MPIF Grand Prize in the Electronic/Electrical category (Courtesy MPIF)

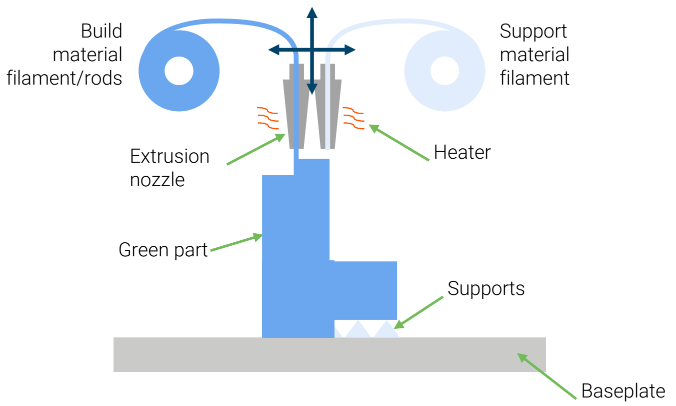


Fig. 6 Principle of metal FDM using filament or rods (Courtesy Ampower)

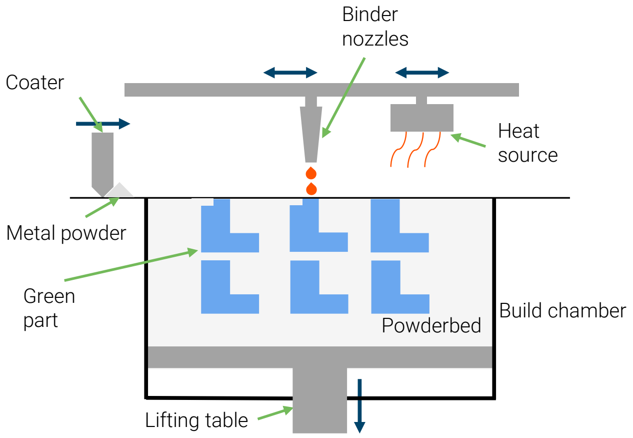


Fig. 7 Principle of Binder Jetting (Courtesy Ampower)

are currently available from several system manufacturers. While Binder Jetting has its roots in the Additive Manufacturing of sand cores, metal FDM is based on conventional FDM technology.

Metal FDM

Metal FDM uses wire, MIM feedstock or rods as the base material (Fig. 6). This raw material feedstock is a compound of metal powder and polymer binder. While the machine principle is very similar to polymer FDM systems, the key difference lies in the extrusion nozzle, which has specific characteristics for applying the metal-loaded feedstock.

With AIM3D, Desktop Metal, EVO-Tech and Markforged, four major suppliers are currently offering metal FDM printing systems. Their business models vary as they each cover different aspects of the vertical value chain. While Markforged offers proprietary material solutions and debinding/sintering solutions alongside their AM system, AIM3D and EVO-Tech use metal filament and MIM feedstock that is readily available on the market from established suppliers, such as BASF. Furthermore, they use common debinding and sintering process equipment offered by a number of tried and tested MIM furnace manufacturers.

Binder Jetting technology

Binder Jetting is based on an MIT-developed technology which originally focused on sand casting forms. After its initial development, ExOne developed the first metal process based on Binder Jetting, with Höganäs's Digital Metal following with its own system. Desktop Metal is currently publicising its binder jet-based Production System and, in September 2018, HP unveiled its first binder jet metal AM system.

The technology principle is still based on the original MIT patents, which refer to a powder bed of sand or metal powder on which binder is locally applied. This fluid binder solidifies by applying heat (Fig. 7). A slightly different approach is described by 3DEO. Here, the binder is applied on the complete powder bed area followed by a milling process of the hardened layer with multiple machining spindles to create the contour of the part in each layer.

Engineering focus: material, quality, design

Material availability and performance is a key enabling factor for new AM applications. At the moment only LB-PBF offers a wide range of materials, with alloys based on aluminium, titanium, nickel, steel and precious metals, as well as other materials in development such as magnesium. In theory, any weldable material can be processed by LB-PBF. A multitude of publications on the mechanical properties of all these alloys means that engineers can be confident in their expected characteristics and ultimately results in a higher acceptance of LB-PBF over less-researched technologies.

As of today, 17-4PH and 316L stainless steel are readily available for Binder Jetting and metal FDM technologies. Digital Metal also offers parts in titanium alloy Ti-6Al-4V. In principle, all known MIM alloys can be used for sinter-based AM technologies. Copper and carbide materials pose particularly interesting opportunities for future applications, since they have certain limitations in LB-PBF. On the other hand, aluminium alloys will remain challenging for the new AM processes due to the difficulty of sintering aluminium.

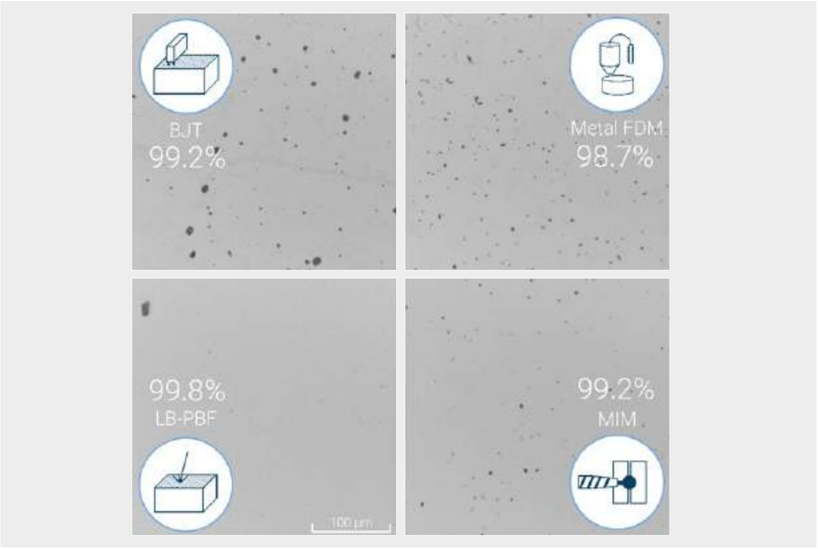


Fig. 8 Micrograph porosity analysis for Binder Jetting, metal FDM, MIM and LB-PBF (Courtesy Ampower)

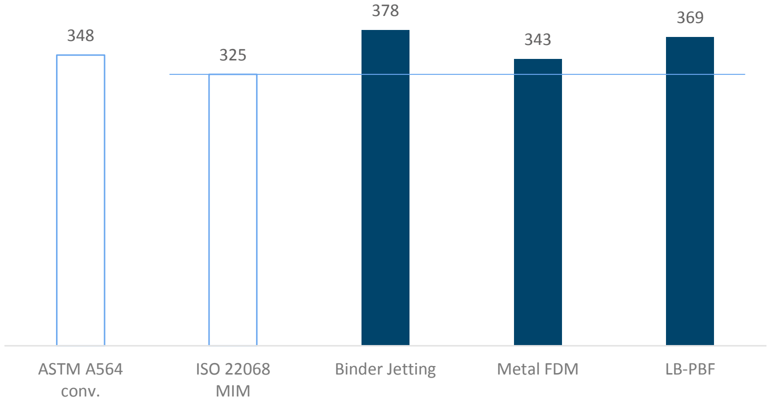


Fig. 9 Hardness of 17-4PH (HV) (Courtesy Ampower)

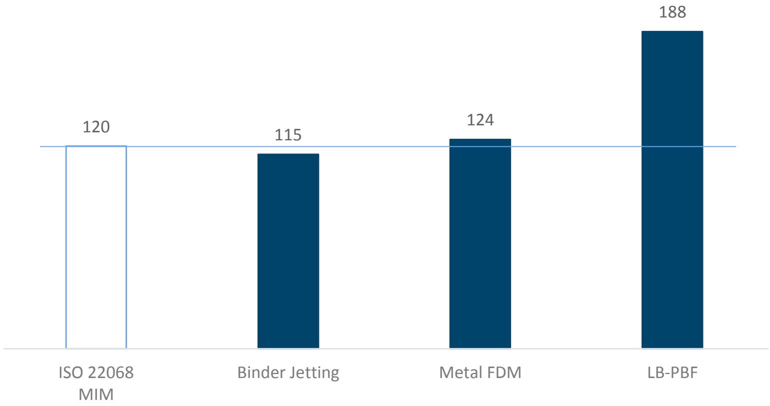


Fig. 10 Hardness of 316L solution treated at 1040°C (HV) (Courtesy Ampower)

Material properties

For this study, stainless steel alloys 316L and 17-4PH were chosen to determine the material characteristics. These alloys are commonly available for the LB-PBF, MIM, metal FDM and Binder Jetting processes and therefore offer the best property comparisons. The obtained results are based on over fifty specimens from eight different system suppliers. The complete test program includes tensile testing, hardness and surface roughness measurements as well as micrograph and µCT analysis.

This report will focus on the hardness measurements and density analysis, which represents a major quality factor for metal parts. A high material density is paramount for good material characteristics such as tensile strength and fatigue behaviour. Also, with design restrictions in mind, a certain density is required for all components which carry fluids or gases. In these applications, low density leads to the need to increase wall thicknesses to achieve the necessary impermeability of the part.

For density analysis, six sections of each technology were analysed by light microscopy. The analysis includes micrographs from several Binder Jetting and metal FDM system manufacturers as well as MIM and LB-PBF specimens. The results show significant differences in pore size, shape and distribution between the technologies (Fig. 8). For all sinter-based technologies, the most likely cause of this is the different debinding and sintering strategies and not the specific Additive Manufacturing mechanism. It is worth mentioning that the density of all analysed MIM samples exceeds the standard MIM as-sintered density range of 95–97%. This however is unsurprising, as the selected supplier targets demanding applications with high performance requirements.

To minimise the influence of sintering temperature and other process-related factors on the mechanical properties, and to increase the comparability of processes, all specimens were additionally heat treated after sintering in identical cycles. All specimens were solution treated at 1040°C for 1 h in a vacuum. The 17-4PH specimens were additionally hardened to H1025 at 550°C for 4 h in atmosphere. Figs. 9-10 show the resulting hardness measurements. It is evident from these results that sinter-based AM

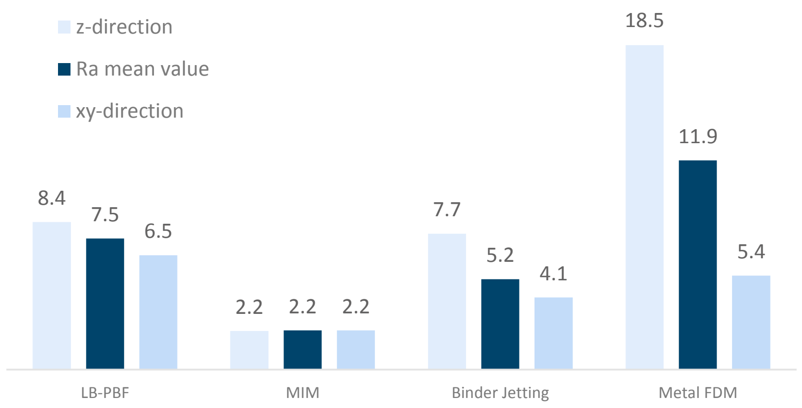


Fig. 11 Arithmetic average surface roughness in µm of emerging Additive Manufacturing technologies in comparison to LB-PBF and MIM (Courtesy Ampower)

technologies achieve values close to the requirements for metal injection moulded materials as defined in ISO 22068 for 316L, and exceed the standard value for H1025 hardened 17-4PH.

Design

Additive Manufacturing technologies offer superior design possibilities compared to conventional manufacturing processes; however, residual stresses and the need for support structures add restrictions to the freedom of design when using AM technologies such as LB-PBF.

> "While Binder Jetting requires no supports during the build process, the sintering step may require additional supports to prevent deformation of the part. An alternative can be achieved by using ceramic 'setters' that hold the component in place..."

While Binder Jetting requires no supports during the build process, the sintering step may require additional supports to prevent deformation of the part. An alternative can be achieved by using ceramic 'setters' that hold the component in place and support areas that are prone to deform during sintering. This would require higher production volumes to amortise the associated costs.

Regarding part size, MIM parts are characterised by rather small component dimensions of typically 50 mm or smaller. The reason for this limitation lies in the debinding and sintering process. From a practical point of view, debinding limits the maximum material thickness to 5–10 mm. Exceeding this value increases the debinding time exponentially or makes complete debinding impossible. Additionally, sintering requires temperatures close to the material melting point, which can cause deformation when large masses or geometric complexity exist. During the sintering phase, the part undergoes the most significant shrinkage and a suitable surface is therefore required to allow this movement.

All these MIM restrictions also apply to sinter-based metal AM technologies. With dimensional distortion during sintering difficult to predict, one of the major advantages of Additive Manufacturing – the ability to deliver very low volumes or one-off parts – is negated. Developing a sinter-based process for complex parts requires several test loops to control any distortion during sintering. This limits these AM technologies to either simple part geometries or trial and error loops for complex parts.

Surface

Another important factor in metal Additive Manufacturing is the surface quality, as high accuracy and low surface roughness might make additional mechanical post processing unnecessary. In this regard the surface finish of parts made by LB-PBF is often compared to the surface quality of cast parts. While functional surfaces must be post-processed, free form surfaces can be kept as-built or simply sand blasted. In MIM, as-sintered quality usually fulfils the requirements for functional surfaces. The surface roughness, as well as the repeatability of dimensional accuracy, allows the production of highly precise parts without mechanical post-processing. If all the functional surfaces cannot be achieved in the moulding process, it is common to process the parts in the green state. Milling operations are significantly easier while the part is unsintered and the same holds for sinter-based AM parts.

This study analysed the arithmetic average surface roughness in the as-sintered state by tactile measurement. The values were obtained by measuring the specimens' surfaces in the zx- and xy-plane. The mean value of both measurements allows a technology comparison. However, especially for metal FDM, the surface roughness depends significantly on the build direction (Fig. 11).

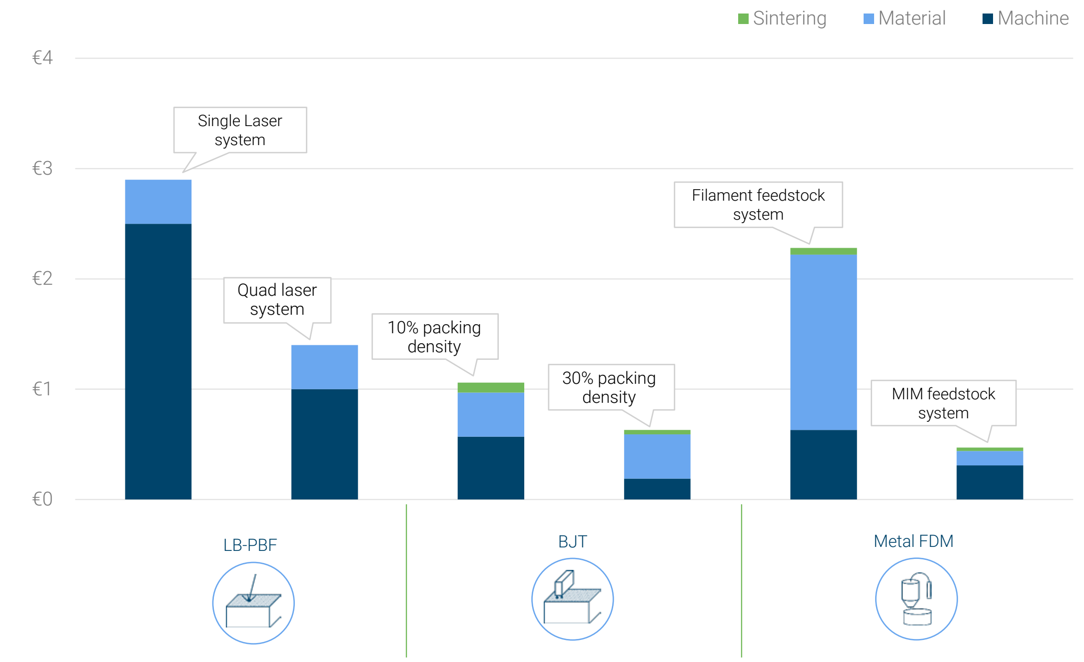


Fig. 12 Average cost per demonstration part (Fig. 1) of emerging Additive Manufacturing technologies in comparison to LB-PBF (Courtesy Ampower)

Business focus: cost and value chain

In the case of LB-PBF, metal Additive Manufacturing is characterised by high machine cost, low production speed and high material cost. Thus, not every part that is technically feasible is financially viable. Sinter-based metal AM technologies promise to change this and lower the cost for metal AM parts significantly.

Material cost

The cost for metal powder suitable for LB-PBF ranges from €40 to €400 per kg, depending on the alloy. For stainless steel, the cost is at the lower end, between €40 and €80 per kg. As with LB-PBF, current Binder Jetting technologies use spherical powder particles; however, many of the new technologies, such as that of Desktop Metal, use conventional MIM powders. Since the cost for stainless steel MIM powder such as 17-4PH is only €5–10 per kg, this offers great potential for reducing material cost by 80–90%, although the cost of the binder material must also be added.

For metal FDM the feedstock consists of wire, granulate or rods made of metal powder and polymer binder compound. Here, the cost of binder is already included. However, the spread in feedstock cost is significant. While granulates are based on conventional MIM feedstocks and range between €15–18 per kg for 316L, filaments such as BASF's Ultrafuse 316LX are priced at around €200 per kg. However, similar metal filaments are also sold from other suppliers for €100 per kg. While Binder Jetting and granulate based metal FDM are leading to massive cost reduction on material, other metal FDM technologies result in even higher feedstock pricing than LB-PBF.

System investment

The typical investment for a twin laser LB-PBF system is around €500,000 and the depreciation and consumables add up to an average hourly machine rate of €30-40. Single laser systems are at the lower end of this range while the newest quad laser systems cost up to €55 per hour.

Binder Jetting systems which offer comparable build envelopes in the range of edge lengths of 300 mm have similar investment cost covering only the part build process, excluding the debinding and sintering systems. Additionally, costs for consumables and maintenance have little impact in both technologies which results in similar machine hourly rates for Binder Jetting. Future Binder Jetting machines are expected to carry an even higher investment cost of around €1 million, excluding debinding and sintering, but promise a further increase in productivity.

For metal FDM systems, the cost for investment, maintenance and consumables is considerably lower. Focusing only on the build process, machine cost ranges between €60,000–100,000 resulting in hourly rates of €5–8.

Production cost

The production cost for the series production of the AM demonstration part (Fig. 1) has been calculated by the production speed in cm³/h and the machine hourly rate for the respective AM system (Fig.12). Additional costs from any necessary mechanical post-processes as well as inspection efforts for quality assurance are excluded.

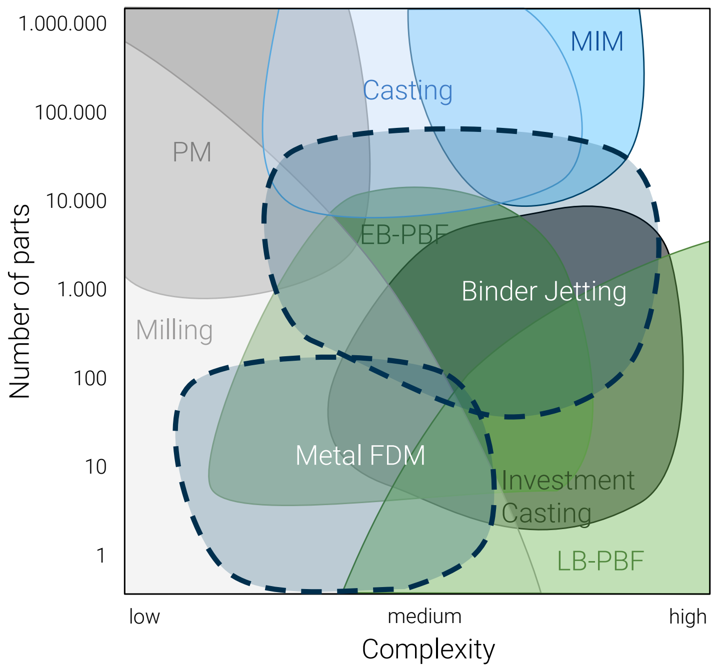


Fig. 13 Technology classification regarding number of parts and part complexity (Courtesy Ampower)

Comparing the production speed proves to be challenging. While LB-PBF and FDM systems can be quantified by their build rate (volume over time in cm³/h), the build rate of Binder Jetting processes largely depends on the packing density. Build jobs of the same height usually take the same amount of total build time independently from the aggregated part volume.

> “For metal FDM, the layer thickness is the key factor to increase the build volume per time. By increasing this parameter, the production rate increases but also leads to a significant reduction in resolution...”

Analysis shows that LB-PBF production speed mainly depends on the number of lasers working in parallel in the build chamber. Based on the mentioned hourly rate, the resulting cost per volume varies between €1-3 per cm³ for stainless steel. For metal FDM, the layer thickness is the key factor to increase the build volume per time. By increasing this parameter, the production rate increases but also leads to a significant reduction in resolution and surface quality. As previously mentioned, the cost of feedstock also varies depending on the system. Taking these parameters into account, the resulting cost for stainless steel is estimated to be between €0.5 and €2.5 per cm³.

Production speed in Binder Jetting is calculated from the total build job time and packing density. The packing density reflects the sum of all part volumes referred to the complete build envelope. Packing density is typically 10% for mixed build jobs with different parts and 30% for optimised stackable parts in a large volume production. Build times are between twenty and forty hours. Considering the claimed improvements in the technology in the next few years, the build envelope will increase while the total build time reduces to ten hours thanks to single pass jetting. With the systems available today, the cost of a build with stainless steel is between €0.5 and €1 per cm³.

Sintering process

Binder Jetting and metal FDM printing processes are always followed by an additional debinding and sintering process. The costs for this largely depends on the specific debinding and sintering technology used by the system supplier. In MIM, catalytic debinding and sintering processes dominate, thanks to their high productivity and good process control. On the other hand, the catalytic process requires a high level of equipment investment, process knowledge and the use of hazardous consumables such as nitric acid.

To reduce complexity, some sinter-based metal AM technology vendors use a one-step thermal debinding and sintering process. For components with wall thicknesses of up to 3-4 mm, this takes about sixteen hours in a typical furnace with a volume of 50,000 cm³. The hourly rate for a thermal debinding and sintering furnace ranges between €13 and €23, with the lower estimate being for a typical debinding operation and the higher figure representative of a typical sintering operation. This figure is based on a calculation that includes utilities and consumables such as electricity, process gas, the cost of a standard furnace with deprecation over five years with an annual run time of 6,000 hours, and furnace maintenance. Excluded from the calculations are labour, infrastructure and overheads, etc. Assuming a packing density of 10%, the cost for thermal debinding and sintering is estimated at €0.08 per cm³. In contrast, the cost for catalytic debinding and sintering adds up to about €0.28 per cm³.

The impact of sinter-based AM technologies on end users and supply chain

The end user

Component manufacturers now have more options than ever when it comes to choosing the right technology for their application. However, this choice also challenges engineers to develop knowledge of several different production technologies. In the past few years, casting and forging engineers have had to adopt and develop knowledge about LB-PBF. Now, the technologies of Binder Jetting and metal FDM offer an even wider choice. More than ever, the knowledge about possibilities, limitations and characteristics of the different manufacturing technologies becomes a crucial factor for engineers of tomorrow. Fig. 13 shows a technology map to support the choice of technology based on manufacturing volume and part complexity.

At Ampower we expect the main impact for Binder Jetting to be seen in the higher production volume applications as, for example, seen in the automotive industry. Metal FDM technology will enable applications in the machine industry, especially when it comes to low production volumes, prototypes or jigs and tools. Due to the high requirements on material properties, we expect it to be unlikely that aviation and implant manufacturers will adopt sinter-based AM technologies for highly loaded parts.

The supply chain

The AM supply chain is bound to experience changes with the adoption of these emerging technologies. Starting with material feedstock, today's metal powder suppliers face new markets in Binder Jetting and metal FDM technologies. However, both technologies will have different requirements for their products.

We expect existing electron and laser beam PBF system manufacturers to further focus on demanding, high-end markets such as medical and aviation industry. The superior material properties and a high technology readiness level of PBF systems will also keep binder technologies at a distance in these high-end sectors. Mass markets such as automotive, however, will gradually shift their focus from LB-PBF to Binder Jetting. The prototyping and tooling market will quickly adapt to the cost potentials of metal FDM.

The major limit of binder technologies will remain in the part size and complexity limitations of the sintering process. Here, manufacturers of sintering equipment and toll sintering operations will experience a significant growth in interest in their products and services. Furthermore, we expect that many conventional MIM producers will integrate sinter-based AM technologies into their portfolio.

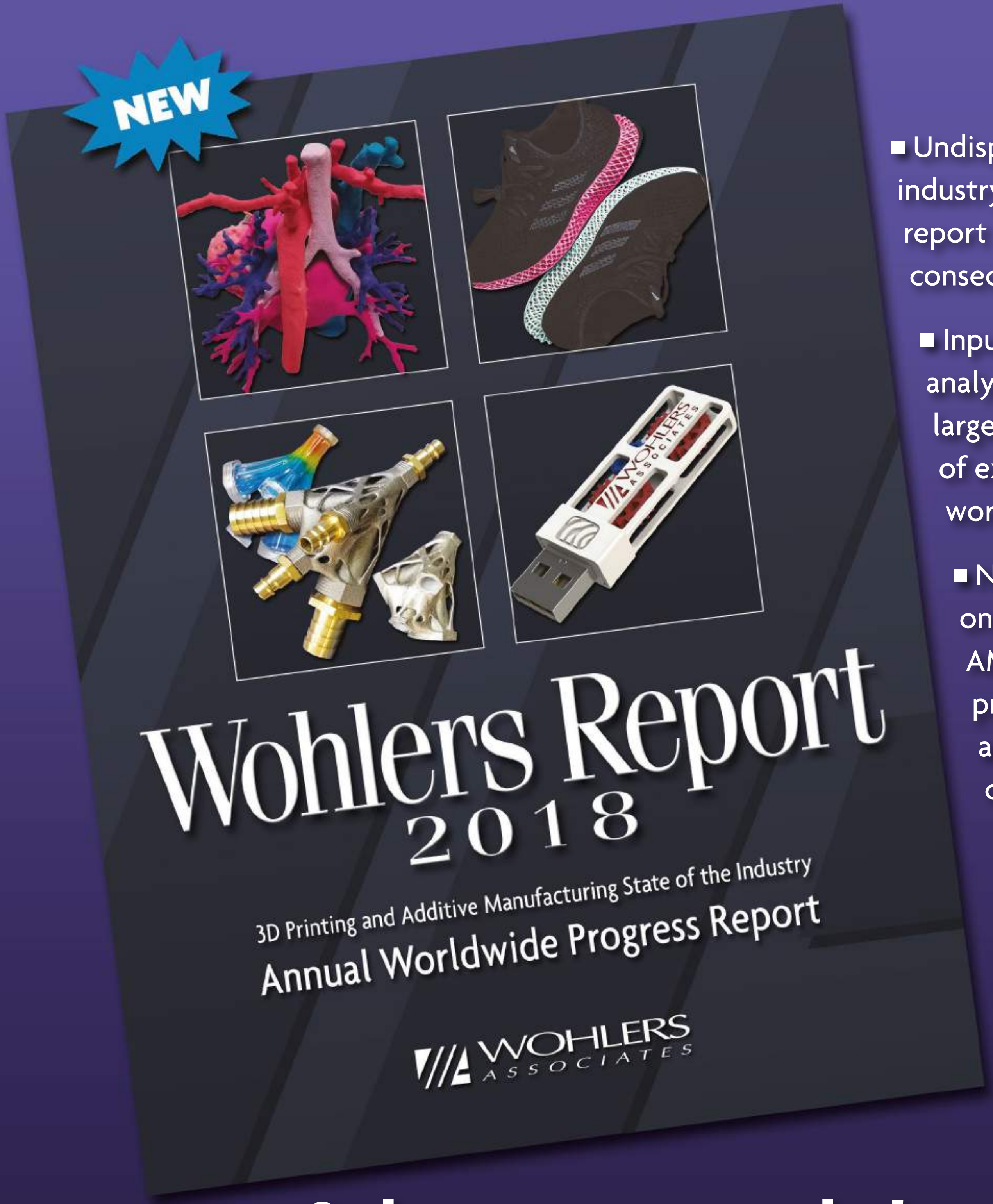
Authors

Maximilian Munsch, Matthias Schmidt-Lehr and Eric Wycisk
Ampower GmbH & Co. KG
ZAL TechCenter
Hein-Sass-Weg 22
21129 Hamburg
Germany

Tel: +49 40 99999 578
Email: schmidt-lehr@am-power.de
www.am-power.de

This report is based on a forthcoming publicly available study that offers a detailed look into these new metal AM technologies. The full study will be available through www.am-power.de.

Ampower is a leading consultancy in the field of industrial Additive Manufacturing. The company advises its clients on strategic decisions by developing and analysing market scenarios as well as compiling technology studies. On operational level, Ampower supports the introduction of Additive Manufacturing through targeted training program as well as identification and development of components suitable for production. Further services include the setup of quality management and support in qualification of internal and external machine capacity. The company is based in Hamburg, Germany.



Additive Manufacturing: Myths, misconceptions and untruths

The past decade has seen tremendous growth in metal Additive Manufacturing. To a certain degree, the field has become a victim of its own success, resulting in a number of myths, misconceptions and untruths. Some of these are even becoming detrimental to the further adoption of AM around the world. Olaf Diegel and Terry Wohlers draw on their combined industry experience to address the ten most common misunderstandings and myths relating to AM and present the reality of the technology at its current stage.

Additive Manufacturing will replace conventional manufacturing

A number of articles have suggested that AM is the future, and that someday, almost everything will be made by it. This is unlikely to occur in the foreseeable future. The cost of producing AM parts will decline in the coming years, but it will nevertheless remain a more expensive option for the production of high quantities of components. This will especially be the case for low-value products. The layer-by-layer nature of AM makes it relatively slow, which contributes greatly to the cost.

Those intimately familiar with AM see it as complementary to conventional manufacturing. Certain jobs can be achieved with AM which would not be possible with conventional manufacturing. These include complex shapes and geometric features, often using less material, resulting in lighter-weight parts. Also, it is possible to produce some types of custom products affordably, especially ones that would be inconceivable using conventional methods of manufacturing. Parts that can be easily manufactured on a three-axis CNC machine are usually best produced in this way.

Metal AM will contribute substantially to the sale of countless CNC machines and other conventional tools and methods, such as heat treatment, surface finishing, and inspection, to support the post-processing of parts. The factory of the future is likely to include an array of manufacturing technologies; the challenge for product development engineers will be to know when to use a particular technology to add the most value to products.


Fig. 1 Metal AM will not replace conventional manufacturing: parts that can be easily manufactured on a CNC machine are usually best produced in this way (Photograph courtesy Glenn McKechnie)

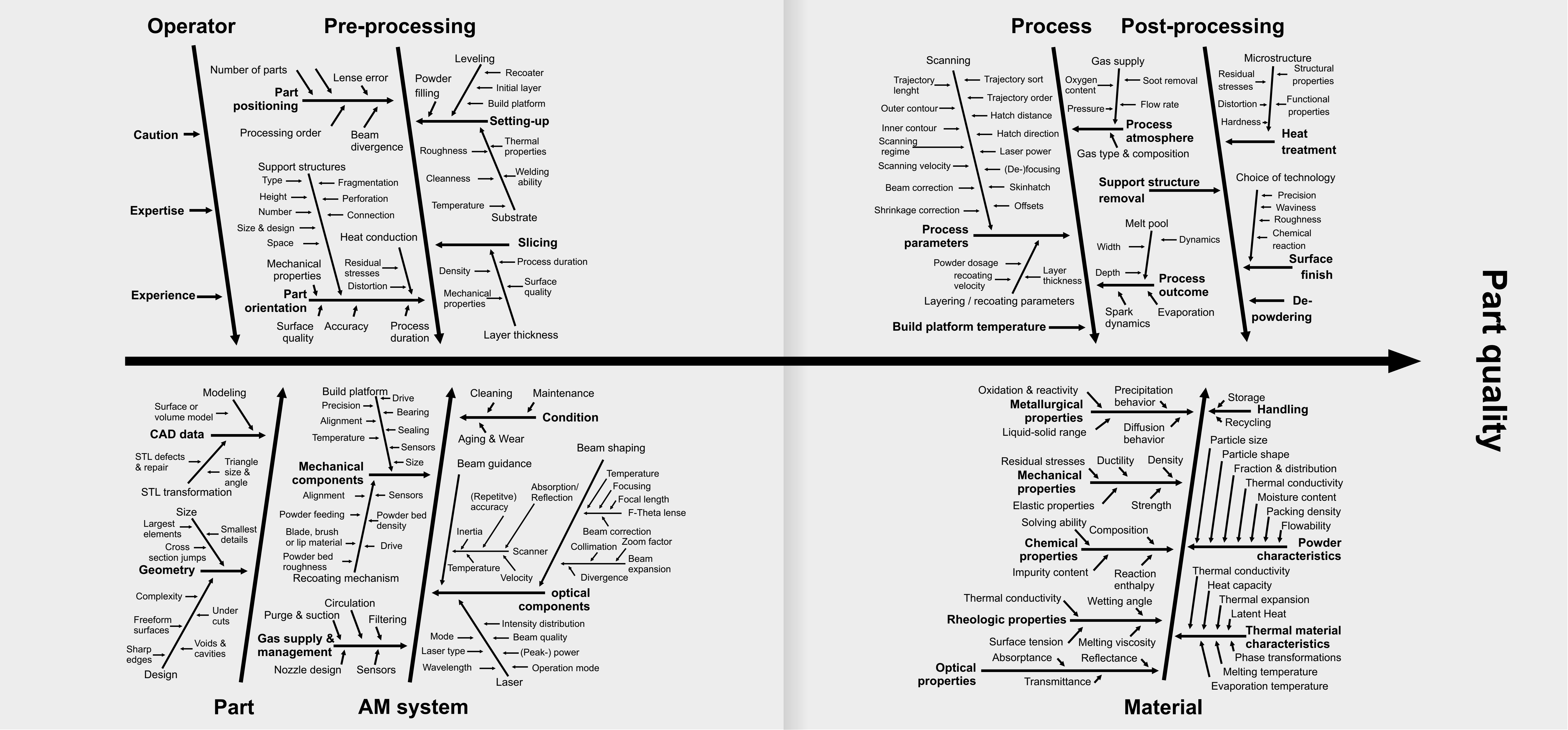


Fig. 2 Ishikawa diagram of parameters affecting metal AM parts (Courtesy Dr Christoph Haberland, Siemens Industrial Turbomachinery AB)

Almost anything can be made by AM

One of the catch-phrases of AM for many years has been that you get 'complexity for free.' This refers to AM being well-suited to making extremely complex parts that would not, or could not, be made conventionally. Adding to part complexity does not add a great deal to the cost of building a part on the machine, but this saying does not take into account the added design time or post-processing required.

What is interesting is that the inverse is also true. In other words, geometrically simple parts are often not commercially viable to make by AM. This does not mean that they cannot be made by AM, but making them in this way often does not add enough value to justify the higher cost of the process.

Press the print button and the machine does the rest

This is one of the biggest myths in AM, especially metal AM. Most metal AM systems produce near net shape parts. This means that they are not capable of producing parts with the same engineering precision as conventionally made parts; parts requiring high precision are machined or post-processed in another way. Some manufacturers are beginning to address this by integrating AM into CNC machines to produce hybrid systems.

Parts made by metal AM usually require a substantial amount of pre- and post-processing. In fact, a survey conducted in connection with *Wohlers Report 2018* found that about 46% of the cost of a metal AM part is from pre- and post-processing. In research conducted by the the NextGenAM project, EOS, Daimler, and Premium AEROTEC estimate that pre- and post-processing costs could be as high as 70%.

A great number of pre- and post-processing tasks are less than automated and require a great deal of operator knowledge and skill. In preparing a build, the operator must decide how best to orient the parts and where and what type of support structures and anchors to use. Also, a person must determine the best machine build parameters to optimally melt the metal and successfully build good quality parts. Three different operators will often end up with three different part qualities, even when using the same machine and material.

Christoph Haberland of Siemens Industrial Turbomachinery AB has created an Ishikawa diagram of the wide range of factors that impact metal AM part quality. This illustration paints a picture of the sheer complexity involved in building good quality metal parts by AM (Fig. 2).

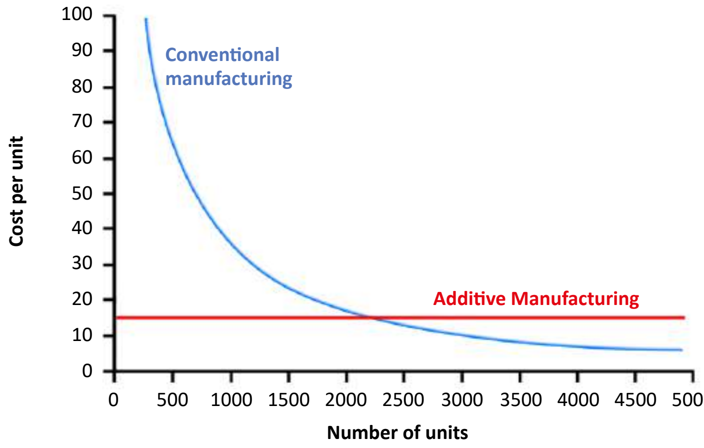


Fig. 3 With conventional manufacturing, costs typically decrease as quantities increase. With AM, costs remain roughly constant, with some exceptions

Fig. 4 The version at the left is not a good fit for AM

Desktop 3D printers are similar to industrial AM systems

Countless news stories, Hollywood films, television series, and personal conversations have portrayed low-cost 3D printers as being capable of producing high-end production-quality parts. In general, this is not true. The recent Ocean's Eight film, for example, portrays a desktop 3D printer producing gold and precious stone jewellery in quality levels that are just not achievable. Some high-end industrial machines can process precious metals, such as gold, but good results can require days of post-processing.

Material extrusion-based metal AM systems are now available commercially, so it is only a matter of time before metal AM penetrates the low-cost, desktop market. Even so, a wide gap in quality and speed will remain for some time between desktop 3D printers and high-end Additive Manufacturing systems.

This should not be construed as a devaluing of desktop 3D printers in any way. In fact, the opposite is true; desktop 3D printers are incredibly valuable tools for the generation of ideas and for prototyping. We strongly believe that nearly every engineer or designer should have a desktop 3D printer near them. However, they should also have access to industrial production machines when jobs require them.

Metal AM can make parts less expensively

A surprising number of people believe that AM can produce parts at a lower cost. In some case, this may be true but, in general, AM is more expensive, especially as production volumes increase. AM is usually cost-effective when it adds value to a product beyond what is possible with conventional manufacturing.

Fig. 3 shows that, with conventional manufacturing, costs typically decrease as quantities increase. With AM, costs remain roughly constant, with some exceptions. The break even point — the point where the two lines cross — varies widely, depending on the size of the part, price of the material, and speed of the machine, coupled with other factors.

Every home will have a 3D printer

Some believe that most of us will one day use 3D printers at home to produce products. This is highly unlikely to occur in the foreseeable future. One reason is that most modern products contain a range of materials, including metals, plastics, and electronics; high-end systems may be able to process a combination of materials in the future, but these will be very expensive and difficult to use. Even the most basic desktop 3D printers require design skills and software tools beyond the reach of most people.

The future may bring simple and low-cost 3D printers aimed at children and hobbyists, but these will be suited for a limited number of materials and products only. A 3D printer designed for custom food, such as chocolates, is a possibility for homes in the future, but one might argue that this type of work is best left to culinary experts at bakeries and in other commercial settings. The idea of 3D printing at home is akin to many having sewing machines, yet few people are wearing home-made clothing.

Most '3D printed products' are indeed 3D printed

We often discuss '3D printed products' made in metal and/or polymer, but much or most of the product is not 3D printed at all. We see this in footwear where only the sole, or part of an insole or sandal, is 3D printed. The majority of the product is produced using one or more methods of conventional manufacturing.

The 3D printed guitars produced by ODD Guitars are another example. We may refer to them as 3D printed guitars, but only their main bodies are 3D printed. The guitar necks are CNC machined, the bridges and tuners are cast, and the plastic pickup rings and knobs are injection moulded. Other parts of the guitars are produced using other methods (Fig. 4).

Another example are the Invisalign dental aligners from Align Technology. We may refer to them as 3D printed dental aligners, but AM is used for only one part of the process. The aligners, themselves, are not 3D printed. A digital model of the patient's teeth is produced, and an orthodontic specialist manipulates the digital model to produce a series of teeth models. Each 3D model is printed on a vat photopolymerisation system that serves as a 'form' over which the plastic aligner is thermoformed. A five-axis milling machine is used to cut away the excess material so that the aligner fits well along the gum line. Laser engraving, tumbling and other processes are used for marking, polishing, and cleaning. The start-to-finish process truly represents the factory of the future, with AM being a part.

These examples should not denigrate AM at all, particularly if it is being used for the right reasons to help manufacture products. In fact, these types of products would not be possible or affordable without the use of AM.

Most metal AM systems are similar

Most metal AM technologies and systems get lumped together as 'magic' machines that can make impressive parts. In truth, however, they vary widely. Powder Bed Fusion systems are vastly different to Directed Energy Deposition systems; Laser Powder Bed Fusion systems are different to Electron Beam Powder Bed Fusion systems. Parts from these machines can have differing metallurgical properties, support structures and anchors, and surface finishes. Also, the amount of post-processing required can differ greatly.

It is important to understand that no single technology is better than all others, despite what some may claim. Every technology has its advantages and disadvantages, and this applies to machines that produce parts in metal or polymer. Understanding these machine types is essential to knowing when to use one technology over another and how to best design for them.

	Mechanical properties	Surface finish
Sand cast	AM is superior	AM is superior
Investment cast	AM is superior	AM is inferior
Wrought or forged	AM is inferior	AM is inferior

Table 1 General guidelines on how AM parts compare to conventional manufacturing

AM parts are inferior to conventional parts

Engineers are generally conservative, so questions are often asked about the mechanical integrity and the quality of metal AM parts compared to those made conventionally. Articles and research studies reveal differences between the properties of metal AM parts and those produced by conventional manufacturing, but this should not always be seen as a negative. Table 1 provides some general guidelines on how AM parts compare to conventional manufacturing.

For AM to add value, it is recommended that parts are designed for AM. If the design dramatically reduces material and weight, the outcome may be more favorable than suggested by the material properties. In fact, a reduction in material and weight can offer manufacturers the ability to use a stronger and more expensive material, resulting in improved functionality. The total material cost may be lower because less material is used.

An insufficient number of AM materials are available

This myth may be true in some instances. More than anything, it highlights the fact that much of engineering design is related to material choice based on historical use. An alternative is to consider the function of a material when coupled with good design for AM. Materials such as Scalmalloy from APWorks are being developed specifically for metal AM, and in the future, we will undoubtedly see more specialised materials produced for Additive Manufacturing.

Conclusion

As metal AM grows in popularity, more resources will become available to further develop and refine the technology. This will result in faster, more repeatable and lower cost machines. A lack of understanding of the realities of metal AM is an impediment to its wider acceptance and adoption. Knowing what works and what does not, while separating fact from fiction, can help organisations to make the best possible decisions. Good decisions lead to happy AM machines, materials and services suppliers, as well as elated customers.

Authors

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

Metal Additive Manufacturing: A simulation provider's perspective

Over the past few years, metal Additive Manufacturing has received a lot of attention, and with good reason: the technology has the potential to radically alter the design and production of components and products in many industries. Yet in spite of the excitement that surrounds AM, the prospect of wider industrial adoption continues to face significant challenges. Ansys Inc's Dave Conover explains how simulation, traditionally the domain of product design instead of manufacturing, has swiftly gained recognition as a key technology which can be used to ease the transition from conventional to Additive Manufacturing.

Powder Bed Fusion (PBF) is the most widely used metal Additive Manufacturing technology on the market today. In this process, a thin layer of metal powder is spread across the top of a build and exposed to a highly-focused laser or electron beam heat source to melt it in rapidly-solidifying layers corresponding to a 2D slice of the 3D design. This process is carried out repeatedly until the build is complete. (Fig. 1)

AM enables engineers to produce very complex shapes and typically results in a near net-shape part. This design freedom offers a wide range of creative opportunities for lightweighting, part consolidation and customisation. It is this capacity for weight and size reduction and customisation which has attracted the aerospace and biomedical communities to the technology as early adopters.

At Ansys, many of our customers are interested in metal Additive Manufacturing, but few have purchased machines and even fewer have more than several parts in actual production. As a result, the tremendous desire within the industry to take advantage of the opportunities afforded by Additive Manufacturing is not currently being realised in practice. There are more than a few reasons for this, with major factors being the cost of the machines, the staff required to run them, and the design and process changes required to take advantage of AM.

In terms of the Gartner hype cycle, the industry as a whole is past the point of 'inflated expectations'. It has realised the reality and passed through the 'trough of disillusionment' stage, and is on the upward 'slope of enlightenment', moving slowly toward truly productive use of the AM process.

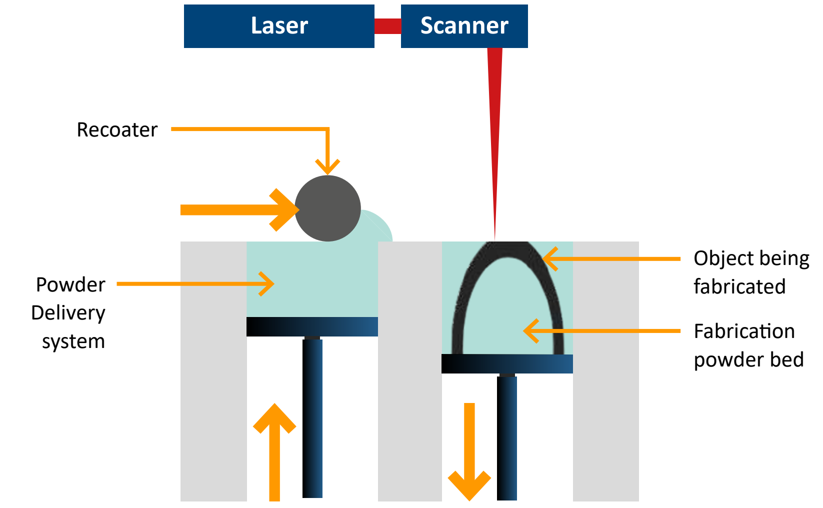


Fig. 1 In the Powder Bed Fusion process, thin layers of powder are melted and solidified to form the part one layer at a time

Fig. 2 Severe distortion in a collar bone implant after removal from the base plate. The distortion was severe enough that the implant could not be used on the patient (Courtesy the University of Pittsburgh)

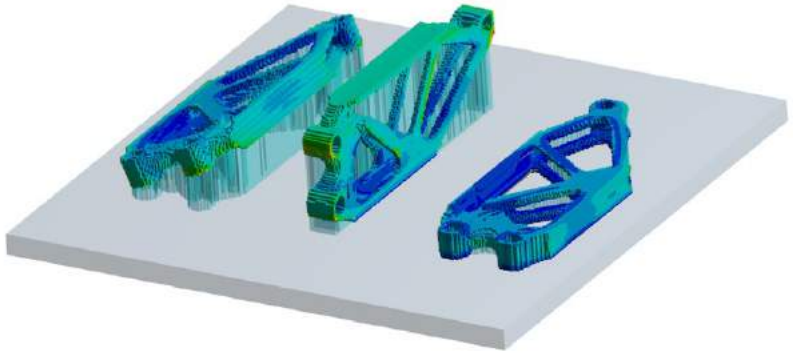


Fig. 3 Simulation of different build orientations in Ansys software and the resulting deformations

Challenges facing wide-scale adoption of AM

There are many other reasons adoption has been slow. The AM process involves very complex and chaotic physics which can be difficult to control, predict and measure. It also involves extreme scales, both in time (microseconds for laser heating, hours or days to build the part) and space (microns for the melt pool size, decimeters for the part size), while the variability in machines and processes can affect the final part quality.

Qualifying and certifying AM parts

The USA's National Institute of Standards and Technology (NIST) defines qualification as "the collection of sufficient data to demonstrate that a material or process will function as expected." Furthermore, the institute outlines three different paths that can be taken to qualification:

- Statistical-based qualification, rooted in extensive empirical testing
- Equivalence-based qualification, achieved through moderate testing to demonstrate that a new material or process is equivalent to a previously qualified material or process
- Model-based qualification, where a material or process's performance is demonstrated in a computer model and verified with minimal testing.

Empirical testing (build and test) is expensive and time-consuming for the AM process. Using this method, it can take years to fully qualify a part and process, especially for the safety-critical parts used in many aerospace components. Using model-based qualification — simulation — is the quickest route to qualification and certification, and provides additional benefits compared to other methods. For example, understanding the impact of variability is one issue that can be cost-effectively solved using simulation. By creating a simulated or model process, the effects of machine parameters and material variation can easily be studied, along with build orientation and support design.

Of course, the design of the part itself also has an impact on the production quality. Quality is measured by two parameters: 1) the conformance of parts to the design geometry (distortion and the underlying residual stresses are endemic problems with metal AM), and 2) material properties of the as-built part.

Understanding and preventing distortion

The layer-by-layer heating and cooling involved in PBF AM induce large thermal strains that cause plastic deformation in the part as it is built. Once removed from the build plate and its supports, the residual deformation can be quite large (Fig. 2), leading to unusable parts or parts requiring extensive machining operations to bring them into compliance. Large residual stresses and plastic strains are also present, requiring heat treatment to relieve the stress, which increases manufacturing cost and time.

While machine parameters such as build plate temperature and scan pattern play a role, the primary mechanism for controlling distortion is the orientation of the part and the support structures (Fig. 3).

Material properties

The PBF Additive Manufacturing process involves quickly heating a very localised area of powder (tens of microns in size) to melt it, followed by rapid solidification. This cooling rate is orders of magnitude faster than casting, causing unique and, in many cases, non-equilibrial microstructures to develop. Since the material is added layer-by-layer, the resulting microstructures are columnar in nature (Fig. 4) leading to a different stress-strain response in the build direction versus the transverse direction.

Scan patterns, part thickness variability, overhangs and the upward or downward sloping of a part face during the build can lead to variable microstructures, resulting in different engineering properties throughout the part. Heat treatment can alleviate this, but at the cost of an additional step in the manufacturing process. Porosity left behind during the process can also be a concern. Hot Isostatic Pressing (HIPing) is required for parts subject to any type of cyclic (fatigue) loadings.

In addition to the potential heat treating and HIPing operations mentioned above, manufacturers must also consider post-processing operations such as support removal, surface finishing and additional machining.

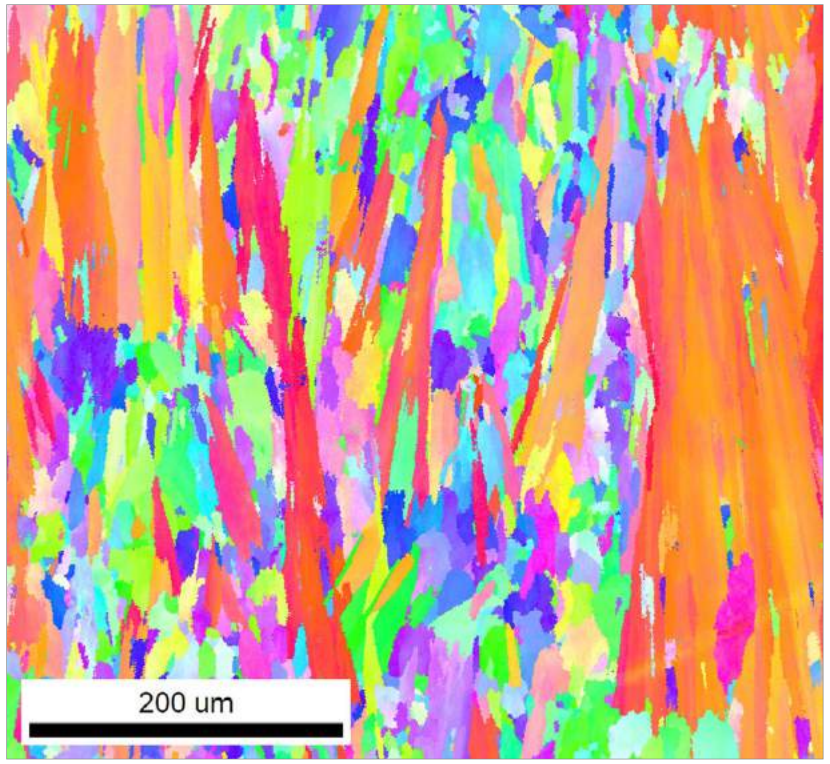


Fig. 4 Columnar microstructure observed via EBSD in built Inconel 718

Simulation as an enabler

Given the issues outlined above, it is perhaps not surprising that companies have been slow to adopt and advance metal AM as a standard (i.e. qualified) manufacturing process alongside machining, casting, forging, etc.

Simulation of the Additive Manufacturing process has now evolved to the point where it can have a measurable impact on the design and production of quality parts. Design here means not only traditional product design (i.e. a product's geometry) but also the design of the machine build parameters, part orientation, supports and post-processing steps.

This is not to claim we are at the point where simulation can completely replace trial and error builds, but it can certainly augment and significantly reduce the need for them. Additionally, simulation can be used to understand and quantify variability, providing valuable insight and direction that a single test build cannot provide. This allows

How simulation is driving forward the adoption of AM

When the author started at Ansys almost forty years ago, simulation (then predominately structural finite element analysis, or FEA) was relegated to a few PhDs in an analysis group, and then only in companies that had access to the funds required and for which the technology was absolutely necessary: namely the aerospace and nuclear industries, where failure was not an option. A coalescing of three technologies eventually led to the widespread adoption of simulation: the maturing of FE theory and algorithms, the validation of the same and the availability of cheap and powerful computing (from mainframes to minicomputers to Unix workstations to PCs).

Forty years ago, companies relied almost completely on build-and-break testing — with prototypes, subassemblies and assemblies, and eventually full-scale products — to validate designs. Using this qualification method, a new car line would take five years to move from conception to rollout. Today, simulation is used throughout the design process and, in many cases, is used as the validation step. Testing, when carried out, is performed more to validate the simulation and provide data for the next simulation than as the primary method for qualification. As a result, new car lines can now move from concept to production in a matter of months.

This same phenomenon can be seen in Additive Manufacturing. As intensive global research provides more insight into the physics, and methodologies and algorithms are created to support the process, the technology is quickly maturing. Simulation of AM is being validated daily and users are gaining experience and confidence. Widespread adoption of simulation in AM will lead not only to a faster lead-time from design to completed part, but also to a qualified process and a qualified part.

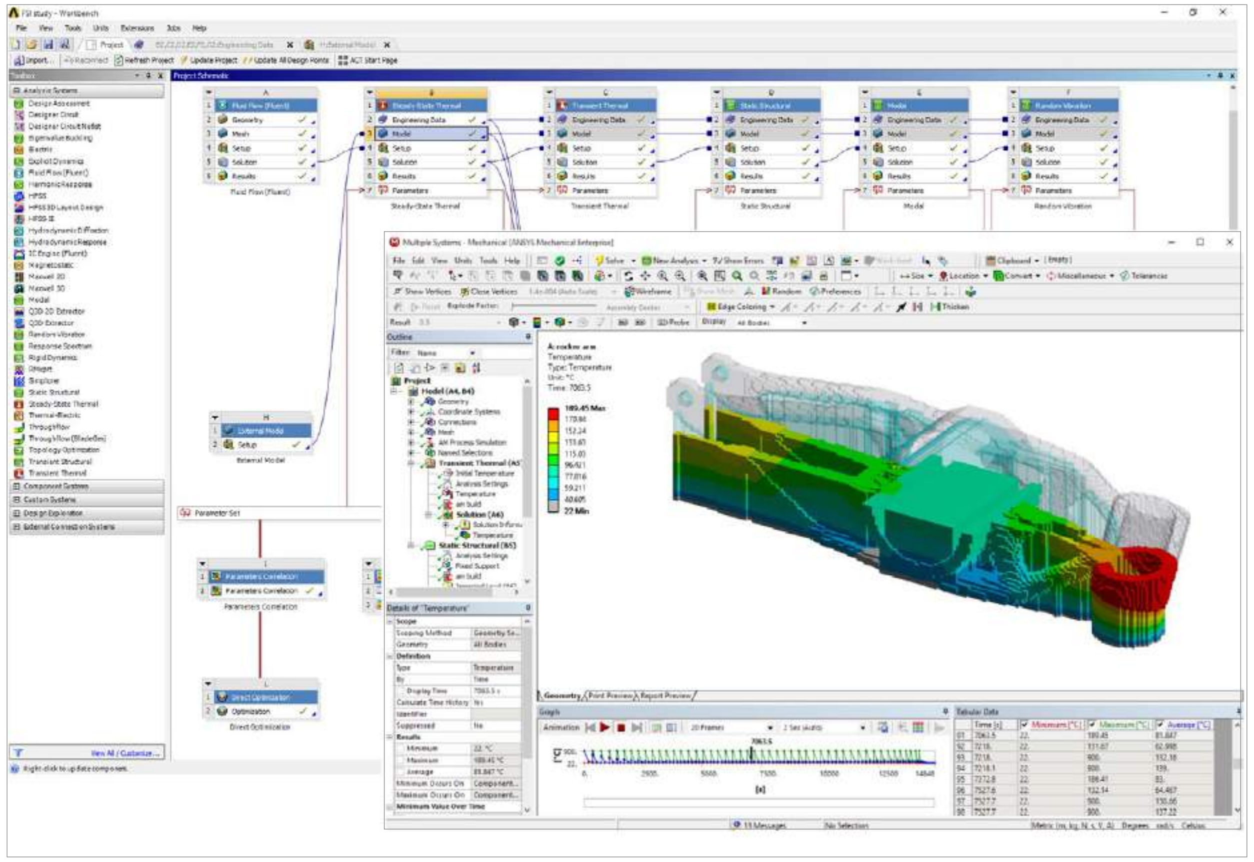


Fig. 5 Full design-build-validation simulation workflow for Additive Manufacturing in Ansys Workbench and Mechanical

companies to manage the risk of AM and achieve certification via model-based qualification. (Fig. 5).

Ansys recognises that there are three roles involved in the path to quality: the product design team, the machine operator and the manufacturing specialist/materials engineer.

Product design

Simulation has long played a role in the product design cycle. Now, engineers are increasingly asked to design for the additive process. For effective Design for Additive Manufacturing (DfAM), they should ask:

- Is this design good for AM?
- Does it make use of its benefits (geometric complexity, part consolidation, unique cooling channels, etc.)?
- Will this part build correctly?
- Is distortion going to be a problem?
- How should I design the supports?

Many companies have found that upfront engineering is required for good support design — meaning adequate strength and sufficient support locations — rather than depending on geometry-based processors downstream to the design process.

Ansys Workbench Additive enables engineers to answer these questions. In addition to the usual simulation of how a part works in the field, designers can also simulate the build process to look at distortions and residual stresses and how orientation and support design will affect them, including their optimisation. Workbench Additive also includes topology optimisation, a generative design tool which lays out part geometry based on the loads encountered, leading to shapes that can be produced easily by the AM process.

Machine operator

The operator of an AM machine receives a design (typically in STL format) from the design group, and their job is to successfully build it. Success means one build job, with minimal distortion (conforming to the desired geometry), minimal residual stress, minimal build time and minimal supports (since these take time and material to produce).

Ansys Additive Print enables the operator to investigate the best options for a part build. It uses simulation 'under the hood', but the interface is geared toward a technician rather than an engineer. Additive Print allows the operator to investigate orientations and optimise support sizing to achieve a successful build first time. Additionally, the operator can have the software modify the STL file that is input to the AM machine so that when the built part does distort, it distorts to its as-desired shape (Fig. 6).

Fig. 6 Distortion compensated design from Ansys simulation results in the originally designed geometry when built

Inherent strain or thermo-mechanical solution?

Most AM process simulation software on the market, including Additive Print, uses an 'inherent strain' approach to solve for the distortions and residual stresses.

Inherent strain is a technique developed for welding simulations: if you know the residual strains in a weld after the welding and cool-down process, you could apply these directly to the part as an input strain and directly compute the distortion without having to do a long and complicated thermo-mechanical simulation. This same approach is available in Additive Print — if you know the strain induced by the additive process, you can apply it directly for a quick distortion evaluation.

Two camps exist for determining this strain (which is material- and machine-dependent): build a simple part and measure distortions to back-calculate these strain values, or perform a detailed thermo-mechanical solution on a small cube and extract the residual strains. In either case, detailed machine information is necessary and calibration is required to achieve good correlation.

A thermo-mechanical process model performs a detailed thermal simulation of the build and feeds those temperatures to drive thermal distortion. Various levels of fidelity and abstractions can be used to obtain good solutions in a reasonable time frame. This methodology requires little machine information and is more suitable for the product design group, who typically do not have access to those details or the machines themselves.

Manufacturing specialist

The manufacturing specialist provides the 'recipe' — the machine parameters, including laser power and speed, hatch spacing, scan patterns, etc. — to the operator in order to meet the desired part quality. They also supply design guidelines to the product design group. Historically, this knowledge is built up through experience of many test builds, starting from single beads, to cubes and pads, to canonical geometries, to prototype parts. Testing this way offers good insight but is insufficient for qualification without prior months or even years of data acquisition.

Ansys Additive Science provides insight into machine parameters and materials. It allows the manufacturing specialist and the materials scientist to answer such questions as how machine parameters like power and speed affect melt pool size and porosity. The laser power-speed process map (Fig. 7) can be found experimentally for a given machine and material. However, simulation provided by Additive Science lets the manufacturing specialist explore these boundaries to understand how variability in, say, laser power degradation over time, affects the built part.

Additive Science can also provide detailed microstructure output to explore material variability due to scan strategies and part location (Fig. 8).

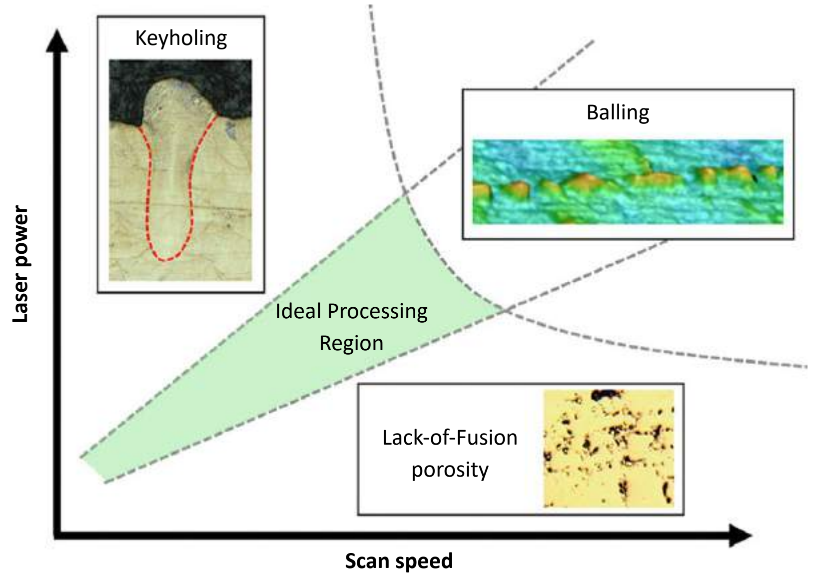


Fig. 7 Power vs Speed process map showing the problem regions of processing space in addition to the ideal processing region where more reliable results can be achieved

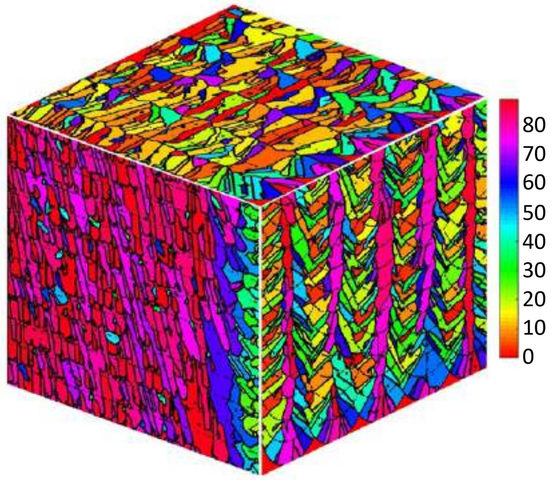


Fig. 8 Simulation of the Inconel 718 microstructure that develops as a result of the Additive Manufacturing process

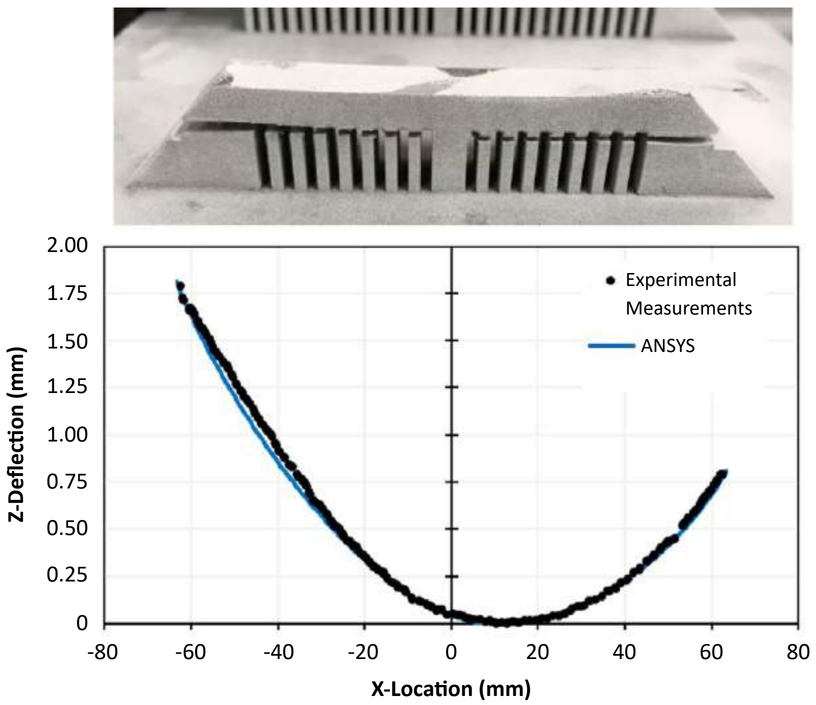


Fig. 9 Good agreement between an Ansys simulation and experimental results for a double cantilever model additively manufactured in Ti-6Al-4V (part produced at the University of Pittsburgh)

An important output from full-part simulation is sensor readings, which allow correlation with actual sensor outputs. Having a simulation model of the expected sensor readings — a 'digital twin' of the actual build process — allows understanding and correction of builds during the process.

Future trends

Because AM is a rapidly evolving field, the future is difficult to predict with certainty, but there are some overarching trends. New machine manufacturers are appearing, along with new and significant upgrades to existing machines. These machines are becoming more reliable. As one customer stated, "they are becoming industrial machines and not prototypes". Multiple lasers and enhanced scan patterns are leading to more even heating on a layer, reducing distortion and providing more even microstructure.

Novel alloy development will accelerate, taking advantage of the fact that, in AM, the material is built as well as the part. Mixing powder chemistries and taking advantage of non-equilibrial cooling rates will lead to the development of materials unthought of today.

Software — from design to simulation to build preparation to machine interfacing — is maturing and consolidating, providing a more even user experience. Simulation software in particular is maturing, as researchers advance the state-of-the-art and users gain experience. Ansys provides a Validation Manual with its software (Fig. 9) which not only gives users confidence in their AM simulation, but also insight into the usage and best practices of simulation. More automation and optimisation, such as orientation, support design and sizing, and even setting of machine parameters, will evolve in simulation software, leading to a 'push-button', right-first-time Additive Manufacturing experience.

Final words

The last few years have been quite a ride for metal Additive Manufacturing. While the promises of metal AM are great, the reality of investment cost and qualification continues to limit its growth. Simulation, though, can smooth and accelerate the road to adoption and acceptance.

Author

Dave Conover
Chief Technologist, Mechanical Products
Ansys, Inc.
Southpointe
2600 ANSYS Drive
Canonsburg, PA 15317
USA
Email: dave.conover@ansys.com
www.ansys.com

AMPM2018: Process parameter control, corrosion resistance and feedstock extrusion highlighted

AMPM2018, the fifth annual Additive Manufacturing with Powder Metallurgy Conference, was held in San Antonio, Texas, USA, from June 17-20, 2018. The event continues to enjoy impressive growth as the breadth and depth of its technically focused progamme expands. In this report, Dr David Whittaker reviews three presentations that cover the characterisation of hard-to-weld nickel-base superalloys, the corrosion behaviour of 420 stainless steel and the extrusion of feedstock containing water atomised 17-4 PH stainless steel powder

The AMPM (Additive Manufacturing with Powder Metallurgy) conference series, sponsored by North America's Metal Powder Industries Federation (MPIF), was initiated in 2014, running in parallel with the POWDERMET2014 conference, Orlando, Florida. The fifth conference in the series, which continues to run in parallel with the POWDERMET conference, was held in San Antonio, Texas, June 17-20, 2018. Contributions to the conference covered a broad range of topic areas, including process parameter control for difficult-to-process materials, achievable properties in AM-processed materials and studies of 'MIM-like' AM processes. This report will review examples of presentations in each of these categories.

Characterisation of hard-to-weld nickel-base superalloys

In the first category, Kristiina Kupi, Abdul Shaafi Shaikh, Kevin Minet-Lallemand and Tatu Syvanen (EOS Finland) discussed a study of the processing of hard-to-weld nickel-base superalloys by what EOS calls Direct Metal Laser Sintering (DMLS), or Laser Powder Bed Fusion (LPBF). Nickel-base superalloys, on the basis of their excellent high-temperature corrosion and creep resistance, are largely used in aerospace and land-based gas turbine engines.

Alloys such as IN939, IN738 and MAR-M247 are required for components with high service temperature and generally contain a high fraction of 'gamma prime' strengthening phase. Unfortunately, their poor weldability is a challenge

Fig. 1 James Adams, Executive Director of the Metal Powder Industries Federation, welcomes delegates to POWDERMER2018 and AMPM2018

Cr	Co	C	Fe	W	Mo	Nb	Ta	Ti	Al	Zr	B	Ni
22.5	19.0	0.15	-	2.0	-	1.0	1.4	3.7	1.9	0.1	0.01	Bal.

Table 1 Nominal composition of IN939 – all values in wt.% [1]

Parameter	Volume energy density E_v [J/mm^3]	Hatch distance h	Layer thickness d [µm]
Parameter 1	56	narrow	40 µm
Parameter 2	72	narrow	40 µm
Parameter 3	88	narrow	40 µm
Parameter 4	75	wide	40 µm
Parameter 5	100	narrow	20 µm

Table 2 Main process parameters used for manufacturing the test parts [1]

for production by Additive Manufacturing [1]. The nature of layer-wise manufacturing, with fast cooling rates and heat cycling, can potentially form cracks through different mechanisms such as HAZ liquation, solidification cracking and strain-age cracking.

The reported study focussed on the effect of the DMLS process on defect formation within hard-to-weld superalloys and on attempts to improve weldability through the adjustment of critical process input factors. The process monitoring tool EOSTATE MeltPool was used to observe melt pool behaviour and detect locally overheated areas.

The DMLS machine used for building experimental samples was an EOS M 290 system equipped with EOSTATE MeltPool, a photodiode-based monitoring system. When the standard process window is set, MeltPool monitoring can be utilised to spot differences between process parameters and deviations in processing. In this study, the on-axis photodiode was used for the measurements.

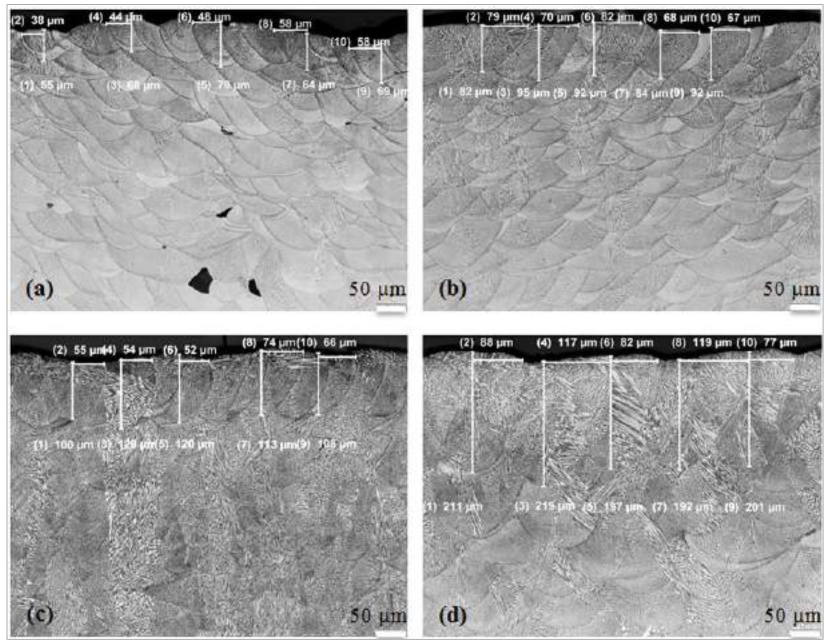


Fig. 2 Melt pool with (a) Parameter 1, (b) Parameter 2, (c) Parameter 3 and (d) Parameter 4 [1]

The material selected for the experiments was EOS Nickel Alloy IN939, with a nominal composition as presented in Table 1. The usual particle size distribution (PSD ~ 15-45 µm) and morphology for DMLS were used.

The key process input parameters, namely laser power, scan speed and hatch vector spacing, exert a strong influence on the resulting microstructure and quality of the processed part within a defined layer thickness. However, surface properties and buildability are also partly determined by the bulk parameters (hatch vectors that create the solid part). Accordingly, the effect of the key process input parameters was first characterised.

To be able to investigate the effect of key process input factors on the resulting melt pool dimensions and creation of different kinds of defects, different process parameters were used to build the sample geometries, but no additional parameters were used to improve the surface properties. The hatch vector orientation was rotated from layer to layer by 67° to homogenise the structure. The key factors are presented in Table 2.

The power used in the experiments varied between 100 and 370 W. The volume energy density E_v is calculated from the key process input factors:

$$E_v = \frac{P}{v_s h d}$$

where P is laser power, vs is the scanning speed, h is the hatch vector spacing and d is the layer thickness.

To optimise the bulk properties, but also the buildability and surface properties of the manufactured parts, more fine-tuning parameters were taken into the experimental loop. These parameters are aimed at reducing heat accumulation in areas where the hatch vectors are not exposed in full length and where the component contains, for example, thin walls and fine details. Also, down-facing areas are typically problematic to build without overheating because of the reduced heat conductivity of the powder bed compared to the solid part. These parameters are referred to as the 'Power Reduction Factor' and 'Time Homogenisation'. The Power Reduction factor (PR) reduces the laser power as a function of vector length and Time Homogenisation (TH) homogenises the energy input for short hatch vectors, by keeping the energy input per unit time and volume constant. These factors were used together with Parameter 2.

Parameter	Melt pool depth [µm]	Melt pool width [µm]	width-to-depth ratio
Parameter 1	67	98	1.5
Parameter 2	89	146	1.6
Parameter 3	112	120	1.0
Parameter 4	204	193	0.9

Table 3 Melt pool dimensions with Parameters 1-4 [1]

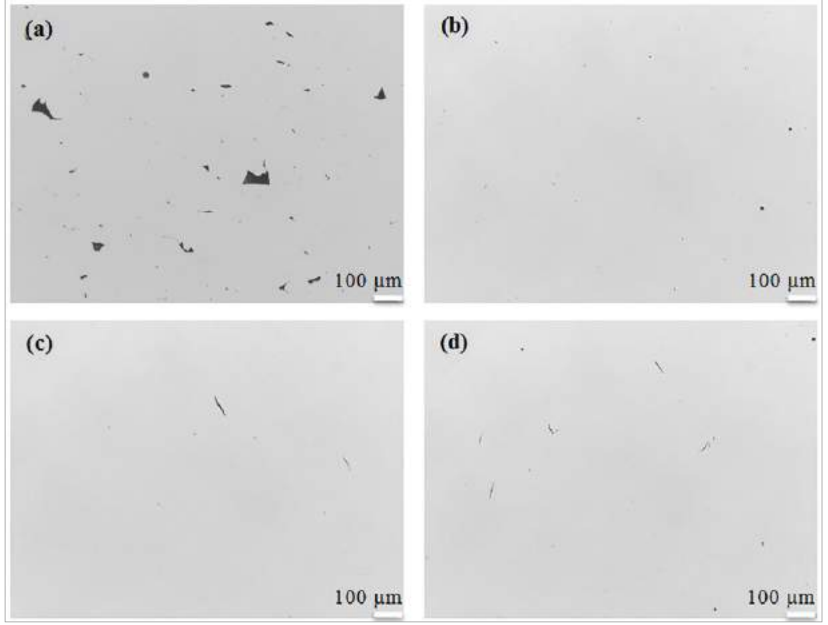


Fig. 3 Defects in samples built with (a) Parameter 1, (b) Parameter 2, (c) Parameter 3 and (d) Parameter 4 [1]

The effects on melt pool size and shape of the different key process parameters are shown in Fig. 2. Parameter 1, with the lowest energy input, results in the shallowest melt pool, while Parameter 3 produces a deeper melt pool. Moreover, the effect of a change in hatch spacing (Parameter 4 compared to the others) is noticeable. The average melt pool depths and widths resulting from the different parameters were measured and are presented in Table 3.

In addition to changes in melt pool depth, the process parameters also change the width and shape of the melt pool. The width-to-depth ratio increases from Parameter 1 to Parameter 3. With Parameter 4, the melt pool depth is increased significantly and the impact of key-hole can be plainly observed.

The process parameters used also affect the formation of diverse defects. Insufficient energy density results in improperly molten powder layers, as seen in Fig. 3(a). Parameter combinations resulting in higher energy density yield a fully dense microstructure as seen in Fig. 3(b). The lack-of-fusion defects in the sample, built with Parameter 1, are due to improper melting of powder layers. The melt pool depth for Parameter 1 was measured to be around 67 µm. The melt pool for Parameter 2 was measured to be around 89 µm deep and, in this case, complete fusion was achieved. Hence, it was inferred that, for a layer thickness of 40 µm, the melt pool should be at least 80 µm deep, i.e. twice the layer thickness.

High energy density may result in a higher level of cracking, as seen in Fig. 3(c) (Parameter 3). With Parameter 4, the hatch spacing was increased from Parameter 2 and laser power and scanning speed were adjusted to reach the desired energy density. Even though the energy densities are close to each other, Parameter 4 creates more cracks. This shows that it is not just overall energy density, but a combination of individual process parameters, that may cause cracking. The resulting melt pool for Parameter 4 (~ 204 µm) is much deeper than for Parameter 2 (~ 89 µm). The larger melt pool may result in slower cooling, allowing more time for segregation of low-melting elements. Hence, the ideal process parameters must be balanced between having just enough energy density to ensure melting across two layers and achieving cooling rates high enough to avoid detrimental segregation.

The DMLS process is operable over a range of layer thicknesses. The chosen layer thickness not only has a profound effect on productivity, but also affects the energy density required to produce a consistent and defect-free microstructure. It was observed that a 20 µm layer thickness processed with energy density in excess of 100 J/mm^3 (Parameter 5) produced a very high crack density in the built material.

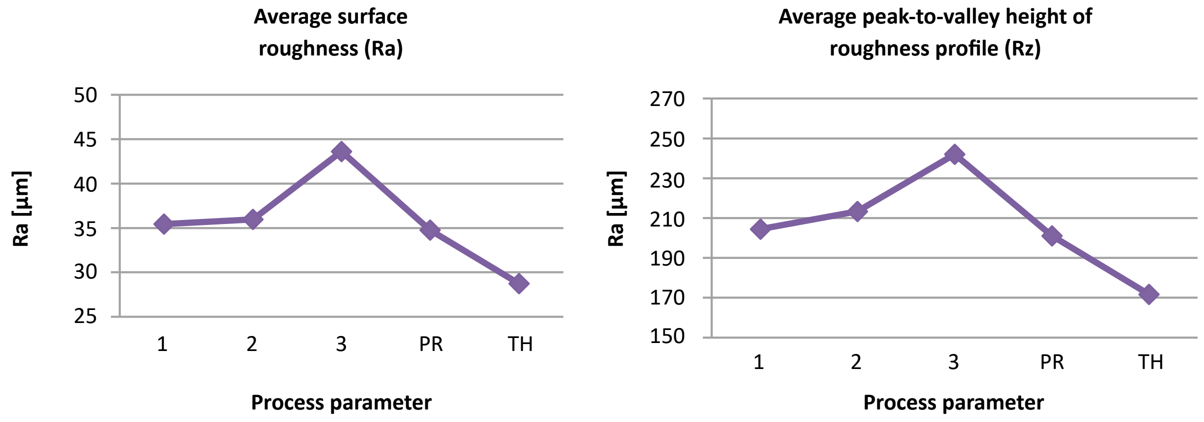


Fig. 4 Process parameters' effects on surface roughness of 45° angle down-facing surface. The used process parameters correspond with the ones in Table 2. PR = Power Reduction factor with Parameter 2, TH = Time Homogenisation with Parameter 2 [1]

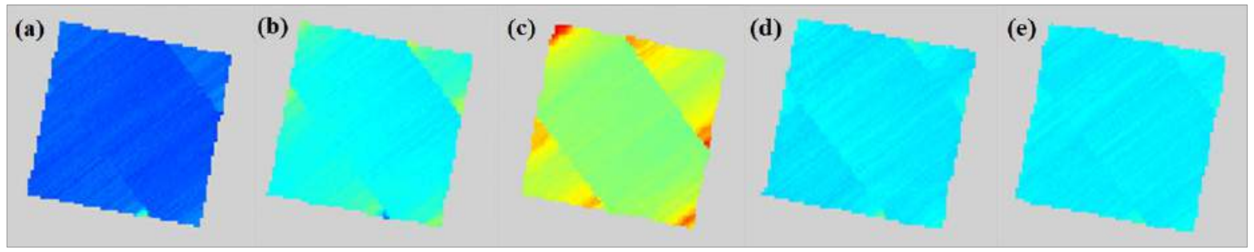


Fig. 5 EOSTATE MeltPool data visualisation: (a) Parameter 1, (b) Parameter 2, (c) Parameter 3, (d) Parameter 2 with Power Reduction Factor, (e) Parameter 2 with Time Homogenisation [1]

The effects of process parameters on surface quality of down-facing areas and up-facing surfaces were examined with samples, which included a 45° angle, and sample cubes with an up-facing surface. The aim was to be able to evaluate the severity of overheating and resulting surface properties of the built parts. The results of the roughness measurements are presented in Fig. 4.

As can be observed from Fig. 4, the energy density for the bulk also affects the properties of the down-facing areas below the 45° angle. Parameter 1 with the lowest energy density results in the best surface roughness, while Parameter 3, with the highest energy density, results in the worst surface roughness. The roughness of the surface built with Parameter 2 can be further improved with the Power Reduction Factor and, even more, with Time Homogenisation (TH). Similar observations can be made from top surface profiles. When energy density is insufficient, some balling occurs and the powder is not fully molten and, when there is an excessive amount of energy, the top surface is not as flat and the sample edges start to rise. These raised edges may cause buildability issues by interfering with the recoating process.

The overheating of certain parts and areas in the samples can be readily observed with the EOS MeltPool monitoring tool. Analysis tools were used to visualise and measure the change in intensity levels caused by the different energy inputs and short vectors, as shown in Fig. 5. One clear observation is the difference between Parameters 1, 2 and 3, (Figs. 4(a), (b) and (c)), in which the increased energy density affects the intensity profile. In addition, the effect of Power Reduction factor and Time Homogenisation on the shortest hatch vectors is seen, when comparing Fig. 5(b) to Figs. 5(d) and (e). The mean intensities, calculated with the offline toolbox, are presented in Table 4.

Parameter	Mean intensity (St. Dev)
Parameter 1	8750 (1828)
Parameter 2	12622 (2070)
Parameter 3	16036 (2510)
Parameter 4	22804 (3018)
Parameter 2 + PR	11996 (1729)
Parameter 2 + TH	12102 (1550)

Table 4 Calculated mean intensities from EOSTATE MeltPool Analysis Toolbox (with intensity corrected data) [1]

Chemical analysis- wt. %									
Alloy	Fe	Cr	Mn	Si	P	C	S	O	N
420	Bal.	12.8	0.72	0.79	0.012	0.3	0.008	0.044	N/A
AISI standard	Bal.	12-14	< 1.0	< 1.0	< 0.04	> 0.15	< 0.03	-	-

Table 5 Chemical composition of AISI 420 stainless steel powder [2]

Energy density J/mm^3	Condition	Archimedes density (g/cc)	Density of wrought (g/cc)	Relative density (%)	Ultimate tensile strength (MPa)	Elongation (%)	Hardness (HRC)
63	As-built	7.67 ± 0.03	7.74	99.20 ± 0.3	1050 ± 25	2.5 ± 0.2	55 ± 1
63	Heat-treated	7.67 ± 0.03	7.74	99.20 ± 0.3	1520 ± 30	6.3 ± 0.4	53 ± 1

Table 6 Physical and mechanical properties of LPBF 420 stainless steel [2]

The mean intensity was calculated for each Parameter from the data recorded by the on-axis photodiode.

Without Power Reduction factor and Time Homogenisation, areas with short hatch vectors are overheated, because of the shortened cooling phase and increased exposure frequency. The process-stabilising effect of these factors can be observed from the smaller standard deviations (Parameter 2 + Power Reduction Factor / Parameter 2 + Time Homogenisation). The homogenisation of energy input achieved with these factors could be favourable in parts that have thin walls and small details and, therefore, more areas that would contain the short vectors.

The authors drew the overall conclusion that the obtained results indicated that it is possible to improve processability significantly and to reduce cracking by using optimised process parameters.

Investigation of the corrosion behaviour of 420 stainless steel processed by Laser Powder Bed Fusion

Next, a paper from Subrata Deb Nath, Harish Irrinki, Gautam Gupta and Sundar Atre (University of Louisville, USA), Martin Kearns (Sandvik Osprey Ltd., UK) and Ozkan Gulsoy (Marmara University, Turkey) investigated the corrosion behaviour of 420 stainless steel processed by Laser Powder Bed Fusion [2].

There is a high demand for the development of patient-specific surgical tools. However, customisation of tools is limited when using high-volume manufacturing processes such as investment casting and Metal Injection Moulding (MIM). In contrast, Additive Manufacturing processes such as LPBF allow the on-demand manufacture of surgical tools to customised shapes and sizes.

One of the most widely used material systems in the surgical tools industry is 420 stainless steel. Depending on carbon content and heat treatment, the ultimate strength of this martensitic stainless steel can be as high as 1800 MPa. The presence of 12% to 14% chromium in the composition confers good corrosion resistance. However, the LPBF of 420 stainless steel is not well investigated and, in fact, no data were found on the corrosion behaviour of LPBF 420 stainless steel. The reported study was therefore aimed at addressing this knowledge gap by analysing the corrosion characteristics of LPBF specimens and comparing them with wrought 420 stainless steel.

In this study, nitrogen gas atomised 420 stainless steel pre-alloyed powder, supplied by Sandvik Osprey Ltd., was used as the starting material. The chemical composition of this powder is given in Table 5. The powder had a median particle size (D$_{50}$) of 28 µm and 90% of the particles were below 50 µm. The powder particles were mainly spherical in shape, with few satellite particles attached to the surfaces of the larger particles. From Table 5, the chromium and carbon contents of the powder were 12.8% and 0.3% respectively, within the range of the AISI standard.

A Concept Laser M Lab Cusing R, fitted with a Yb-fibre laser, was used to perform the LPBF experiments. Flat type tensile specimens, as per ASTM E8 standard, with a gauge length of 35 mm, width of 6.2 mm, thickness of 3 mm and total length of 75 mm, were fabricated at an energy density of 63 J/mm^3, based on choosing a layer thickness of 20 µm, a laser power of 90 W, a scan speed of 600 mm/s and a trace width of 120 µm. A continuous line strategy with alternating layers at -45°, + 45° angle was chosen as the scan pattern. The as-built tensile bars were heat treated at 315°C for 2 hours followed by air cooling.

The LPBF parts were measured to be above 99% dense, based on the Archimedes density method. The as-built LPBF parts exhibited an ultimate tensile strength of 1050 ± 25 MPa and an elongation of 2.5 ± 0.2% (Table 6). After heat treatment, ultimate tensile strength and elongation improved to 1520 ± 25 MPa and 6.3 ± 0.4% respectively. The yield strength also improved from 700 ± 15 MPa to 950 ± 20 MPa after heat

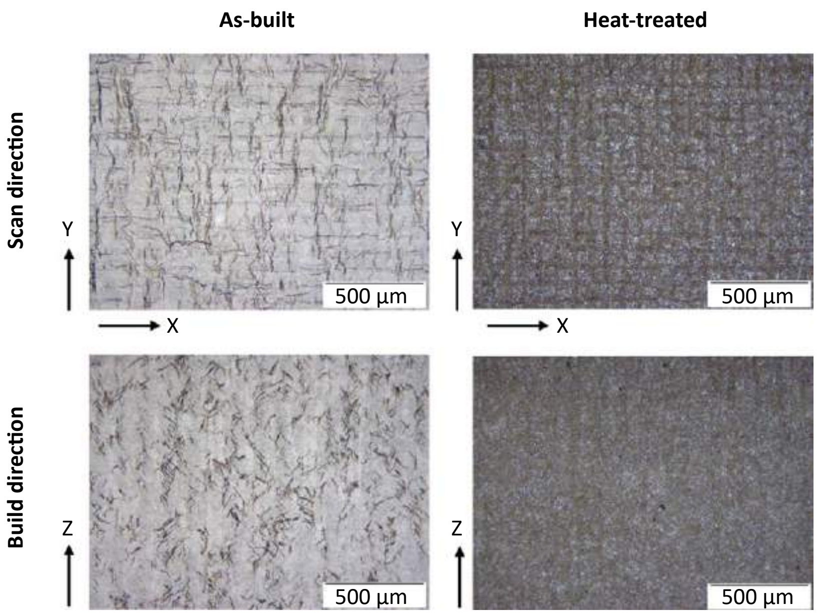


Fig. 6 Etched cross sectional microstructure of as-built and heat-treated LPBF 420 stainless steel in scan and build direction. Kalling agent II was used as etchant in this study [2]

treatment. The hardness of the LPBF parts was measured as 55 ± 1 HRC in the as-built condition. After heat treatment, the hardness remained similar at 53 ± 1 HRC. These values were superior to MIM 420 stainless steel properties reported in the literature: 1350 ± 50 MPa, elongation of 2 ± 1 % and hardness of 48 ± 2 HRC. For comparison, cast 420 stainless steel has a hardness of 53 ± 2 HRC in the as-quenched condition.

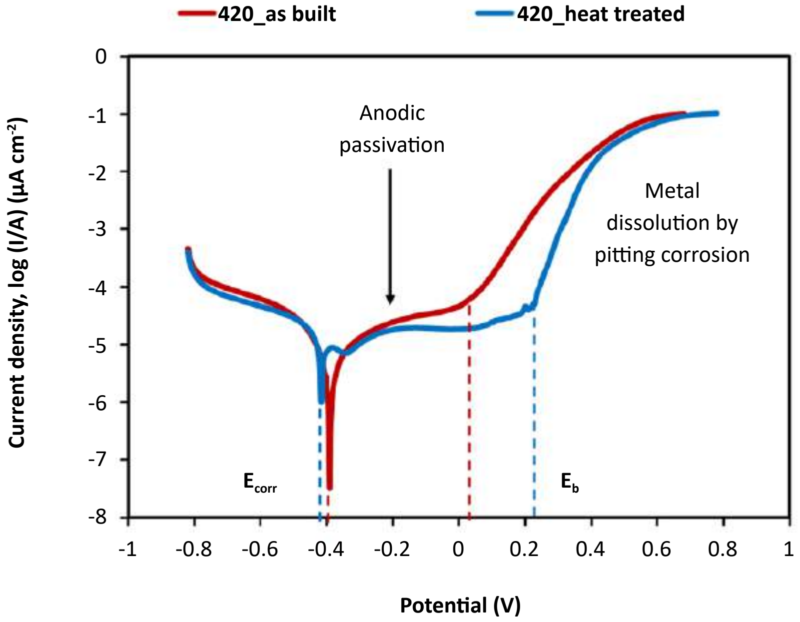


Fig. 7 Potentiodynamic polarisation curves for as-built and heat-treated LPBF 420 stainless steel in aerated aqueous solution containing 3.5% NaCl. Operating condition-reference electrode: Ag/AgCl; cathode: Pt wire; pH= 6.0; scan rate: 0.01 mVs^{-1} [2]

The etched microstructures of the as-built tensile bars, fabricated by LPBF using the D_{50}: 28 μm powder, are shown in Fig. 6. The austenite phase appears white, whereas the martensite phase appears as gray laths or needles. After heat treatment, the parts appeared to be richer in martensite and ferrite phases. In addition, directionality in the martensite laths was observed in the scan direction. More martensite laths appeared on the edge of the scan track or the overlapping of two tracks. Further, the average distance between the laths was found to be 120 μm, equal to the trace width or distance between laser scan tracks used in this experiment.

The electrochemical corrosion behaviour of as-built and heat-treated LPBF parts was measured using potentiodynamic polarisation experiments in 3.5% NaCl solution. Linear Sweep Voltammetry (LSV) was carried out in the potential range between –600 mV and 1000 mV from Eoc at the forward scan rate of 0.01 mVs^{-1} with the current density limit of 10 mA.cm^{-2}, to determine the corrosion potential (E_{corr}), pitting potential (E_{pitt}) and breakdown (E_b) potentials. Tafel plots were created from the voltage and current measurements to calculate quantitative corrosion characteristics.

The cathodic and anodic polarisation curves, obtained from the potentiodynamic polarisation experiments on as-built and heat treated 420 stainless steel fabricated by LPBF, are presented in Fig. 7. The trends in the LPBF data are similar to the corrosion behaviour with wrought stainless steels, where the regions of cathode reaction, passivation and pitting are clearly apparent. The anodic polarisation curves suggest an extremely active dissolution after the sample reaches the breakdown potential (E_b). The pitting corrosion was presumed to be preceded by uniform thinning of the hydroxide/oxide protective film that prevails over the pitting corrosion prior to the pitting potential. The as-built and heat-treated LPBF parts differ in the potential range and potential where the passivation initiated.

Process	Corrosion current I_{corr} (μA/cm^2)	Corrosion potential E_{corr} (V)	Breakdown potential Eb (V)	Resistance potential by Tafel plot (Ω/cm^2)	Corrosion rate (μm/year)	Source
LPBF as-built	2.85 ± 0.4	-0.36 ± 0.03	0.05 ± 0.02	17100 ± 520	2.8 ± 0.2	Current study
LPBF heat treated	3.5 ± 0.1	-0.39 ± 0.02	0.22 ± 0.01	16800 ± 700	3.4 ± 0.5	Current study
Wrought	2.1 ± 0.1	-0.35 ± 0.02	0.18 ± 0.02	18700 ± 350	2.3 ± 0.4	Literature

Table 7 Corrosion parameters of LPBF and wrought 420 stainless steel in 3.5% NaCl solution [2]

The corrosion current (I_{corr}), corrosion potential (E_{corr}) and cathode and anode slopes were measured using a standard extrapolation method to calculate the polarisation resistance and corrosion rate and these are tabulated in Table 7.

From Table 7, the as-built LPBF 420 stainless steel exhibited an I_{corr} of 2.85 ± 0.4 μA.cm^{-2}, which was slightly higher than Icorr of wrought 420 stainless steel (2.1 ± 0.1 μA.cm^{-2}). Heat-treated LPBF parts exhibited a slightly higher current density of 3.5 μA.cm-^{2}. I_{corr} gives a measure of passivation; the smaller the current, the greater the passivation. The as-built and heat-treated LPBF 420 stainless steel parts exhibited polarisation resistances of 17100 ± 520 Ω.cm^{-2} and 16800 ± 700 Ω.cm^{-2} respectively, slightly lower than the wrought material properties of 18700 ± 350 Ω.cm^{-2}. In this study, the LPBF 420 stainless steel parts showed a corrosion rate of 2.8 ± 0.2 μm/year in the as-built condition. A slightly higher value of 3.4 ± 0.5 μm/year was observed with the heat-treated parts. In comparison, wrought 420 stainless steel has been reported to have a corrosion rate of 2.3 ± 0.4 μm/year.

From Tafel plots, a corrosion potential (E_{corr}) was calculated as -0.36 ± 0.03V for the as-built 420 stainless steel parts. The heat-treated LPBF parts exhibited a corrosion potential of -0.39 ± 0.02V.

The corrosion potential is determined as the potential, where the anodic reaction of metal dissolution is equal to the rate of the cathodic reaction. The breakdown potential (E_b) is determined at the inflection point value and is an indication of the stability of the passivation layer formed on the metal surface. The higher the corrosion potential, the more resistant is the passive layer. In this study, the heat-treated 420 stainless steel parts showed the highest E_b at 0.22 ± 0.01V. In comparison, the as-built 420 stainless steel experienced breakdown of the passive layer at 0.05 ± 0.02V.

It was observed that regular large pores formed on the metal surface during the corrosion tests, following the breakdown potential, indicative of pitting corrosion. No intergranular cracking corrosion was observed. No significant difference could be found between as-built and heat-treated samples. Therefore, it can be concluded that 420 stainless steel fabricated by LPBF retained its corrosion properties after heat treatment.

The quantitative difference between wrought and LPBF parts may be explained by differences in the microstructure. Also, the difference in Eb can be caused by the removal of residual stresses through heat treatment. Further X-ray diffraction and X-ray photoelectron spectrometry will be conducted on the corroded surfaces to understand the changes in chemical composition and determine if there are any mechanistic changes in the corrosion process of LPBF parts.

Extrusion based AM of water atomised 17-4 PH stainless steel powder

Finally, a paper from Harshal Dhamade, Nishant Hawaldar and Jing Zhang (Indiana University - Purdue University Indianapolis (IUPUI), USA) addressed the extrusion-based AM of water atomised 17-4PH stainless steel powder [3]. The extrusion-based AM (Robocasting) process extrudes a metal-based binder system, forming the desired component layer by layer.

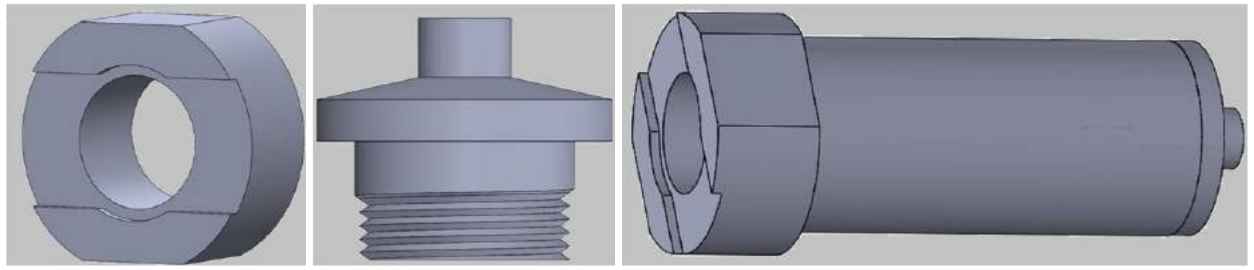


Fig. 8 Heating extruder: (a) flange (b) nozzle (c) extruder assembly [3]

Trial	Composition	Heating	Results of green components	Resulting green components
B1	17-4 PH: 62.5 vol.% Binder: 37.5 vol.% • 55% paraffin wax • 30% polyethylene • 15% stearic acid	PA and poly. mixed at 130°C for 1 hour Stearic acid added and mixed at 100°C for 30 min 17-4 PH mixed at 150°C for 1 hour 2 min rest, then 200°C for 10 min	Consistent flow and reached desired viscosity, feedstock did not mix properly as liquid had visible solid particles.	 
B2(C)	17-4 PH: 65 vol.% Binder: 35 vol.% • 40% paraffin wax • 40% polyethylene • 20% stearic acid	All binder mixed: 130°C for 1 hour 150°C for 1 hour 100°C for 30 min rest 17-4 PH added: 150°C for 30 min 200°C for 30 min 150°C for 30 min	High viscosity at 200°C, unsuitable for AM due to poor flow characteristics	 
B2(A)	17-4 PH: 65 vol.% Binder: 35 vol.% • 65% paraffin wax • 35% polyethylene • 10% stearic acid	Polyethylene and PW only 130°C for 1 hour 130°C for 1 hour (SA added) 150°C for 1 hour all components	Consistent flow and reached desired viscosity, lack of visible particles during flow	
B3(A)	17-4 PH: 93 vol.% Binder: 7 vol.% • 70% paraffin wax • 20% polyethylene • 10% stearic acid	Polyethylene and PW only 130°C for 1 hour 130°C for 1 hour (SA added) 150°C for 1 hour (all components)	Unable to form liquid slurry; sample solidified into small clumps due to lack of binder Additional binder added with the same heating process - viscosity of modified sample was low and formed inconsistently	
B5(A)	17-4PH: 57 vol.% Binder: 43 vol.% • 65% paraffin wax • 25% polyethylene • 10% stearic acid	Polyethylene and PW only Mixed at 125°C-140°C for 1 hour (SA added) 150°C for 1 hour (all components)	The slurry formed had very good mix of all components and the flow and viscosity was gradual as compared to other slurries.	

Table 8 Slurry composition and green component property table [3]

The process deposits powdered material in a slurry form and subsequently sinters the powder to create solid parts with high density.

The project team designed the extruder, to heat and extrude a slurry of water atomised 17-4 PH stainless steel powder, using SolidWorks. Taking as a reference a conventional injection moulding extruder, modifications were made to the outer diameter of the plunger. The heating extruder parts are shown in Fig. 8.

To prepare the required slurry feedstock, 55-65 vol% water atomised 17-4PH stainless steel of 45 µm particle size was mixed with a binder system consisting of paraffin wax, polyethylene, and stearic acid. The binders were mixed using a high-intensity mixer at the speed of 1200 rpm. After mixing the binders, the 17-4 PH stainless steel powder was added and mixing continued until the slurry was even. This helped in creating a bubble-free slurry consisting of stainless steel powder and binders. A range of batches with changing compositions of metal powder and binders was prepared and, after analysis of flow, viscosity and cooling rate, an optimised slurry was found, which was tested by moulding into cylinders. The various iterations in this slurry optimisation process are summarised in Table 8.

The optimised slurry was loaded into the designed heating extruder mounted on the horizontal arbor of a computer-controlled Delta printer. The temperature of the extruder was held at 100°C to maintain the viscosity of the slurry. A cylinder was selected as the print geometry, with 22 mm diameter and 20 mm height. Fig. 9 shows the AM samples. After building, the parts were kept in a furnace at 80°C for 30 min for debinding.

Overall, it was concluded that the reported study had successfully demonstrated slurry preparation and the AM of 17-4PH stainless steel parts with the customised AM machine, incorporating the specially designed extruder. However, it was recognised that further optimisation of binder percentage in the slurry will be required in future work.

Fig. 9 Additively manufactured 17-4PH stainless steel samples [3]. The logo of IUPUI is shown on the plate sample

References

[1] Characterization of hard-to-weld nickel-base superalloys in Additive Manufacturing, Kristiina Kupi *et al.* As presented at the AMPM2018 Additive Manufacturing with Powder Metallurgy Conference, San Antonio, Texas, USA, from June 17–20, 2018, and published in the proceedings by the Metal Powder Industries Federation (MPIF).

[2] Investigation of the Corrosion Behavior of 420 Stainless Steel Processed by Laser-Powder Bed Fusion, Subrata Deb Nath *et al.* As presented at the AMPM2018 Additive Manufacturing with Powder Metallurgy Conference, San Antonio, Texas, USA, from June 17–20, 2018, and published in the proceedings by the Metal Powder Industries Federation (MPIF).

[3] Extrusion based 3D printing of water atomized 17-4 PH stainless steel powder, Harshal Dhamade *et al.* As presented at the AMPM2018 Additive Manufacturing with Powder Metallurgy Conference, San Antonio, Texas, USA, from June 17–20, 2018, and published in the proceedings by the Metal Powder Industries Federation (MPIF).

Author

Dr David Whittaker
Tel: +44 1902 338498
Email: whittakerd4@gmail.com

Proceedings

Advances in Powder Metallurgy & Particulate Materials—2018, the proceedings of the technical sessions, poster programmes and special interest programmes (where applicable), is published in digital format by the MPIF along with selected papers from AMPM2018. These proceedings are provided to full-conference registrants free of charge or they can be purchased from the MPIF's Publications Department.

www.mpif.org

AMPM2019

AMPM2019, the International conference on Additive Manufacturing with Powder Metallurgy, will take place from June 23–26, 2019 in Phoenix, Arizona, USA.

www.AMPM2019.org

industry events

2018

Euro BLECH - 25th International Sheet Metal Working Technology Exhibition
October 23-26, Hannover, Germany
www.euroblech.com

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

Metal Additive Manufacturing Conference
November 21-23, Vienna, Austria
www.mamc2018.org

Inside 3D Printing Mumbai 2018
December 19-20, Mumbai, India
www.inside3dprinting.co.in

2019

3D Medical Printing Conference & Expo
January 30-31, Maastricht, The Netherlands
www.3dmedicalconference.com

APMA 2019
February 18-21, Pune, India
www.apma2019.com

TCT Asia 2019
February 21-23, Shanghai, China
www.tctasia.com.cn

MIM2019
February 25-27, Orlando, USA
www.mim2019.org

Asiamold - 3D Printing Asia 2019
March 10-12, Guangzhou, China
www.asiamold-china.com

PM China 2019
March 25-27, Shanghai, China
www.pmexchina.com

AMUG 2019
March 31 - April 4, Chicago, United States
www.amug.com/amug-conference

Rapid + TCT 2019
May 21-23, Detroit, United States
www.rapid3devent.com

AMPM2019
June 23-26, Phoenix, USA
www.ampm2019.org

POWDERMET2019
June 23-26, Phoenix, USA
www.powdermet2019.org

PMTi 2019
September 24-27, Salt Lake City, USA
www.pmti2019.org

Euro PM2019
October 13-17, Maastricht, The Netherlands
www.europm2019.com

Courses & Seminars

SME's Quality Processes & Regularity Considerations for Metal AM Seminar
October 23, Philadelphia, United States
www.smartmanufacturingseries.com

SME's Metal Additive Manufacturing Developments Seminar
October 24, Philadelphia, United States
www.smartmanufacturingseries.com

SME's Digital Transformation: Implementing Smart Manufacturing
October 25, Philadelphia, United States
www.smartmanufacturingseries.com

Pick up your free copy! *Metal AM* magazine is exhibiting at and/or being distributed at events highlighted with the *Metal AM* cover image

advertisers' index