Vol. 5 No. 2 SUMMER 2019

THE MAGAZINE FOR THE METAL ADDITIVE MANUFACTURING INDUSTRY

METAL AM

in this issue

AM AT UNITED TECHNOLOGIES CORP.

HP'S AM CENTRE OF EXCELLENCE

POWDER REMOVAL

Published by Inovar Communications Ltd

www.metal-am.com

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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. 5 No. 2 Summer 2019

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

METAL ADDITIVE MANUFACTURING

The future is now

Stop thinking of Additive Manufacturing as an industrial process of the future and focus on what it can do for you now. This was the crux of the message to industry from HP's executives at the recent opening of its new 14,000 m^2 3D Printing and Digital Manufacturing Centre of Excellence in Barcelona, Spain.

Such a message implies that Additive Manufacturing as a whole has reached the point where it can meet the users' expectation of a 'mature' technology. This is, of course, only true to a certain degree – the term metal Additive Manufacturing covers a broad range of technologies, some more progressed towards being production ready than others.

Whilst the technology readiness level of AM must therefore be considered on a process-by-process basis, those observing the technology from the sidelines – waiting for the right time to jump in – should not underestimate just how fast each metal AM technology is evolving. Why wait? Before you know it, your competitors will be reaping the rewards of tool-free manufacturing, multiple part consolidation, previously impossible to manufacture internal part complexity and much more besides.

The future will present you with the same number of AM technology choices as today – do not believe that by sitting back you can wait for the winning technology to come to the fore. PBF, Binder Jetting, FFF, DED and others will all have a place in an industry that does not recognise boundaries. The future is now – take the leap!

Nick Williams
Managing Director
Metal Additive Manufacturing

Cover image
An Inconel 625 additively manufactured heat exchanger developed by UTC and its project partners

METAL ADDITIVE MANUFACTURING





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GE Aviation ramps up AM turbine blade production with a further twenty-seven Arcam EBM systems

Arcam EBM machines at Avio Aero's Additive Manufacturing factory in Cameri, Italy (Courtesy Avio Aero)

GE Additive announced during the Paris Air Show in June 2019 that GE Aviation has made a significant investment in its Arcam Electron Beam Melting (EBM) technology, purchasing an additional twenty-seven Arcam systems, including seventeen A2X systems and ten Spectra H systems.

Adding to the existing fleet of thirty-five Arcam EBM systems in operation at Avio Aero, a GE Aviation company, Cameri, Italy, the investment brings the total Arcam systems operated by GE Aviation to sixty-two. The additional machines will be installed at GE Aviation and Avio Aero facilities in the US and Europe, where they will be used primarily for the production of titanium aluminide (TiAl) blades on the low-pressure turbine for the GE9X engine.

The TiAl blades are said to be roughly half the weight of traditional nickel-alloy turbine blades. Arcam EBM A2X machines are capable of producing six blades per batch, while the Spectra H system can produce up to ten blades in around the same time. For the GE9X engine, developed by GE Aviation for Boeing's 777X wide-body jet, the weight saving is said to contribute to a fuel consumption reduction of 10% compared to its predecessor, the GE90.

"Avio Aero's Cameri site has been a great testing ground to see the Arcam EBM machines in action and how they scale. We're looking forward to continuing the expansion in Cameri and rolling them out to a US location in the coming months," stated Eric Gatlin, General Manager, Additive Integrated Product Team, GE Aviation.

Karl Lindblom, General Manager, GE Additive Arcam EBM, commented, "GE Aviation has doubled its fleet of Arcam EBM machines in a relatively short period. We're thrilled and it's a great endorsement for our team, for EBM and in particular for the Spectra H."

www.ge.com/additive

Sintavia opens advanced manufacturing facility in Florida

Sintavia, LLC, Davie, Florida, USA, has opened a new 5,100 m² advanced manufacturing facility in Hollywood, Florida. The new plant, which also serves as the company's headquarters, will house over $25 million of advanced manufacturing equipment, including medium- and large-scale metal AM systems, EDMs, post-processing machines, wet-booths, and multiple furnaces.

The grand opening of Sintavia's new advanced manufacturing facility (Courtesy Sintavia)

"This new facility is the first of its kind in North America to offer large-scale AM production coupled with a robust aerospace quality management system," commented, Brian Neff, Chairman and Chief Executive Officer at Sintavia. "As we grow, it will serve as a template for future vertically-aligned advanced manufacturing facilities around the US and the world."

Masaki Nakajima, CEO and President of Sumitomo Corporation of Americas, a growth equity investment partner of Sintavia, stated, "Sintavia has again proven itself as a leader in the industrialisation of AM production. We are excited to work with the entire Sintavia team in their new facility as they continue to grow."

The new facility will reportedly be capable of producing tens of thousands of parts, representing in excess of $100 million of AM revenue annually, and will bring more than 130 new jobs to the region.

www.sintavia.com


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Desktop Metal and Indo-MIM partner to scale up metal AM

Desktop Metal, Burlington, Massachusetts, USA, has announced a strategic partnership with Indo-US MIM Tec. Pvt. Ltd., a leading global manufacturer of components by Metal Injection Moulding (MIM), headquartered in Bangalore, India. The agreement sees Indo-MIM become a full-service manufacturing partner for Desktop Metal, meeting the needs of customers looking for mass-produced metal parts in quantities ranging from tens of thousands to one million.

Indo-MIM has MIM production facilities in both India and USA, as well as further sales offices in Europe and Asia. The company will deploy metal Additive Manufacturing at scale for its customers using Desktop Metal's Production System, to be installed at its San Antonio, Texas, factory this summer.

In addition to Additive Manufacturing capacity, Indo-MIM will also offer customers consulting services and finishing processes, key to entering the production phase.

"This is a major step forward in the progress of Additive Manufacturing," stated Krishna Chivukula, Jr., CEO of Indo-MIM. "As the world's largest MIM house, we know our customers in automotive, aerospace and other key industries will reap the benefits of this new mass manufacturing technology. We are excited to partner with Desktop Metal to bring metal AM closer to those companies looking to achieve the speed, cost, and quality benefits to their businesses."

"With the Production System now joining our state-of-the-art factories, we will be fully integrated to provide customers with a one-stop resource for the manufacturing of complex precision components and sub-assemblies with Additive Manufacturing," he concluded.

The Production System is designed to print a broad range of alloys, including reactive metals such as titanium and aluminium. Designed to take advantage of MIM's chemistry and powder supply chain, the Production System is said to offer access to a large and established ecosystem of high-quality alloys with a mature supply chain and well-studied controls.

"The synergies of our companies are profound – both Desktop Metal and Indo-MIM are deeply rooted in MIM technology and we share an unbridled commitment to accelerate the availability of industrial Additive Manufacturing technologies," commented Ric Fulop, CEO and Co-founder of Desktop Metal. "This collaboration with Indo-MIM will help deliver the power and promise of our Production System to companies with diverse manufacturing needs and to shift the paradigm from prototyping to include full scale metal manufacturing."

www.desktopmetal.com
www.indo-mim.com

Desktop Metal's Production System draws on the chemistry and material supply chain of the Metal Injection Moulding industry (Courtesy Desktop Metal)

Liberty Powder Metals orders new ASL atomiser for high quality AM powder production

Atomising Systems Ltd. (ASL), Sheffield, UK, has been awarded a contract for the turnkey installation of a 250 kg Vacuum Inert Gas Atomiser at Liberty Powder Metals Ltd, a subsidiary of Liberty House Group, also located in Sheffield.

Working in co-operation with Consarc Engineering, a supplier of vacuum melting technology, ASL has equipped the atomiser with its proprietary anti-satellite and hot gas atomisation systems.

"The anti-satellite technology is a game changer in terms of powder shape and flow properties. Coupled to a vacuum melting furnace from a renowned specialist like Consarc, Liberty will be set to supply their clients with powder of the highest quality," stated Dr Paul Rose, ASL Commercial Director.

The high-specification atomiser is expected to enable Liberty to produce highly spherical, extremely free flowing, special steel-based and non-ferrous alloy powders for its demanding aerospace clients to use in Additive Manufacturing, as well as Hot Isostatic Pressing (HIP) and Metal Injection Moulding (MIM) applications.

www.libertyhousegroup.com
www.consarceng.com
www.atomising.co.uk

Shining 3D launches EP-M150 system for small metal AM applications

Shining 3D Tech. Co., Ltd., headquartered in Hangzhou, China, released its new EP-M150 system at Rapid + TCT 2019, held in Detroit, Michigan, USA, from May 20–23. The company stated that the EP-M150 was developed to provide support to the growing market for small-scale metal Additive Manufacturing applications, and that its size makes it suitable for a range of industries such as medical, dental and jewellery.

According to Shining 3D, the EP-M150 is capable of additively manufacturing five-hundred dental crowns using only 1 kg of powder, while maintaining low gas usage and a high material consumption rate. The design of the system was reportedly made to be as convenient and simple to maintain as possible.

The company explained that, thanks to its proprietary operating software, once set up the EP-M150 can additively manufacture using a 'one key print' function. Additionally, the entire process can reportedly be analysed using the system's internal smart network.

http://en.shining3d.com/

EOS adds four new metal powders for Additive Manufacturing

EOS, Krailling, Germany, has introduced four new metal powders for use with its Additive Manufacturing systems: EOS StainlessSteel CX, EOS Aluminium AlF357, EOS Titanium Ti64 Grade 5 and EOS Titanium Ti64 Grade 23. The metal powders have reportedly been tailored to suit a range of applications, including automotive and medical.

EOS currently offers a range of twenty different metal powders. At EOS Oy in Finland, the company concentrates solely on the development, qualification and quality assurance of metal materials and processes. Hannes Gostner, Director of Research and Development at EOS, stated, "At EOS, the development of systems, materials, process parameters, software, and services have always gone hand in hand. All of the elements are perfectly aligned to each other. The result is reproducible high-quality parts at a competitive cost per part. This combination is of crucial importance, particularly for series manufacturing."

EOS StainlessSteel CX is a new tooling grade steel developed for production with the EOS M 290 that is said to combine excellent corrosion resistance with high strength and hardness. Components made from this material are reportedly easy to machine and enable a polished finish.

EOS Aluminum AlF357 is a material suitable for applications that require light weight combined with excellent mechanical and thermal strength. Components made from this material are characterised by their light weight, corrosion resistance and high dynamic loading. It has been developed for production with the EOS M 400, but the company expects to make it available for the EOS M 290 system in future.

EOS Titanium Ti64 Grade 5 has been developed for its high fatigue strength, without the need for Hot Isostatic Pressing (HIP). It is reportedly suitable for production with the EOS M 290, and also offers corrosion resistance, making it ideal for aerospace and automotive applications.

EOS Titanium Ti64 Grade 23 has also been developed for its high fatigue strength without HIP and for production with the EOS M 290. When compared to Ti64, the Ti64 Grade 23 reportedly offers improved elongation and fracture toughness with slightly lower strength. Thanks to these properties, it is particularly well suited to medical applications.

Comprehensive data on the material properties of all four metals, which includes the number of test specimens on which the mechanical properties are based as well as scanning electron microscope images, is available from EOS.

www.eos.info

GKN Powder Metallurgy opens North American headquarters and AM Customer Center

GKN Powder Metallurgy has opened its new North American Powder Metallurgy Headquarters and Additive Manufacturing Customer Center in Auburn Hills, Michigan, USA. The new facility will house over eighty employees from the three divisions of GKN Powder Metallurgy; GKN Hoeganaes, GKN Sinter Metals and GKN Additive.

The building includes a 297 m^2 Additive Manufacturing Customer Center, equipped with two EOS M290 metal Laser Powder Bed Fusion (L-PBF) systems. EOS's systems are capable of manufacturing functional metal prototypes within a two-week lead time and allow customers to test factors such as usability, ergonomics, manufacturability and materials in the early stages of the development process. It is expected that the full 3,554 m^2 combined facility will expand the company's global Additive Manufacturing network and the scope of its in-house Powder Metallurgy capabilities.

Reid Southby, President of GKN Sinter Metals Large Segment, stated, "We are excited to start a new journey in Auburn Hills with a space that is dedicated to our team, our community and the advanced technology we create for our customers. This building reinforces our commitment to the North American market and continued global growth."

"GKN Powder Metallurgy is at an exhilarating point in its journey of growth and innovation," Southby continued. "We now have the opportunity to provide our customers and strategic partners with local and exceptional support on all fronts of our business."

www.gknpm.com

GKN Powder Metallurgy opens North American PM Headquarters and AM Customer Center (Courtesy GKN Powder Metallurgy)

Aerojet Rocketdyne acquires 3DMT from ARC Group

Aerojet Rocketdyne Holdings, Inc., headquartered in El Segundo, California, USA, has acquired 3D Material Technologies (3DMT) from ARC Group Worldwide, Inc. 3DMT, based in Daytona Beach, Florida, USA, is a provider of Additive Manufacturing services to the aerospace, defence, medical and industrial markets. Terms of the deal were not disclosed.

The acquisition is said to complement Aerojet Rocketdyne's industry-leading capabilities to develop and produce metal AM parts for aerospace propulsion and power systems. Aerojet Rocketdyne has qualified production parts for the RL10 and RS-25 liquid rocket engines and reportedly sees growth opportunities for these complex, high-value systems. Additionally, the company's defence business unit continues to develop and demonstrate the benefits of Additive Manufacturing for its hypersonic propulsion systems.

"The addition of 3DMT's capacity and expertise in metal alloy Additive Manufacturing expands our range of products and services in the space and defence markets," stated Eileen Drake, CEO and President of Aerojet Rocketdyne Holdings, Inc. "As we look to the future, AM will continue to play an important role in lowering costs and production timelines. This deal allows Aerojet Rocketdyne to broaden its application of this revolutionary technology. We respect the long-standing reputation for quality and customer focus that 3DMT has built in the aerospace industry and we are thrilled to welcome them to our company."

Aerojet Rocketdyne has more than 5,000 employees at fourteen sites around the USA, including approximately 650 employees at its facilities in West Palm Beach and Orlando, Florida. 3DMT will continue to operate with its existing workforce at its facility in Daytona Beach, Florida.

www.aerojetrocketdyne.com
www.3dmt.com

3DMT is a leading Additive Manufacturing service provider specialising in complex technical components (Courtesy 3DMT)

Dyndrite introduces accelerated geometry kernel and Additive Toolkit

Dyndrite Corporation, a software developer based in Seattle, Washington, USA, launched its Dyndrite Accelerated Geometry Kernel, along with the Dyndrite Additive Toolkit, on the opening day of the Additive Manufacturing Users Group (AMUG) Conference in Chicago, USA, in April 2019.

Reported to be the world's first fully GPU-native geometry engine, the Dyndrite Kernel is said to be capable of representing all current geometry types and handling AM-specific computations such as lattice, support and slice generation. It also provides both C++ and English-readable Python APIs, making application development more accessible to users, and offers the ability to quickly develop sophisticated applications and interactive workflows.

"The Dyndrite Accelerated Geometry Kernel promises to do for 3D printing what Adobe and PostScript did for 2D printing in the 1980's," stated Shawn Hopwood, Dyndrite's Chief Marketing Officer and Head of Developer and OEM Relations. "Laser printing technology powered by PostScript set off a revolution that forever changed how people communicate. In the new revolution, 3D printers powered by Dyndrite have the potential to change every aspect of the things we make, where we go, and how we live."

The Dyndrite Additive Toolkit is the first customer-facing application built on the new Dyndrite kernel. It is designed to improve the productivity of AM technicians, and streamlines the CAD-to-Print process by directly importing CAD design files, maintaining the original spline data, and using that data to drive the AM process. Working directly with CAD data is said to provide numerous advantages over STL files. The STL file is a thirty-year-old format that Dyndrite believes provides a major bottleneck in AM workflows, being difficult to modify safely, and with files typically requiring time-consuming manual repair work prior to use. Additionally, STL's fixed reliance on triangles is said to limit the precision of the workflow model and the output quality.

Working directly with CAD spline data and the richer information it provides enables Dyndrite users to eliminate model prepping steps and determine desired output quality. The underlying GPU-based kernel means other AM workflow processes which used to take hours of processing time – such as creating lattices or lightweighting, support generation, slicing, hatching and toolpath generation – can now be completed much more quickly.

"Dyndrite is delivering on the promise of modern design and manufacturing," stated Harshil Goel, Dyndrite's Co-founder and CEO. "We are excited to play an important role in fostering the evolution of design and manufacturing software."

Developer Program and Developer Council

During AMUG, Dyndrite also has launched its Developer Program and announced the inaugural members of its Developer Council. The Dyndrite Developer Program is designed to provide the tools, resources, and community that application solution providers and OEMs need to create and exchange new AM applications, workflows and best practices. "Our goal is to provide an infrastructure that fosters innovation and information exchange and that helps pioneers bring new solutions, we could never imagine, to market," added Hopwood.

The Dyndrite Developer Council is a member-based group of industry leaders that will help steer the future development of the Dyndrite platform. Inaugural members include Aconity3D, EOS, HP, NVIDIA, Plural AM and Renishaw.

"We have been really impressed by Dyndrite in their efforts to develop a ground-breaking, GPU based geometry kernel," added Stephen Anderson, Additive Manufacturing Business Development Manager at Renishaw, Inc. "We are keen to see such technologies introduced into Additive Manufacturing to further empower users in novel design, where greater power is required to handle complexity effectively."

www.dyndrite.com

Rolls-Royce adds SLM 500 to advance adoption of metal AM aerospace components

Rolls-Royce is reported to have selected the SLM®500 metal Additive Manufacturing system, produced by SLM Solutions AG, Lübeck, Germany, to advance its adoption of the technology for aerospace components. With four lasers enabling build rates of up to 171 cm^3/h, the SLM 500 is the company's flagship system for high-volume metal AM, also offering automated, closed-loop material supply, recovery and sieving to minimise operator handling of metal powder.

Speed and safety are required in the majority of industries, but manufacturing parts for aerospace involves a particularly rigorous certification process. Meddah Hadjar, CEO of SLM Solutions Group AG, stated, "Rolls-Royce is very advanced in additive layer manufacturing, with a state-of-the-art approach and expert team working on extremely complex metal Additive Manufacturing solutions. SLM Solutions recognised the need at Rolls-Royce for a supplier to support with equipment qualification."

"We work closely to develop products that meet their needs to assure aerospace certified part quality levels," he explained. "This way the Rolls-Royce team can document their expertise and control of the systems adhering to strict regulations and keep their ambitious and innovative additive production plans on track."

Neil Mantle, Head of Additive Layer Manufacturing at Rolls-Royce, commented, "We are delighted to be working with SLM Solutions and using their quad-laser machines. Rolls-Royce continues to develop our additive layer manufacturing capability to ensure we are at the forefront of advanced manufacturing. We knew that transferring our expertise and knowledge gained from single laser machines to multi-laser platforms would require a close working relationship and SLM Solutions have provided this."

It was stated that Rolls Royce required multi-laser systems to meet productivity demands, as well as maintaining rigorous quality controls previously established. Also key to the selection was the control of inert gas flow offered within the multi-laser machine. This was said to have been rigorously investigated by the Rolls- Royce team because of its direct correlation to build quality.

www.slm-solutions.com
www.rolls-royce.com

Farsoon Europe partners with Awexim to support AM in Poland

Farsoon Europe GmbH, Stuttgart, Germany, and Awexim A. Wodziński I Wspólnicy Sp. J., located in Warsaw, Poland, have signed a sales agreement which enters them into a partnership with the aim of supporting the industrialisation of Additive Manufacturing in Poland with Farsoon's open-platform Laser Powder Bed Fusion (L-PBF) systems.

Farsoon Europe is a subsidiary of Farsoon Technologies, headquartered in Changsha, China, a supplier of industrial grade Additive Manufacturing systems for both metal and plastic. Farsoon Europe provides the full range of its parent company's machine portfolio as well as local service and maintenance activities. Awexim is a supplier of tools and machine tools which it sells to over 1,000 customers annually, and has over 500 systems and production lines.

"We are delighted to enter into a partnership with Awexim, who is very well experienced in selling machines and tools into the classical manufacturing industry in Poland. The production industry in Poland will strongly benefit from combining competencies of classical with Additive Manufacturing," stated Dr Dirk Simon, Managing Director of Farsoon Europe.

"Farsoon's strength in industrial laser sintering systems ideally supports our strategy to enter into the 3D printing market," commented Andrzej Wodzinski, Managing Director of Awéxim. "We have supported industrial customers in Poland for almost thirty years with top quality tools, machine tools and especially top quality technical and customer service."

Farsoon's FS421M metal Additive Manufacturing system (Courtesy Farsoon Technologies)

"We are glad to start cooperation with such a solid partner as Farsoon, whose approach and vision is similar to ours," he continued. "This cooperation opens huge possibilities to bring even more solutions for our customers on solving their needs. 3D printing is a future of industry, and we are sure that the connection of Farsoon and our team will have a big influence on this industry in Poland."

http://en.farsoon.com/
www.awexim.pl

Continental opens new Additive Manufacturing competence centre

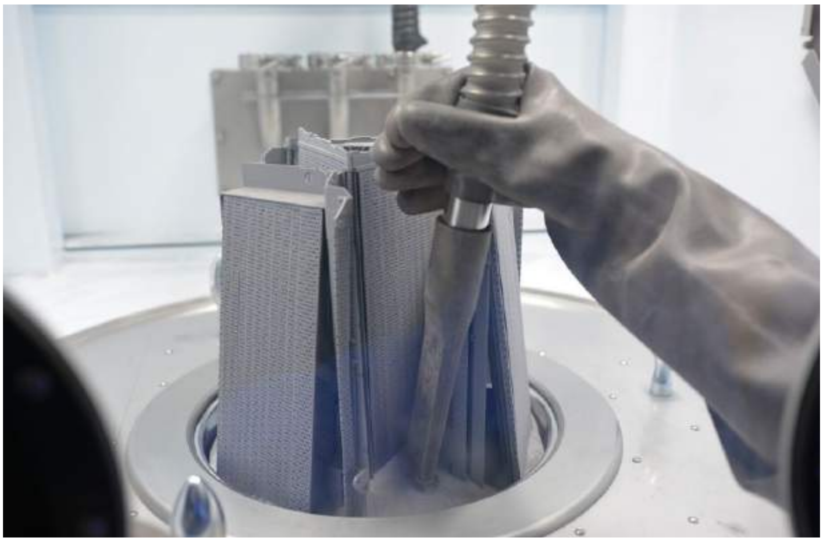
Automotive manufacturing company Continental AG, headquartered in Hannover, Germany, has opened an Additive Manufacturing competence centre in the town of Karben, Germany. Under the leadership of its development and production service provider, Continental Engineering Services, the company stated that it plans to use the new centre to implement AM for production across all its divisions.

In addition to Additive Manufacturing technology, Continental Engineering Services' Karben facility houses high-performance CNC machines, injection moulding and laser welding systems, and state-of-the-art electronics manufacturing for printed circuit board assembly. The combination of a variety of environmental testing facilities and small-series manufacturing technologies is said to create an ideal setting to enable the right manufacturing technology or combination of technologies to be selected for each task.

"We make 3D scans of the components, edit them followed by printing them with the desired material. For example, we are able to produce a high-quality metal part in place of a plastic part," stated Stefan Kammann, Head of Business Segment Additive Design and Manufacturing within the Product Solutions division at Continental Engineering Services. "Furthermore, design changes can be handled flexibly depending on the product. The process lowers production costs with shorter production times."

Torsten Rauch, Karben Plant Manager, stated, "3D printing is becoming more and more important thanks to its many advantages. This is reciprocated by the ever-increasing demand for additively manufactured parts. With our competence centre in Karben we are now able to test technologies, develop processes and procedures and roll out our production worldwide."

www.continental-corporation.com



Powder removal from an AM part (Courtesy Continental)

TWI Ltd invests in Electron Beam AM system from Chernova Hviluya

TWI Ltd, headquartered in Great Abington, Cambridge, UK, has invested in a new xBeam-18/I Electron Beam Additive Manufacturing (EBAM) system from Chervona Hvilya, a metal Additive Manufacturing company located in Kyiv, Ukraine. The xBeam-18/I reportedly uses a unique hollow conical electron beam as the heating source and a coaxial supply of wire feedstock to the deposition area.

An order for the xBeam-18/I with Wire Feed Electron Beam Additive Manufacturing (W-EBAM) capability was placed following a public tender. The system will be located at TWI's Cambridge facility, where it will reportedly be applied to the Open Architecture Additive Manufacturing (OAAM) project, on which TWI is lead partner.

The project plans to develop Directed Energy Deposition (DED) Additive Manufacturing technologies that can be scaled up to accept multi-metre component sizes for the benefit of the UK's aerospace industry. These new platforms are expected to enable aerospace manufacturers and their supply chains to develop advanced AM concepts.

TWI and Chervona Hvilya are said to be working closely to deliver a system which, they state, will meet the specific requirements of the OAAM project. This includes the development of special software routines specified by TWI, and CAD/CAM control interfacing across the range of OAAM DED technologies, which is being created with the assistance of Autodesk. The xBeam system is due to arrive at TWI's facility in Autumn 2019.

Dr Sofia Del Pozo, Senior Project Leader at TWI, commented, "The xBeam system and its unique feature that allows feeding the wire coaxially will give us the opportunity to explore a great number of possibilities for 3D printing parts with wire. The system will offer a high level of flexibility along with precise process control. We are really excited about being the first ones to develop the xBeam coaxial system to produce metre-scale parts for the aerospace sector."

www.twi-global.com
www.xbeam3d.com

HP launches global network for Additive Manufacturing production

HP Inc. has announced the launch of its new HP Digital Manufacturing Network, described as a global network of HP production partners which will help design, produce, and deliver both polymer and metal additively manufactured parts at scale. The network is expected to enable customers to speed the development of new products, shorten time to market, create leaner supply chains and reduce their carbon footprint.

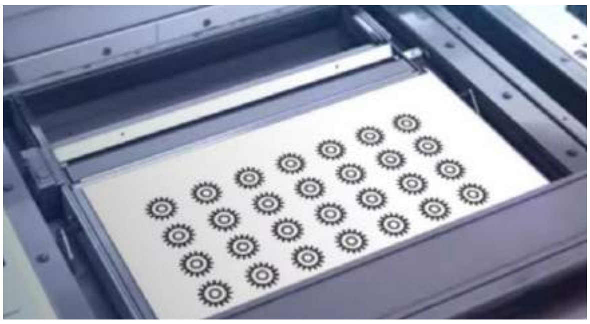
The HP Digital Manufacturing Network initially includes partners in the United States, Asia, and Europe. The company stated that it will further expand the network into other target markets with additional qualified partners in the coming months.

Initial partners include GKN Powder Metallurgy, Parmatech, Materialise, Forecast 3D, GoProto, Jabil and ZiggZagg NV. Each partner will use HP's Additive Manufacturing solutions and draw on their own Additive Manufacturing expertise, high-volume production capacity and end-to-end manufacturing processes to meet customer needs.

Fried Vancraen, Founder and CEO, Materialise, commented on the network's launch, "Our customers are excited by our tighter integration with HP, our joint work on new applications and materials, and our commitment to scale high-quality part production. Together we are helping our customers win in an increasingly competitive marketplace."

"The Fourth Industrial Revolution is one of the most transformative forces in our lifetime. New technology innovations will be required, new partnership models will emerge, and new modes of doing business will unfold," stated Christoph Schell, President of 3D Printing and Digital Manufacturing, HP. "HP is committed to helping customers with diverse manufacturing needs turn change into opportunity by delivering the most innovative solutions portfolio and comprehensive ecosystem of industry-leading partners."

www.hp.com



HP's Metal Jet system can produce high volumes of parts, with a Binder Jetting build size of 430 x 320 x 200 mm (Courtesy HP)

MEBA introduces new solution for metal Additive Manufacturing build plate removal

MEBA Metall-Bandsägemaschinen GmbH, Westerheim, Germany, has introduced a new bandsaw system for the separation of metal additively manufactured parts from the build plate. The new MEBA3D metal bandsaw incorporates a moveable and precisely alignable clamping device to hold the build plate at the correct angle, enabling the gentle removal of AM workpieces.

The company has been involved in the development of metal bandsawing machines since 1958, and believes that its new technology can offer faster processing times and very good cutting results at lower costs than existing build plate removal technologies.

Compared with conventional productions processes such as wire eroding, MEBA reports that its sawing concept is less complicated, with only a few operating steps. The acquisition and maintenance costs are also said to be significantly lower, thanks to the long service life of the sawblade.

www.meba-saw.com

Protolabs expands metal AM production service and adds copper

Protolabs, headquartered in Maple Plain, Minnesota, USA, has added new production capabilities to its metal Additive Manufacturing business. The new updates include secondary processes to improve the strength, dimensional accuracy and cosmetic appearance of metal parts, as well as enhanced inspection reporting capability.

Greg Thompson, Global Product Manager for 3D printing at Protolabs, stated, "We see it every day. The designers and engineers we work with in industries like aerospace and medtech are choosing Additive Manufacturing for complex components in high-requirement applications. These new production capabilities help them optimise their designs to enhance performance, reduce costs, and consolidate supply chains – and do so much faster than ever before."

Protolabs uses Additive Manufacturing to produce parts for a range of customers. Its process is ISO 9001 and AS9100D-certified and, once parts are built, several secondary options like post-process machining, tapping, reaming, and heat treatments can be completed in-house, as well as quality control measures such as powder analysis, material traceability, and process validation.


Protolabs has twenty-five GE Additive Concept Laser systems

"We're committed to servicing our customers' needs," Thompson explained, "throughout the product life-cycle across both conventional and AM processes."

The company has recently taken a number of steps to reinforce this effort, including joining GE's AM Network and MIT's AM consortium, as well as teaming with Wohlers Associates to develop a course on Design for Additive Manufacturing (DfAM). The company has also added capacity to support the growth of its metal AM services, and now houses twenty-five GE Additive Concept Laser Mlab and M2 machines.

Copper powder added

Protolabs also added copper to the list of materials it makes available to customers of its metal Additive Manufacturing service. The company can now produce complex parts from CuNi2SiCr, a low alloy copper said to combine electric and thermal conductivity with good mechanical properties and corrosion resistance.

The company stated that this service will be ideal for the production of parts with features such as intricate internal channels or honeycomb structures designed to save weight. CuNi2SiCr also has the benefit of allowing customers to develop parts for harsh environments, where the use of pure copper is not feasible.

www.protolabs.com

Carpenter Technology and IAI to employ metal AM for commercial aircraft parts

Carpenter Technology Corporation and Israel Aerospace Industries (IAI) have announced their collaboration to produce additively manufactured components for a serial production commercial aircraft. The collaboration will result in IAI's first metal AM-produced parts, which are expected to provide significant manufacturing benefits and lay the groundwork for future design improvements and enhancements.

IAI is reported to be working closely with Israel's Civil Aviation Authority for approval of the parts, which when accomplished will represent the first time this technology has been approved for commercial use in Israel. Carpenter Technology, through its Carpenter Additive business unit, is producing the parts and providing supporting information to assist with their approval.

"Together, Carpenter Additive and IAI are pioneering the use of this technology for new platforms and applications," stated Marshall Akins, Carpenter Technology's Vice President, Aerospace Markets. "This collaboration speaks to the trust major aerospace entities like IAI have in Carpenter Additive's capabilities, and to IAI's forward leaning vision to rapidly realise the benefits of this technology."

"We are pleased to see the fruits of our development efforts leading towards the certification of a flightworthy metallic additively manufactured part," added Zvi Genisher, VP & General Manager, Engineering & Development Division, IAI Aviation Group. "We look forward to strengthening our collaboration with Carpenter Additive."

www.iai.co.il
www.carpenteradditive.com

Amastan announces $11 million funding round, acquires AL Solutions for production of AM titanium powder

Amastan Technologies, a producer of advanced metal, ceramic, and composite materials headquartered in North Andover, Massachusetts, USA, reports that it has raised $11 million in new funding. The Series B-2 funding round, led by venture capital firm Anzu Partners, also includes existing investors Launch Capital, Material Impact and RKS Ventures. This funding round follows Amastan's initial $13.85 million Series B funding round in Q4 2017.

Amastan uses advanced microwave based plasma systems capable of manufacturing a broad array of materials for the advanced materials markets (Courtesy Amastan)

The company further announced that it has acquired AL Solutions, Inc., Burgettstown, Pennsylvania, USA, a producer of refined titanium materials for the aerospace, automotive and medical industries. AL Solutions employs a proprietary technology to recycle titanium scrap from machining operations into essential inputs for metal alloys. It is reportedly ISO 9001 certified and produces over one million pounds of its Ty-Gem™ titanium alloying compacts annually.

Amastan states that investments are planned in the Pittsburgh, Pennsylvania area to expand Ty-Gem production capacity and build a new AM metal powder production facility, combining AL Solutions' proprietary metal handling processing and Amastan's UniMelt™ technology. AL Solutions, to be rebranded as Amastan Additive, is expected to launch a range of premium powders in late 2019 for the metal Additive Manufacturing markets.

"This additional infusion of capital, along with the acquisition of AL Solutions, accelerates Amastan into full production mode and creates a clear and unique pathway for us to manufacture premium metal powders that are derived from sustainable sources," stated Aaron Bent, PhD, CEO of Amastan Technologies.

Frank Roberts, AL Solutions' CEO, has been named President of Amastan Additive. Roberts commented, "We are excited to become part of the Amastan team. Our company has a one-of-a-kind production technology to process titanium and other metal streams from subtractive machining processes. This capability will provide Amastan Additive with a sustainable, low cost, and infinitely flexible feed-stock source for high performance additive/3D metal powders."

www.amastan.com

Arcast metal powders certified for commercial, aerospace & defence industries

Arcast Inc. and Arcast Materials Division, Oxford, Maine, USA, have achieved certification to ISO 9001:2015 and AS9100D for the manufacture and sale of metal powder and castings for commercial, aerospace and defence applications. Arcast stated that it built its new materials division around these quality management systems to ensure its ability to meet the industry's most demanding requirements.

The new certification means that Arcast's metal powders, as well as its casting products, can now be sold to a wide range of markets, including aerospace, with the confidence that it can meet the quality standards required by its customers.

"Our ultra-clean and high-performing processing method offers the highest possible quality powder and is now backed up by a quality standard that matches it," commented Sasha Long, Arcast Vice President.

Fine titanium powder

The company also announced that it has successfully produced a titanium superalloy powder with an as-atomised D50 of 20 μm, with narrow size distribution and with little-to-no oxygen pick-up. The alloy was produced using Arcast's proprietary atomising process.

Arcast's process is said to consume relatively little gas and has zero risk of ceramic/oxide contamination. Powders produced by this method can be used in Additive Manufacturing, Metal Injection Moulding and other Powder Metallurgy processes.

Arcast stated that the new alloy is now being produced in significant quantities. With its growing capacity to produce as-atomised, advanced titanium alloys (along with other challenging metal alloys) from a range of low-cost feedstock, Arcast states that it can offer a complete solution for Additive Manufacturing, Metal Injection Moulding and other Powder Metallurgy markets.

www.arcastinc.com

GKN Aerospace commissions second pilot production cell for large-scale metal AM at ORNL

GKN Aerospace has commissioned its second pilot production cell for large-scale metal Additive Manufacturing at the U.S. Department of Energy's (DOE) Oak Ridge National Laboratory (ORNL), Tennessee, USA. Located at the DOE's Manufacturing Demonstration Facility at ORNL, Cell 2 is said to be the largest pilot production cell of its kind in the world and represents the next stage in GKN Aerospace's AM research and development targeting the manufacture of large-scale structural aircraft components using Laser Metal Deposition with wire (LMD-w).

Mike McCann, CEO of GKN Aerospace's Aerostructures North America, stated, "We are proud to introduce the next step in our Additive Manufacturing research as we continue to push the boundaries of this transformative technology. We believe this to be the largest LMD-w pilot production cell in the world. With this, we will target large-scale aerostructure components with a focus on dramatic improvements in buy-to-fly and cost reductions over plate and forgings."

GKN Aerospace's pilot production cell at Oak Ridge National Laboratory (Courtesy GKN Aerospace)

GKN Aerospace has been using LMD-w technology for more than a decade, beginning at its aero-engine systems business, Sweden and, in 2017, expanding into large-scale aerostructures components with the signing of a five-year $17.8 million research agreement with ORNL.

"We are extremely proud to strengthen our relationship with this world-renowned laboratory to accelerate our progress towards fully industrialising these processes for large-scale aerostructures components. Through our cooperative research, we have seen first-hand how Additive Manufacturing will continue to revolutionise the design and manufacture of aircraft structures. This cell will allow us to create complex components without compromising performance," stated McCann.

"Our research collaboration with GKN Aerospace demonstrates the rapid progress that can be made when industry and the national labs work hand in hand," added Moe Khaleel, Associate Laboratory Director for Energy and Environmental Sciences at ORNL. "We are pleased to see our relationship with GKN expand, and look forward to continued technological innovation in our mission to translate science into solutions for advanced manufacturing."

The 2017 agreement included the opening of GKN Aerospace's first prototype cell at ORNL, which over the past two years has transitioned technology from GKN Aerospace engines to aerostructures applications and implemented closed-looped controls to manage the process with complex geometries. Features of Cell 2 include:

- 20 kW laser
- 8-axis motion
- A large-area inert enviroment
- A 52 in x 32 in max substrate size
- Two-sided deposition capability

Applications of the cell are expected to include product development, low-rate initial production and the transition of technology development into production solutions. GKN Aerospace already has additively manufactured components flying on seven different major platforms today across the commercial, military, rotorcraft, business jet and space markets.

www.gknaerospace.com

MSU receives $2.3 million grant for additively manufactured heat exchanger project

The U.S. Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) has awarded a grant of $2.3 million to Michigan State University (MSU), East Lansing, Michigan, USA, to develop its expertise in metal Additive Manufacturing for high-efficiency power generation. The project involves the development of a plate-type heat exchanger manufactured using new, high-temperature alloys by Powder Bed Fusion (PBF).

Andre Benard, MSU's Associate professor of Mechanical Engineering, will serve as lead investigator on the project. The goal is to develop a highly scalable, compact and low-cost metallic heat exchanger that is resistant to corrosion and can remain strong at the highest operating temperatures.

"The heat exchangers we're working on are needed in systems like concentrated solar towers, nuclear power systems and for recapturing energy from industrial gas furnaces," Benard stated. "There is a demand for compact heat exchangers that can operate at temperatures close to 2,000°F (1,093°C) – and the existing ones are large, costly and do not meet the temperature requirement."

Grid-scale power plants can be much more efficient when using supercritical carbon dioxide – which is a state of matter where liquid and gas phases are indistinguishable – as a working fluid instead of water. "The new and efficient CO_2 plants envisioned by many scientists require highly efficient heat exchangers," Benard explained. "We are pushing the boundaries with these new metallic systems that can operate at high pressure and extreme high temperature. These breakthrough power plants will require less thermal energy to produce electrical energy, be more compact, and will lower costs for customers and electric utility companies."

The aim of the project is that the new heat exchangers will handle the required power and durability of a power plant's lifetime. MSU researchers serving as co-investigators are James Klausner, Patrick Kwon, Joerg Petrasch, Alex Diaz, Haseung Chung and Himanshu Sahasrabudhe and Rohini Balachandran. Curtiss Wright, Solar Turbine and UHV are also part of the team.

www.msu.edu

www.arpa-e.energy.gov

Submitting news..

Submitting news to *Metal AM* is free of charge and reaches a global audience. For more information contact Paul Whittaker:
paul@inovar-communications.com

Sintavia joint venture with Howco Group to focus on Oil & Gas industry

Sintavia, LLC, has announced that it has signed a term sheet to form a joint venture with Howco Group in support of the development of Additive Manufacturing within the Oil & Gas industry. The JV will be branded under the Howco Group name and be co-located at Howco's North American headquarters in Houston, Texas.

"Many of the proprietary Additive Manufacturing processes that Sintavia has developed for the Aerospace & Defense industry apply equally to the Oil & Gas industry," stated Brian Neff, Sintavia's Chairman and CEO. "We are excited to work with Howco to deliver the economic and technical benefits of AM to our joint customers in the Oil & Gas industry."

Howco, a wholly owned subsidiary of Sumitomo Corporation, is a global distributor of raw material and manufacturer of turnkey components for Downhole, Subsea and Surface equipment. The new venture will focus on material common to both the Aerospace & Defense and Oil & Gas industries, including nickel alloys and stainless steel.

www.sintavia.com | www.howcogroup.com

SLM-XL 3D project aims to drive the adoption of L-PBF for large-scale metal AM parts

SLM-XL 3D, a project consortium led by equipment manufacturer Adira Metal Forming Solutions, Vila Nova de Gaia, Portugal, with the collaboration of research organisations Instituto Superior Técnico, Lisbon, Portugal; Universidade Nova de Lisboa, Lisbon, Portugal; and end-user Manuel Da Conceição Graça, Lda, Lisbon, Portugal, is seeking to drive the adoption of Laser Powder Bed Fusion (L-PBF), referred to by the project as Selective Laser Melting (SLM), for large-scale metal additively manufactured parts.

According to the consortium, L-PBF technology has so far been confined to the production of relatively small parts. The difficulty of increasing the size of parts, while maintaining their mechanical and other properties, has prevented its utilisation for large scale part production. The SLM-XL project consortium hopes to address this challenge.

The project involves the production of 316L stainless steel structures with a prototype large-scale L-PBF machine developed by Adira, and the project's outcomes are expected to include a methodology for the selection of parameters to fabricate large metal parts in stainless steel 316L, as well as contributing to the development of the final prototype machine.

The machine used to produce the samples for the SLM-XL project has been displayed at several industry exhibitions and has gained market recognition as well as being awarded the Product Innovation category by COTEC-ANI in 2017 for its TLM (Tiled Laser Melting) Additive Manufacturing process technology.

The project consortium reports that it is currently focused on the influence of an enlarged build envelope on the porosity and mechanical properties of 316L stainless steel samples. It states that there is a significant lack of knowledge and understanding about the correlations between process parameters and mechanical properties for high-power L-PBF systems with increased build rates.

As a result of increased laser powers, of up to 1 kW, solidification conditions are altered, significantly affecting the microstructure of components in terms of size of dendrites and grains.

Consequently, the SLM-XL project is focusing on the investigation and correlation of process parameters (e.g. laser power, scan speed, layer orientation, hatch distance, vector length), and on the density (Archimedes, imaging technique), microstructure (scanning electron microscopy) and resultant mechanical properties (hardness, tensile and compression tests) of samples with different geometrical characteristics produced in different areas of the powder bed.

www.adira.pt

Desktop Metal increases production of its Studio Systems

Desktop Metal, Burlington, Massachusetts, USA, has increased the production of its Studio Systems. The company is now reportedly shipping at a rate of 550 complete systems per year, with a two-week delivery time for new orders to customers throughout the USA and Canada.

The Studio System is reportedly designed to make metal AM more accessible, enabling design and engineering teams to additively manufacture metal parts faster, without the need for special facilities, dedicated operators or expensive tooling. The three-part solution, including printer, debinder and furnace, automates metal AM by tightly integrating through Desktop Metal's cloud-based software to deliver a seamless workflow for additively manufacturing complex metal parts in-house, from digital file to sintered part.

According to Desktop Metal, over a period of six months, Studio Systems have been used to produce more than 8,000 parts globally. Key use applications reportedly include functional prototyping of extruder nozzles and shock absorber pistons; jigs and fixtures including robotic end effectors and break calliper fixture; manufacturing tooling of zipper moulds inserts and extrusion dies; and low volume production of gears and motor mounts. Each of these benchmark parts has reportedly shown a reduction in cost, some by as much as 90% relative to machining and Laser Powder Bed Fusion (L-PBF) as well as speed in fabrication, which enables the company to reportedly produce parts in days rather than weeks or months.

Desktop Metal's Studio System can be scaled to meet low-volume production of metal AM parts (Courtesy Desktop Metal)

Customers of the Studio System include Ford, Stanley Black and Decker, Goodyear, 3M, Google's ATAP, BMW, ProtoLabs, Owens Corning, L3, TerraPower, Medtronic, Continental AG, Applied Materials, TECT Aerospace, US Department of Defense, Department of Homeland Security, MITRE and leading educational institutions such as MIT, University of Texas, Texas A&M and Diman Regional Vocational Technical High School, said to be the first high school in the USA to install a metal AM system.

Ric Fulop, CEO and co-founder of Desktop Metal, stated, "Leading companies, such as Ford, Google's ATAP, Goodyear, BMW, and ProtoLabs, are now benefiting from the ease of use and accessibility provided by the Studio System. To meet continued demand, we have scaled up production capacity to allow us to deliver complete systems for fast installation."

www.desktopmetal.com

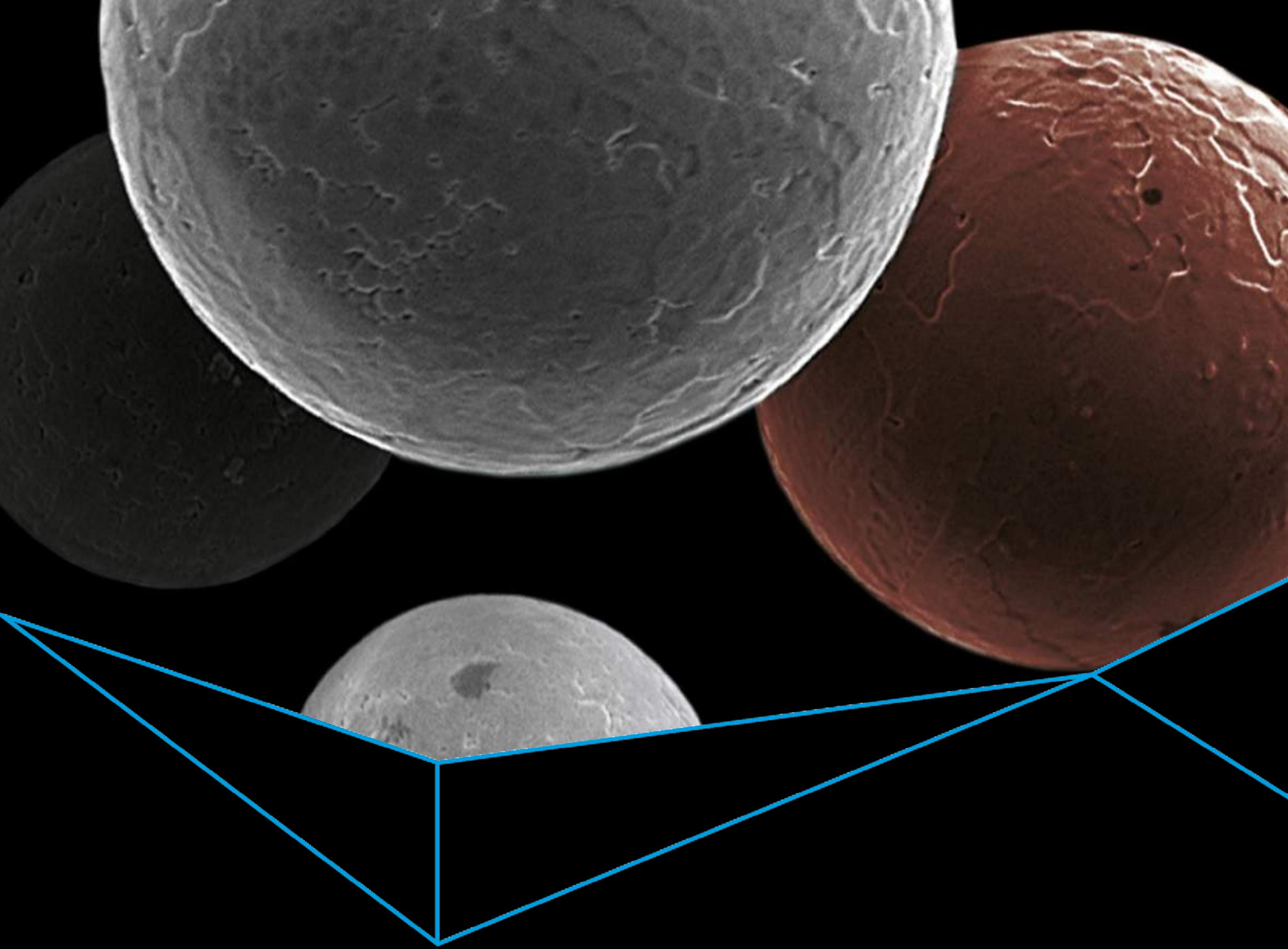
SLM Solutions opens metal AM application centre in China

SLM Solutions Group AG, Lübeck, Germany, has opened a new application centre in Shanghai, China, and expanded its Chinese head office. The new facility is reported to be equipped with four of its metal AM machines: an SLM®125 system, two SLM®280 systems, and one SLM®500 system. The application centre is also said to house equipment to support the full AM process chain, including post-processing capabilities, a metallurgical lab and best practice examples for powder storage and use.

The company reported that over a hundred customers, industry contacts, and local government representatives attended the opening ceremony, receiving a tour of the new customer service. Meddah Hadjar, CEO of SLM Solutions Group AG, stated, "China is a growth market for us as the manufacturing sector is continuing to transform with industrial Selective Laser Melting applications. This new office not only continues our commitment to the Chinese market, but also provides more resources for our local experts to support customers, ensuring they are successful and facilitating their innovation."

Jerry Ma, General Manager of SLM Solutions (Shanghai) Co., Ltd., commented, "As we continue to grow our Chinese team, the opening of our Shanghai Application Center is an important milestone in SLM Solutions' development and indicates the confidence in the Chinese market. As part of the global strategy for growth, we have the capacity to more than double our number of employees and the equipment to support all Chinese users with the technological resources shared by our applications centres around the world. We can also provide high quality, fast technical services to better promote the development of selective laser melting and create more value for customers."

www.slm-solutions.com



ExOne reveals new X1 25PRO metal AM system and announces Kennametal as beta customer

The ExOne Company, a provider of Additive Manufacturing systems and services headquartered in North Huntingdon, Pennsylvania, USA, revealed its new X1 25PRO™ metal Additive Manufacturing beta system at Rapid + TCT 2019, Detroit, Michigan, USA, in May 2019. The company also announced Kennametal Inc., a supplier of tooling and wear resistant solutions, located in Latrobe, Pennsylvania, USA, as a beta customer.

During the beta period, ExOne stated that Kennametal will have the opportunity to evaluate the X1 25PRO system and trial new materials and processes. According to ExOne, the high-resolution production machine is capable of Additive Manufacturing metal, ceramic, and other advanced material parts directly, as well as standard industry powders utilised in Metal Injection Moulding (MIM) and other Powder Metallurgy (PM) processes.

"We see Binder Jet technology as a key enabler for our differentiated, high-performance wear materials, such as tungsten carbide and Kennametal Stellite™ alloys," stated, Sherri McCleary, Director of Business Development Additive at Kennametal. "Kennametal is uniquely qualified to supply these additive materials and components, and we're pleased to collaborate with ExOne on cutting-edge technology with the potential to help us advance from prototyping to serial production."

John Hartner, Chief Executive Officer at ExOne, commented, "Working with innovative, global companies like Kennametal is another important step towards integrating industrial 3D printing into existing and new production lines. We are excited to bring Kennametal on as a beta user and look forward to beginning the testing programme."

www.exone.com
www.kennametal.com

The ExOne Company revealed its new X125PRO beta system at Rapid + TCT 2019 (Courtesy ExOne)

The Barnes Group Advisors partners with i-AMdigital to deliver training

The Barnes Group Advisors (TBGA), headquartered in Pittsburgh, Pennsylvania, USA, has partnered with i-AMdigital, an interactive platform designed to help individuals enhance their skills and career growth in the AM industry. Under the agreement, TBGA will deliver training courses through i-AMdigital in order to provide professionals and organisations with the opportunity to expand their knowledge and skill set in AM.

i-AMdigital is said to offer the best learning content in one single platform and uses smart matching and active coaching to provide suitable courses, jobs, and content for each individual, based on their preferences and previous experience in Additive Manufacturing. The company states that its goal is to help professionals up-skill and make a difference within the Additive Manufacturing industry.

Alison Wyrick Mendoza, Business Leader for Additive Manufacturing Training at TBGA, stated, "We are excited to continue to collaborate on the development and delivery of new learning content for both individuals and enterprise."

www.thebarnes.group
www.i-AMdigital.com

NIT's short-wave infrared imaging provides unique view of melt pool

New Imaging Technologies (NIT), a specialist supplier of imaging sensors and cameras headquartered in Paris, France, has demonstrated the use of its Short-Wave Infrared (SWIR) imaging systems to monitor the metal Additive Manufacturing process. Working in conjunction with the Institut Maupertuis, a French research centre specialised in automated production processes, the company has released detailed footage of the melt pool formed during certain metal Additive Manufacturing processes.

Screen images highlighting the improved definition seen using short-wave infrared imaging (Courtesy NIT)

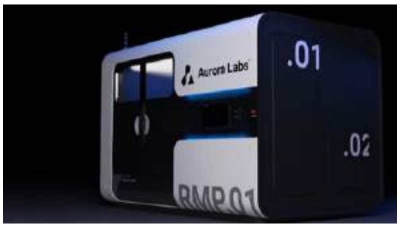
When dealing with metals, the company states, laser wavelength has to be carefully selected in a region where the metal absorption level is at its maximum. Common metal materials, such as aluminium, copper, chromium, iron, nickel, tungsten or even platinum have their maximum absorption in a wavelength region between 1–2 µm, contrary to polymer where the maximum absorption wavelength is above 10 µm.

A camera, with the appropriate wavelength, will give the operator the ability to clearly optimise the fabrication processes. Having imaging information or analysis on the melt pool, during the operation of the AM machine, could provide valuable information for process optimisation and in-line quality control, the company states.

In the video footage, NIT illustrates how its WiDy SenS SWIR camera performs in the very high flux scenes of the melt pool in wire-arc Additive Manufacturing (WAAM) and laser Additive Manufacturing processes. Thanks to its high dynamic range, the true shape and geometry of the melt pool can be seen without any blooming effect. The camera can operate up to several hundred frames per second, making it possible to capture fast Additive Manufacturing processes without losing details, such as the ejected droplets around the melt pools.

http://new-imaging-technologies.com/en

Aurora Labs launches its RMP1 Beta Printer for metal AM



Aurora Labs' RMP1 Beta Printer (Courtesy Aurora Labs)

Aurora Labs, Bibra Lake, Australia, has announced that it has finalised the build and first live test of its pre-production AM system – the RMP1 Beta Printer. The pre-production system is reportedly more sophisticated than Aurora Labs' previous AM systems. The build plate is 450 mm x 400 mm and can additively manufacture parts ten times the volume of the company's previous test system (the Alpha2), as well as having three times the processing capacity.

According to Aurora Labs, parameters for the initial AM materials have already been developed on the Alpha systems and will only require minimal testing for the RMP1 Beta Printer to allow rapid commercialisation. Along with the upgraded design, these tests are expected to prove the speed increase of the RMP1 Beta system over the Alpha 2. After commissioning the new system, the company will be holding an open day to invite industry partners, investors and individuals from the AM industry to view the technology in action.

David Budge, Aurora Labs' Managing Director, stated, "The fact that the RMP1 Beta Printer is operational is a key milestone for the team here. Developing and refining our technology has been long in the making and the RMP1 Beta Printer is now built and ready to go live. We are transitioning from a heavy R&D phase with the RMP1 Beta Printer and we will now be able to move to a commercialisation and sales stage much more strongly with the technology we have developed."

"We have prioritised optimising speed increases and print quality which are key pillars of the Aurora strategy, and the team has made substantial progress achieving speed increases throughout the last few months, resulting in the print of a series of 10 mm high, titanium hexagon parts in a time-frame of only twenty minutes. This was particularly notable as numerous industry parties commented on the speed of the machine and the fact that machines they are currently using would take two-three days to achieve a similar result," continued Budge.

www.auroralabs3d.com

On-demand spare parts for Deutsche Bahn made using Gefertec AM machines

Germany's Deutsche Bahn and metal AM machine supplier Gefertec, Berlin, Germany, have reported the results of a pilot project conducted on the use of metal AM for the on-demand production of spare parts for locomotives.

For the more than 7,000 Deutsche Bahn employees who are responsible for maintaining a fleet of several thousand vehicles, the storage and procurement of spare parts is said to involve major challenges. The Additive Manufacturing of components as they are required could significantly improve the availability of hard-to-procure spare parts.

"Availability is a big issue for our company," stated Dr Tina Schlingmann, who began investigating potential applications for AM at Deutsche Bahn last year. According to the materials science specialist, this technology is not only valuable in prototyping and tooling, it is especially valuable in the spare parts business. Deutsche Bahn purchases trains and locomotives and then handles vehicle maintenance in-house. One of the problems in servicing thousands of vehicles is that, for older locomotives, maintenance crews are often faced with the challenge of obtaining parts that are no longer supplied by manufacturers.

Over the past few years, Deutsche Bahn has researched the possibilities of AM in more than one hundred use cases. A recent case involved a wheel-set bearing cover for a Class 294 locomotive, a model that was put into service in the 1960s and 1970s. The original casting has a diameter of 374 mm, a height of 78 mm, and weighs 11.5 kg. If the cover is missing, lubricant can leak out, resulting in damage to the bearing, and can even cause the locomotive to derail. Delivery of the component would traditionally take up to nine months, and during this time the locomotive would be out of service, which leads to high costs.

As part of its pilot project, Deutsche Bahn worked to develop an alternative solution with Rolf Lenk GmbH, a German-based AM specialist. Rolf Lenk acquired a Gefertec arc605 3DMP® system, designed for the production of large metal components at high speed. "Production on the Gefertec machine takes only about eight hours – including set-up," commented Matthias Otte, Project Supervisor at Rolf Lenk. From the initial design to reverse engineering and production, including machining of the near-net shape part, the project was completed within two months. "This amount of time is only necessary for the first-time production of a work-piece. Depending on machine availability, we will be able to produce this component in two to three weeks," Otte stated.

According to the company, the finished component was thoroughly tested by Deutsche Bahn, as well as in the German Federal Railway Authority's Materials Laboratory. After the certification process is complete, the part will be ready for use.

www.bahn.com
www.gefertec.de

An additively manufactured wheel-set bearing cover for a Class 294 locomotive, produced on a Gefertec arc605 system at Rolf Lenk (Courtesy Deutsche Bahn)

Bodycote invests in new North American heat treatment facility

Bodycote plc, a global provider of heat treatment and specialist thermal processing services headquartered in Macclesfield, Cheshire, UK, is expanding its capabilities in North America with the launch of a new heat treating facility in Elgin, Illinois, USA. According to the company, the new facility will offer advanced heat treating technologies such as low pressure carburising and carbonitriding, vacuum nitriding and ferritic nitrocarburising, Bodycote's Corr-I-Dur® process, and traditional carburising of large parts.

Operating from more than 180 accredited facilities in twenty-three countries, Bodycote provides conventional heat treatment and specialist technologies including Hot Isostatic Pressing (HIP) to a wide range of industries, including aerospace, defence, automotive, power generation, oil & gas, construction, medical and transportation. The new facility is expected to be operational by late 2019, and will reportedly support the automotive, agricultural, mining, construction and other manufacturing supply chains in the Upper Midwest region of the USA.

Dan McCurdy, Bodycote's President of Automotive & General Industrial, North America & Asia division, stated, "This investment demonstrates Bodycote's commitment to serving the Midwest with the services our customers ask for and require."

www.bodycote.com

Link3D enhances AM workflow software with True Shape Nesting


Link3D has introduced new tools to enhance its AM workflow software

Link3D, an Additive Manufacturing software company, located in New York City, USA, introduced a number of new tools to enhance its range of AM workflow software features at Rapid + TCT, Detroit, Michigan, USA, in May 2019. At the show, the company unveiled its True Shape Nesting tool, said to be a major enhancement to its Build Simulation software which powers auto-quoting, production planning and machine scheduling of AM parts.

According to Link3D, its Build Simulation software will estimate production time and material usage based on over five-hundred industrial Additive Manufacturing systems across 1000 materials in relationship to their parameters. True Shape Nesting reportedly enables Multi Jet Fusion and SLS technologies to identify the best nesting strategy based on the actual shape. 2D True Shape Nesting is used presently by FDM and Laser Powder Base Technologies. Link3D states that depending on the use cases, customers can adjust True Shape Nesting to utilise any orientation for parts, allowing them to be oriented around Z-axis.

"As Link3D prepares for the future of Additive Manufacturing, it is our belief that series production will ramp up at an extreme pace. To understand true production cost and achieve optimised production planning, MES toolsets need to become more agile in order to dynamically plan and increase throughout," stated Shane Fox, CEO of Link3D. "We have spent over the last eighteen months in R&D and have understood the need for an API-based True Shape Nesting solution that can be utilised beyond just build preparation for costing and planning."

Vishal Singh, CTO of Link3D, commented, "Link3D's production planning tool is developed for companies to adopt serial production with Additive Manufacturing. With shape-based nesting, Link3D will help AM facility operations maximise machine utilisation, understand the number of machine runs needed to fulfil the order and reduce the manual effort with build preparation. It will help our customers reduce cost and drive production efficiency."

https://solution.link3d.co

Carpenter Technology forms new Additive Manufacturing business

Carpenter Additive offers a range of metal powders optimised for use in metal AM machines (Courtesy Carpenter Additive)

Carpenter Technology Corporation, headquartered in Philadelphia, Pennsylvania, USA, has formed a new business unit, Carpenter Additive. The company anticipates that the new business unit will help build on its reputation as an established powder metals supplier, to become an influential leader in the Additive Manufacturing industry.

Carpenter Additive offers a comprehensive range of off-the-shelf metal powders under its PowderRange brand. Optimised for use in metal AM machines, the metal powder is sold in multiples of 10 kgs and orders are dispatched within 24 hours. The range of stock powders includes aluminium, Scalmalloy, cobalt, copper, nickel, refractory metals (tantalum, tungsten, molybdenum), steel, titanium and tungsten carbide.

In addition to its PowderRange, Carpenter Additive can size powders and produce materials to meet individual customer specifications. From a single metal powder test to new alloy development, the company can design and develop novel metal alloys, atomised in-house.

Prototyping and test builds can be performed on its range of AM machines, as well as offering full machining, heat-treatment, HIP, post-build clean-up and inspection capabilities along with mechanical, physical characterisation and complete qualification data packages.

"From powder production to manufacturing and finishing parts, the full spectrum of our capabilities is what differentiates Carpenter Additive from the rest of the AM industry," stated Tony R. Thene, Chief Executive Officer, Carpenter Technology. "We are revolutionising how customers approach this disruptive technology by offering end-to-end solutions through an array of technical expertise, powder production, parts production, and material life-cycle management. Carpenter Additive is working with our customers and driving industry-wide change."

www.carpenteradditive.com

HRE introduces its second generation additively manufactured titanium wheel

HRE Performance Wheels, headquartered in Vista, California, USA, unveiled the second generation of its additively manufactured HRE3D+ titanium wheels at this year's Rapid + TCT show, Detroit, Michigan, USA. To further improve the HRE3D+ concept, the company once again collaborated with GE Additive to utilise multiple Additive Manufacturing systems in its development.

The company reports that in addition to a futuristic design, which it states is impossible to create with traditional manufacturing systems, the second generation HRE3D+ revolutionises the wheel manufacturing process by reducing overall material waste from around 80% to 5%.

The latest HRE3D+ wheel is also reported to be significantly lighter, with the 20 and 21-inch wheels of the first generation weighing 20 and 23 pounds (9 kg and 10.5 kg) respectively, while the more advanced design of the second generation allows for a total wheel weight of only 16 and 19 pounds (7.25 kg and 8.6 kg) for the same size wheels. The first HRE3D+ concept comprised of six parts, including a centre cap and lug seat section holding the spokes against the vehicle. The company states that it further reduced the weight for the second generation wheel by redesigning the centre area to reduce the part count to just five additively manufactured sections.

According to HRE, its experience of working with AM has prompted significant refinements in the technique which has opened up possibilities for future advancement, including the Additive Manufacturing of one-piece wheel centres. During the Rapid event, the company unveiled the second generation of the HRE3D+ wheel on a 2019 Ford GT in GE Additive's booth.

Alan Peltier, President/CEO of HRE, stated, "We're proud to be breaking new ground in wheel manufacturing with the updated HRE3D+ wheels. Working with GE Additive have given us access to some truly cutting-edge technology, and we're exploring the future of wheel technology together with tools that will continue to evolve over the next few years. We can't wait to see what we're able to accomplish next."

www.hrewheels.com

www.ge.com/additive

The second generation HRE3D+ wheel on a 2019 Ford GT (left), the build-plate (centre) and the finished wheel (right) (Courtesy HRE Performance Wheels)

AM Ventures opens Korean office

AM Ventures Holding GmbH (AMV), an independent, strategic investor in Additive Manufacturing based in Munich, Germany, has opened a new office in Busan, Korea, in order to expand its worldwide activities and to provide a base for investment in Asia Pacific. According to the company, over the last four years it has established sustainable strategic investments and a strong partner network to utilise advanced manufacturing technologies, particularly AM for serial production. AMV's investment portfolio includes: 3Yourmind, Sintratec, DyeMansion, Elementum 3D, Vectoflow and Conflux Technology.

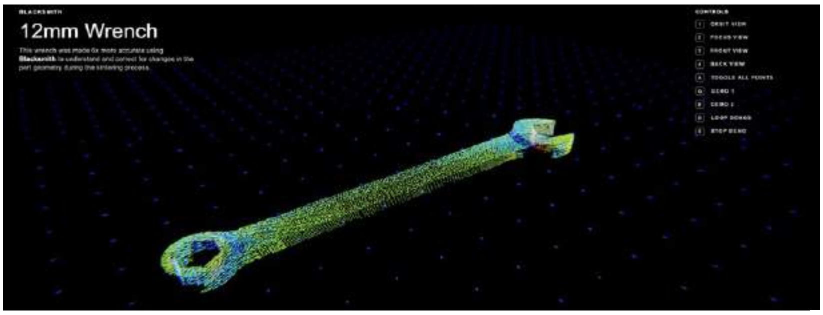
"AMV is pleased to announce the opening of its new office in Korea serving the Asia-Pacific region, a market which is already demonstrating active AM adoption for serial production and a large growth potential. AMV commits to this dynamic region and the investment opportunities available there," stated Arno Held, AMV's Chief Venturing Officer.

Simon (Sangmin) Lee has been appointed as the Regional Director of AM Ventures Asia, bringing significant experience in the region's AM industry thanks to his previous role as sales manager at EOS GmbH in Korea.

"We see great potential to grow our ecosystem throughout Asia supporting Asian startups in the AM industry," Lee added.

www.amventures.com

Markforged launches Blacksmith AI software for smart factories



Markforged's new Blacksmith AI software automatically adjusts programming to ensure every part is produced as designed (Courtesy Markforged)

Markforged, Watertown, Massachusetts, USA, has introduced its Blacksmith artificial intelligence (AI)-powered software, said to make manufacturing systems 'aware', enabling them to automatically adjust programming to ensure every part is produced as designed.

"For the last hundred years, machines have been unaware of what they're creating and would happily waste millions of dollars producing out-of-spec parts. We're going to fix that by connecting the machines that make parts, and the ones that inspect them, with a powerful AI," stated Greg Mark, CEO of Markforged. "Much like the way Tesla is building autopilot for cars, we are building an autopilot for manufacturing."

Markforged states that Blacksmith will create a continuous feedback loop to make additively manufactured parts more accurate. The AI reportedly analyses a design, compares it to the scanned part, and automatically adapts the end-to-end process to produce in-spec parts. The company explains that the intelligent software also cuts waste and accelerates time to market and will be particularly powerful for the new generation of metal AM systems.

Mark added, "3D printing is just the start – we plan to extend the Blacksmith AI to connect all machines in your factory. We will enable the first generation of machines that know what they're supposed to make, and can adjust themselves to produce the right part, every time."

www.markforged.com

Quintus launches new Hot Isostatic Press for the AM industry

Quintus Technologies, Västerås, Sweden, has launched a new Hot Isostatic Press (HIP) targeted to meet the needs of the Additive Manufacturing industry. The new QIH 60 M URC® will reportedly accelerate the Additive Manufacturing process by reducing the number of steps in the production line. The new model combines heat treatment and cooling in a single process for faster throughput and higher work piece quality.

According to Quintus, the QIH 60 features digital controls for precise heating and cooling performance and has been designed to integrate with Industry 4.0 and factory of the future connectivity. The QIH 60 operates at a maximum temperature of 1400°C (2552°F) and pressure of 30,000 psi (2,070 bar) when using the molybdenum furnace. Graphite furnace options are also available for temperatures up to 2000°C (3632°F). The working dimensions of the vessel are 410 mm (16.14") in diameter and 1000 mm (39.37") in height, with a capacity of 600 kg (1,322 lbs) per load, allowing loading of full build plates from the majority of printers.

The company states that its wire-winding technology is recognised as the most reliable and durable pressure containment system ever designed. Completely documented quality systems govern all phases of the production process and comply with ASME U3 and CE (PED) quality standards. Active controlled cooling facilitates stress relief, Hot Isostatic Pressing, quenching, and aging in the same HIP system with higher productivity. Quintus reports that this capability makes the QIH 60 M URC well suited for materials that require rapid cooling or quenching after annealing, decreasing lead times and often eliminating the need for outsourced treatments.

Quintus has launched a new HIP for AM applications (Courtesy Quintus)

Jan Söderström, CEO of Quintus Technologies, stated, "HPHT introduces multiple efficiencies and dramatically lowers per-unit processing costs. We are very pleased with the role this new, state-of-the-art HIP can play in moving Additive Manufacturing forward into robust, lean production."

www.quintustechnologies.com

www.gknpm.com/additive

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GKN ADDITIVE

Wabtec Corporation invests in GE Additive's Binder Jet technology

Wabtec Corporation, a global provider of equipment and services for the freight and transit rail industries, headquartered in Wilmerding, Pennsylvania, USA, is reported to have invested in GE Additive's new H2 Binder Jet technology.

Philip Moslener, global director of WabtecOne Platform & Applied Innovation, stated, "Additive is one of the key technology pillars for our company and central in our efforts to drive innovation in the industries we serve. This binder jet machine will help us design and produce reliable, low-cost components for our current and developmental engines, locomotive, transit and mining programmes."

According to Wabtec, it has already received its first H2 machine, which is currently located at GE Additive's labs in Cincinnati, Ohio, USA. A team from Wabtec will be co-located at the lab to work on technology development, before the machine is relocated to its facility in Grove City, Pennsylvania, later this year. The company has reportedly identified that additive technologies could be used in the production of up to 250 components for its product lines by 2025, and has stated that it will be working closely with the GE Additive team in order to support its industrialisation strategy.

GE Additive revealed the first prototype of its Binder Jet system, then called the H1, in December 2017. The company is now quickly scaling its Binder Jet technology, first into pilot lines, then into a complete, industrialised factory solution, and Cummins Inc., became one of the first customers to invest in the H2 Binder Jet technology last month. It is expected to be commercially available in 2021.

"Throughout 2018, a multi-disciplinary team at GE Additive developed the second generation 'H2' binder jet beta machines. Today, parts are being printed on those machines, which we understand provide the largest format and fastest build speed currently on the market," commented Josh Mook, innovation leader at GE Additive.

"Fast forward to early 2019 and we launched the H2 beta testing and partner programme. We deliberately sought out partners and key customers, like Wabtec, who are committed to mass production, but also known and respected for their commitment to the early adoption of innovation. Most importantly we want to partner with customers whose businesses will benefit tremendously from Binder Jet's ability to reliably print large, complex parts at high throughput and low cost."

www.wabtec.com
www.ge.com/additive

GE's Binder Jet system, the H2, is in its beta-stage (Courtesy GE Additive)

Sandvik Materials Technology to separate from the Sandvik Group

Sandvik AB, Stockholm, Sweden, is to initiate an internal separation of its business division Sandvik Materials Technology. The decision was made by Sandvik's Board of Directors with the reported aim of increasing the structural independence of Sandvik Materials Technology from the Sandvik Group. It is expected that this will put a significant focus on the business's future development possibilities, as well as creating flexibility. The separation is expected to take at least a year, with no guarantee whether a decision to list Sandvik Materials Technology at the Nasdaq Stockholm Exchange will be taken.

"The decision to initiate an internal separation of Sandvik Materials Technology is based on the board's belief that each part will develop more favourably by itself, increasing opportunities for profitable growth and improving long-term shareholder value," stated Johan Molin, Chairman of the Sandvik Board of Directors.

"Sandvik Materials Technology represents the origin of Sandvik and great businesses have sprung out of it to shape the current structure. It is my view that a separation will allow full focus on Sandvik Materials Technology's key strengths and its further improved performance," commented Björn Rosengren, President and CEO of Sandvik.

www.home.sandvik

Reading Alloys appoints Michael Wilkes as its new Product Manager for Powders

Reading Alloys, a division of Ametek Specialty Metal Products (SMP), headquartered in Robesonia, Pennsylvania, USA, has announced the appointment of Michael Wilkes as its new Product Manager for Powders. Wilkes will be overseeing the ongoing growth of Reading Alloys' range of powder-based products, including high-purity titanium and titanium alloy powders produced via a hydride-dehydride (HDH) process and used for coatings in orthopaedic medical devices, advanced electronics, traditional Powder Metallurgy and metal Additive Manufacturing.

Wilkes previously worked as Director of Global Customer Service at Carpenter Technologies in Reading, Pennsylvania, USA. In that role, he was responsible for leading global customer service quality, inside sales and customer service teams at seven global locations while also supporting multiple brands and products. He holds a BSc in Management and Marketing from Pennsylvania State University and has also completed the Executive Education General Management Program at Harvard Business School.

www.readingalloys.com

Reading Alloys has appointed Michael Wilkes as its new Product Manager for Powders

Mimete begins metal powder production at its Italian facility

Mimete S.r.l., Osnago, Italy, a division of the Fomas Group, Osnago, Italy, has started to produce metal powders from its new and customised VIGA (vacuum inert gas atomisation) facility. Mimete's manufacturing plant has been specifically designed by Fomas to serve the Additive Manufacturing market and will target various sectors, primarily biomedical, power generation, aerospace and racing.

According to Mimete, the first atomisation process was monitored through an advanced production management system and the alloy chosen for the first batch of powder was 316L. Production of IN625 and F75 is currently ongoing. The company stated that it then analysed the powders at the in-house laboratory, which will it expects to be accredited to EN ISO IEC 17025 in the near future. Scanning Electron Microscope (SEM) images of the powder produced reportedly showed a morphology that was spherical and homogeneous, and the measured flowability also met the targets set.

Maria Guzzoni, Mimete Strategy & Special Projects Coordinator, stated, "We were all very excited to be together for the first atomisation. It was not about scoring the best result, but it was more about getting to the end of the cycle – the starting point for future challenges and improvements. We studied a lot and we were well prepared for all scenarios, but we were aware that moving from theory to reality always implies a certain level of uncertainty. We were incredibly moved to finally see the successful results of all the hard work and the commitment we went through last year."

www.mimete.com
www.fomasgroup.com

Elcan opens new facility for metal powder testing and recycling

Elcan Industries Inc., Tuckahoe, New York, USA, has established a new lab and particle testing laboratory. The facility features advanced lab equipment for fine particle size determination and evaluations of different products. It also includes a station for recycling Additive Manufacturing powders on Elcan's Hi-Sifter sieving machine and a new Elbow Jet Air Classifier for sub-10 µm particle separation.

According to Elcan, the new laboratory includes a range of testing equipment that will provide the company and its customers with instant feedback on their powders. The facility will also house a Malvern Mastersizer 3000, which reportedly gives accurate Particle-Size Distribution (PSD) print outs and can immediately determine finished product particle size. Elcan also offers Air Jet Sieves and Rotaps for particle size determination and has the ability to microscopically image pictures to show individual particles.

Elcan's Additive Manufacturing powder recycling programme is designed to guide those companies which are new to metal AM with the handling and sieving of metal powders, as well as offering assistance on a tolling basis to those not ready to invest in recycling equipment. By using its proprietary Hi-Sifter technology, Elcan Industries can help companies recycle their AM powders at the desired powder specification. The Hi-Sifter's entire body and all product contact areas of the machine are polished stainless steel and allow for zero contamination, said to make it suitable for aerospace and biomedical applications.

www.elcanindustries.com


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New Rapidia metal AM system uses water as binder

Rapidia, based in Vancouver, British Columbia, Canada, has developed a new metal AM system which uses a water based metal or ceramic paste fed through print heads, similar to those used in Fused Deposition Modelling (FDM) systems.

Unlike many other commercially available binder-based metal AM processes, which use polymer or wax-based binders, the company states that the use of a water-based binder eliminates the need for any debinding stage prior to sintering, helping reduce the overall processing time for each part. Rapidia also stated that the process does not require a base or raft, and in the majority of cases does not use metal support structures, reducing the amount of metal waste generated during the process.

Water-based metal paste is also said to be one of the safest and most environmentally friendly methods of handling materials for Additive Manufacturing, as it allows a solvent-free AM workflow with no requirement for polymer disposal. No fumes or odours are created in the printer during printing, as the only material that evaporates is water. In recent years, a number of metal Additive Manufacturing systems have been developed which use a bound metal feedstock, similar to that used in Metal Injection Moulding (MIM). The MIM process uses a polymer or hard wax binding agent to allow material injected into the mould to solidify in seconds, for rapid removal from the mould. However, Rapidia states that because the build process in metal AM takes significantly more time than MIM, the use of a polymer or wax binding agent is not required – long build times allow a water-based binder to evaporate during the build.

The Rapidia AM machine builds parts using two independent print heads, on a build plate of heated glass and build sheet of aluminium foil or polyester sheet. It has a part manufacturing envelope of 200 x 280 x 200 mm and can build parts to coarse (0.6 mm nozzle) and fine (0.4 mm nozzle) resolutions. According to the company, the machine has a build speed of over 40 cm^3 per hour at coarse resolutions.

On its release, Rapidia's machine will be compatible with seven metal materials and three ceramic materials, with more said to be in development. Described as an 'office-friendly' system, it is said to take up the same footprint as a stove and refrigerator. Its water-based binder technology also eliminates the need for a debinding unit to be installed in an office environment, which can be both highly costly and space-consuming.

www.rapidia.com

Rapidia's new metal AM system and sintering furnace (Courtesy Rapidia)

TWI and Lancaster University launch new AM Innovation Centre

A new Additive Manufacturing Innovation Centre (AMIC), located at TWI Ltd's Technology Centre in Yorkshire, UK, has been officially opened, with Professor Robert Scudamore being appointed Centre Director. It is the second centre to be established by TWI with Lancaster University, building on the previous success of the Joining 4.0 Innovation Centre (J4IC), which opened in April 2017.

TWI is an independent research and technology company with over twenty-four years of industry experience and the AMIC is expected to merge the expertise of TWI and Lancaster University, to develop the international research profile and reputation of both partners in relation to Additive Manufacturing.

AMIC is expected to deliver access to TWI's range of AM systems and support capabilities, including; Laser Metal Deposition (DED), Laser Powder Bed Fusion (L-PBF), and Electron Beam and Arc-based (EBAM) wire deposition systems. In his appointed role, Prof Scudamore will reportedly bring with him extensive experience of industry-driven research as part of TWI; including fourteen years spent in senior management roles.

Prof Scudamore stated, "This exciting new venture will focus on combining Additive Manufacturing with artificial intelligence and machine learning, also looking into new material approaches and processing. There will be a synergy with the J4IC at Lancaster that will be leveraged. We'll also be developing initiatives to certify Additive Manufacturing for serial production."

www.twi-global.com
www.lancaster.ac.uk

TÜV SÜD certifies Rosswag as manufacturer of metal powder for AM

TÜV SÜD Industrie Service GmbH, Munich, Germany, has completed its first audit of Rosswag GmbH, a manufacturer of metal powder, headquartered in Pfinztal, Germany. The audit forms part of a new certification programme based on the AD 2000 Code for pressure equipment and the European Pressure Equipment Directive (PED).

According to TÜV SÜD, it has developed a new certification programme enabling metal powder manufacturers to prove the quality of their processes. The programme maps the essential safety requirements specified in Annex I to the EU Pressure Equipment Directive 2014/68/EU in reference to the material manufacturer, in conjunction with the detailed requirements of the W 0 leaflet of the German AD 2000 Code.

The AD 2000 Code is to specify the essential safety requirements according to the PED. The code includes the general principles for materials, joining methods, personnel and the necessary qualification tests. In addition to quality assurance and traceability, it is also said to cover evidence of the production reliability of certain material groups and the fundamental suitability of the metal powder for Additive Manufacturing.

"In our certification programme for metal powder manufacturers, we have complemented the requirements of the PED and the W 0 leaflet with our expertise and experience in materials and welding technologies," stated Gunther Kuhn, Head of Product Management in the Plant Safety business unit of TÜV SÜD. "The programme provides us with an excellent basis for the reliable assessment and certification of metal powder manufacturers."

In 2017, Rosswag's Additive Manufacturing department introduced in-house metal powder manufacturing for the qualification of new materials. Gregor Graf, Engineering Manager at Rosswag, explained, "The purchase of our own atomising plant made by BluePower Casting Systems GmbH has enabled us to control the entire process chain and massively reduce the time needed for the qualification of new materials. After completing the qualification process, we now have comprehensive data sets comprising metal powder characteristics and PBF process parameters as well as mechanical and technological, chemical and metallographic material properties."

This is said to enable the company to consider the typical characteristics of the future component in conjunction with the manufacturing process, a relevant feature for complex application scenarios involving Additive Manufacturing components. During the certification process, experts from TÜV SÜD focused on the processes applied to the manufacturing, testing and qualification of the metal powder at Rosswag and assessed them extensively in an on-site audit.

Graf added, "The successful audit result confirms that we have full control of our processes and that our production of metal powders for use in Additive Manufacturing satisfies very high quality standards." Rosswag reports that the third-party assessment and certification by TÜV SÜD is an important contribution to maintaining competitive edge in a market that it expects will see high dynamic and strong growth over the coming years. It is anticipated that following the successful audit, the certification process will be completed within two months.

www.rosswag-engineering.de
www.tuvsud.com

Hypermetal launches metal Additive Manufacturing services in Portugal

Hypermetal, Vila Nova de Gaia, Portugal, has launched its metal Additive Manufacturing service, becoming what is believed to be the first company to provide metal AM services in the north of the country. The company has been in full production since the beginning of the year, and serves clients from the aeronautic, aerospace, automotive and moulds sectors.

Hypermetal provides metal AM services from its facility in Vila Nova de Gaia (Courtesy Hypermetal)

With a strong focus on quality and flexibility, Hypermetal stated that its goal is to become a reference partner for innovative companies in the European market, offering metal AM design and manufacturing services using Laser Powder Bed Fusion (L-PBF).

Afonso Nogueira, Managing Partner at Hypermetal, stated, "Metal Additive Manufacturing is fast, flexible, without waste and allows the production of parts that are impossible to obtain by other technologies. There is increasing knowledge and interest by the industry in the potential of 3D printing in general and metal AM in specific, so we believe that it was the right time to enter the market."

"We are currently implementing quality procedures for certification and anticipate rapid growth over the next three years, aiming to strengthen the team with seven more elements until the end of 2021," he added. To date, Hypermetal has produced primarily prototypes, jigs, templates and inserts with conformal cooling channels for plastic injection moulds.

www.hypermetal.eu

SBI International announces M3DP for series metal Additive Manufacturing

SBI International, Hollabrunn, Austria, has introduced a new Wire-Arc Additive Manufacturing (WAAM) machine aimed at the series production of metal parts. Founded in 1999 with the aim of maturing what were then known as rapid prototyping technologies, SBI has over the past two decades established its plasma technologies globally.

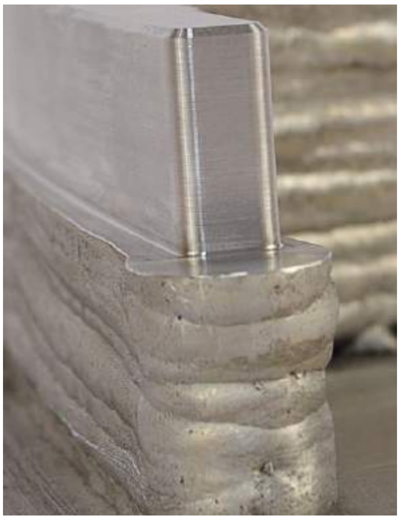
The company began developing its own metal AM machines in 2016, and now reports that it is ready to bring its first machine, the M3DP, to the market. Because the machine uses a focused plasma arc independent from the wire feedstock, SBI stated that the plasma arc can be used for both Additive Manufacturing and heating throughout the build process.

On its launch, the list of materials compatible with the M3DP includes aluminium, titanium, mild steel, stainless steel, nickel-based alloys and copper. When additively manufacturing components in steel, the machine is said to be capable of achieving deposition rates of up to 10 kg/hour. Parts are produced to near-net shape and require some machining to bring them into the required dimensions, but SBI stated that this process remains cheaper than machining the part from a solid block or billet.

During Additive Manufacturing on the M3DP system, the process is video logged, with timestamps, and linked to relevant parameters including the welding current, wire feed speed and travelling speed, to enable post-process analysis and optimisation of future builds. After each layer of the part is built, a 3D scan is conducted to guarantee that the built shape fulfils the part's geometric requirements, and further matched with the CAD file for conformity to the model. This makes it possible to achieve adaptive control of the build process.

Where working with sensitive materials such as titanium and nickel-based alloys, the M3DP can be optionally enclosed by a gas tight cover, enabling the creation of an inert gas atmosphere with less than 15 ppm oxygen and 30 ppm moisture. According to SBI International, the main fields of application for the M3DP will be aerospace, tooling, oil & gas, naval architecture, mechanical engineering and automotive.

www.sbi.at


SBI uses a Wire-Arc AM process (Courtesy SBI International)


Production of an aluminium part using SBI International's M3DP WAAM machine (Courtesy SBI International)

Markforged to open its new European headquarters in Ireland

Markforged, Inc., headquartered in Watertown, Massachusetts, USA, has announced the opening of its official European headquarters in Dublin, Ireland, as part of its planned global expansion for 2019. The new European headquarters has been established with the support of the Irish Government through IDA Ireland. The Dublin office will be the first international office for Markforged. Over the next three years, the company stated that it intends to employ one-hundred new staff, across all functions, at the new location.

"Launching our Dublin operations is a huge milestone for Markforged as we look to strengthen our business overseas," stated Darcey Harrison, Global VP Sales, Services and Partnerships at Markforged. "Our experience working with IDA Ireland has been nothing but exceptional – we're thrilled to be joining such a thriving tech community with such support."

Markforged has begun the process of expanding its international operations over the last two years, developing a global partner network in fifty countries. Stephen Barbuto, EMEA Director of Commercial Sales, will lead the team opening the new Dublin office.

www.markforged.com

ParaMatters releases updated CogniCAD system for Additive Manufacturing

ParaMatters, Ventura, California, USA, a provider of software for generative design, autonomous topology optimisation, parts consolidation and lightweighting, has released the latest version of its CogniCAD generative design software, which employs a cloud-based, cognitive design and high-performance computational platform.

The upgraded CogniCAD 2.1 is expected to offer an enhanced variety of loading conditions, including thermal loads, as a beta release and force / moments via remote points, in addition to existing acceleration (g-forces) and pressure. It will reportedly also allow design for Additive Manufacturing and investment casting as a beta release.

According to ParaMatters, CogniCAD 2.1 works by first importing CAD files into the platform, and then defining loading and design criteria. Users can obtain generative designs verified by built-in Finite Element Analysis (FEM), ready for Additive Manufacturing in both STL and STEP formats.

ParaMatters has released an upgrade of its autonomous design and lightweighting software (Courtesy ParaMatters)

CogniCAD's functional design capabilities include stress, compliance (stiffness) and deformation constraints. The platform also enables users to take an optimal design and find its ideal model orientation for Additive Manufacturing, by minimising unsupported areas or supports volume, while highlighting areas which require reinforcement.

Dr Michael Bogomolny, Co-founder and Chief Technology Officer of ParaMatters, stated, "The most powerful agnostic CAD-to-CAD generative design and lightweighting software offering available on the market just got that much better for the automotive, aerospace, medical, industrial and material industries. With CogniCAD 2.1, users have more options and greater flexibility to create lightweighted objects that meet their design and manufacturing needs for challenging real-life applications."

The CogniCAD 2.1 update can now be accessed as a pay-per-design, cloud-based service via the company's website.

www.paramatters.com

ExOne collaborates with ORNL on Binder Jet Additive Manufacturing

The ExOne Company, North Huntingdon, Pennsylvania, USA, has announced a collaboration with Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee, USA, the largest U.S. Department of Energy (DOE) open science laboratory, to pursue further advancements in Binder Jet Additive Manufacturing.

The collaboration project is initially targeted on the development of technology for new Binder Jetting systems, focusing on optimising chemistry and process parameters for ExOne's sand and metal Additive Manufacturing systems. This includes leveraging ORNL's instrumentation and advanced data analysis methodologies.

The collaboration will reportedly draw on the DOE's Manufacturing Demonstration Facility (MDF) at ORNL and its efficiencies in instrumentation capabilities. Additionally, it will seek to optimise binder development for H13 tool steel. ORNL is targeting the production of 500 tools and dies by 2022 for the moulding, stamping and forging industries, and expects to establish Binder Jetting as the leading low-cost method for the fabrication of advanced tooling.

"We look forward to continuing Binder Jetting research with ExOne," stated Amy Elliott, ORNL Lead Researcher on Binder Jetting. "Over the past several years, we've worked with ExOne on four Binder Jetting systems and we've made exceptional progress in enhancing this Additive Manufacturing technique. Industry collaborations such as this help the US remain competitive in manufacturing."

"By collaborating with a world-class lab like Oak Ridge National Laboratory, we accelerate ExOne's Binder Jetting technology capabilities. We believe these collaborative efforts will effectively and efficiently result in the establishment of new materials, binders and process developments, retaining our significant edge over competitors and other technologies in the industrial manufacturing space," added Rick Lucas, ExOne's Chief Technology Officer.

www.exone.com

LLNL offers solution to negate formation of pores in metal AM components

Researchers based at the Lawrence Livermore National Laboratory (LLNL), California, USA, along with scientists from the SLAC National Accelerator Laboratory, California, USA, have discovered a solution to negate the formation of pores in metal additively manufactured parts.

Pores can be created under the surface of a build and lead to cracking in the finished part when under stress. The team combined high-performance computer simulations with X-ray imaging of the Laser Powder Bed Fusion (L-PBF) metal Additive Manufacturing process, obtained with SLAC's synchrotron radiation facility, to identify a solution to the problem. According to the team, their mitigation strategy involves reducing the power of the laser as it slows down to make turns along the complex path it takes to scan and build a metal layer. By varying the laser power throughout the build, they found they could keep the laser's depression depth shallow and constant.

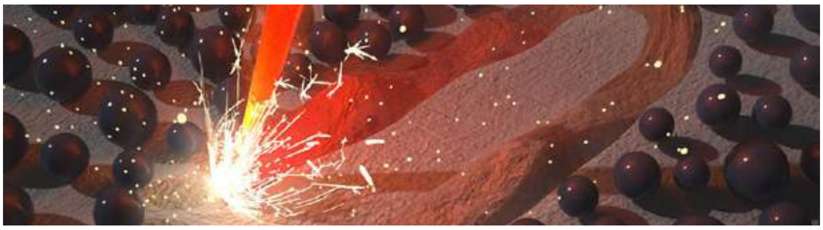
Aiden Martin, LLNL researcher and lead author on the paper, explained, "We found in a lot of parts that at the end of that area where the turnaround is, there's a huge concentration of pores, which affect the material quality. We've had simulations that show this, and we needed some experimental validation. We now have a mitigation strategy where we measure the speed of the laser as it makes that turn, and we change the power dynamically during the turnaround. If we know the speed, we can adjust the power of the laser, and that keeps that depression nice and stable at the surface, and we don't get that depression that forms the pore at the end."

Principal investigator Ibo Matthews, Deputy Group Leader, Condensed Matter & Materials Division at LLNL, who has professionally analysed melt pool dynamics for several years, commented, "It's been a known problem, but this is the first demonstration that we can correct it in a predictive way. Most important is the fact, the pores are always created at a distinct point in time, as the laser accelerates out of the turn. The timing is quite interesting. The assumption was that pores formed only at the deepest part of the melt pool. The fact that the pores occurred after the turn was a surprise to everybody."

Matthews also added that the mitigation technique which the team developed, is part of a suite of tools tied to LLNL's 'intelligent feed-forward' strategy which relies on simulations and model validation prior to Additive Manufacturing and is being adopted by companies in the automotive and aerospace industries. The strategy could reportedly be deployed on virtually any commercial machine by constructing power maps with a 3D slicer software that converts the parameters defined by a CAD file into system instructions.

Saad Khairallah, a computer scientist at LLNL, reportedly developed the simulation model behind the mitigation strategy using a multi-physics code called ALE3D, along with the addition of laser ray tracing which improved the fidelity of the predictions. Khairallah reported, "The way you fix the problem is adding 'cruise control' to your simulation. I simply told the simulation to maintain the melt pool depths constant. That fixed the problem. You don't see pores; you don't see keyholes. And as an added benefit, you get a power map – an output of the simulation model that indicates the power needed as a function of location along the track to prevent pore formation."

By using a test chamber that was built at LLNL, the researchers were able to spread a single layer of powder and capture images of the laser scanning on a synchrotron beamline. Inspired by the results of the simulations and the power map, they performed experiments showing pore formations under the surface when they kept the laser's power constant, and a consistent melt pool depth with no pores when they reduced power



Researchers at Lawrence Livermore National Laboratory and SLAC National Accelerator Laboratory believe they have found a way to negate the formation of pores in metal Additive Manufacturing (Courtesy LLNL)

at the turn. The experiments were then verified by comparing them to the simulations. The team of researchers has concluded that their findings provide further insight into the L-PBF process and demonstrates the potential for science-based approaches to increase confidence in metal components produced by the process.

Martin states that he anticipates the mitigation strategy will be adopted for use by the AM industry, and added, "The pores are a real initiator of failure, like cracking and other processes that occur at the pore sites. So, if we can eliminate the pores in the part, we have a harder part and something we can ultimately certify for use. Right now, it requires additional electronics, but in the future it's something that could probably be incorporated directly into the software. We're hoping with some fine tuning that it can slowly be incorporated into the builds."

LLNL reported that the next step involves incorporating the strategy into actual part builds that can involve more complex scan patterns. The researchers are interested in leveraging these methods to print lattice structures and using thermal, acoustic and tomographic methods to detect where pores begin to form in multi-layered parts.

The work was funded by the Department of Energy's Advanced Manufacturing Office, within the Office of Energy Efficiency and Renewable Energy, Washington, D.C., USA. Ames Laboratory, Iowa, USA, also contributed to related work by completing the design of the powder feed system for in-situ X-ray characterisation during the AM process and participating in the X-ray diffraction studies. The team of researchers was made up of contributors from LLNL including Nick Calta, Jenny Wang, Phil Depond, Gabe Guss and Tony van Buuren, as well as SLAC collaborators including Anthony Fong, Vivek Thampy, Andrew Kiss, Kevin Stone, Christopher Tassone, Johanna Weker and Michael Toney. The Ames Laboratory team included Matthew Kramer and Ryan Ott.

www.llnl.gov

Formalloy releases powder feeder and robotic integration for metal AM systems

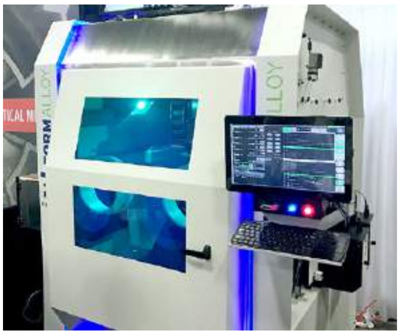
Formalloy, headquartered in San Diego, California, USA, has showcased its award-winning Directed Energy Deposition (DED) systems, including robotic integration and its latest Alloy Development Feeder (ADF), at RAPID + TCT 2019, in Detroit, Michigan, USA.

The company's DED systems feature the Formalloy AX Metal Deposition Head and a customisable build volume, with up to five-axes of motion. Formalloy states that the AX head has proven reliability for up to 8 kW laser power and built-in quick-release features allowing for rapid maintenance and component swaps in less than three minutes.

Regarding the release of its Alloy Development Feeder, Formalloy states that the system enables high throughput bulk alloy synthesis for the development of new materials and alloys. Material development expert, Dr Kenneth Vecchio, a Professor at the University of California San Diego, stated, "The ADF provides an unprecedented capability for material development and research."

According to Formalloy, the need for new alloys optimised for Additive Manufacturing is not only evident by researchers and materials companies, but for end users also. In particular, end users of AM in the aerospace and automotive industries are investing in new materials that feature superior properties to traditional materials.

The company states that in addition to new alloy development, the ADF enables precise deposition of gradient materials as each layer is pre-alloyed to ensure composition accuracy for detailed gradient strategies that are not achievable with other processes.



Formalloy's X-Series (Courtesy Formalloy)

Gradient parts can reportedly provide enhanced material properties and simplification of multiple-part assemblies made of various metals into a single part.

As an alternative to purchasing a turn-key metal deposition system, a robot can be integrated with the Formalloy AX deposition head, ADF or PF powder feeders, and a laser to additively manufacture, clad, and repair metal parts.

www.formalloy.com

EOS celebrates its thirtieth anniversary

Germany's EOS, celebrated thirty years since its inauguration on April 24, 1989. Founded by Dr Hans J Langer, the company is widely regarded as one of the leading suppliers of technology and solutions for the industrial Additive Manufacturing of both metals and polymers.

The family-owned company, which began with four employees, now employs 1,200 and has an installed base of nearly 3,500 industrial Additive Manufacturing systems worldwide. Founded when the AM industry was still a new 'rapid prototyping' market, EOS was initially focused on stereolithography technology, but in 1997 made the shift to focus exclusively on laser sintering, becoming an early proponent of Powder Bed Fusion (PBF) Additive Manufacturing.

A significant factor in the company's success has been that, from an early stage in its development, EOS was able to offer – in addition to its AM systems – the materials, processes, and software tailored to suit these systems for optimal results. In order to offer additional support to companies using AM technology, EOS founded consulting unit Additive Minds in 2015. According to the company, this unit has since consulted on more than 300 successful customer projects.

Over the years since EOS's founding, Dr Langer has also established the EOS Ecosystem, a network of EOS investments and external partners, including the company AM Ventures, which supports promising start-ups. According to EOS, ongoing cooperation between the various companies in the ecosystem enables them to combine expertise to enable the implementation of customer-specific manufacturing solutions along the entire value chain – from concept to design and engineering, production, post-processing, and ultimately the finished part.

In recent years, EOS has turned its attention to the integration of AM into existing serial production environments. The goal is to achieve highly flexible serial production workflow that combines industrial AM and conventional manufacturing technologies in a 'digital factory', making use of machine connectivity and automation.

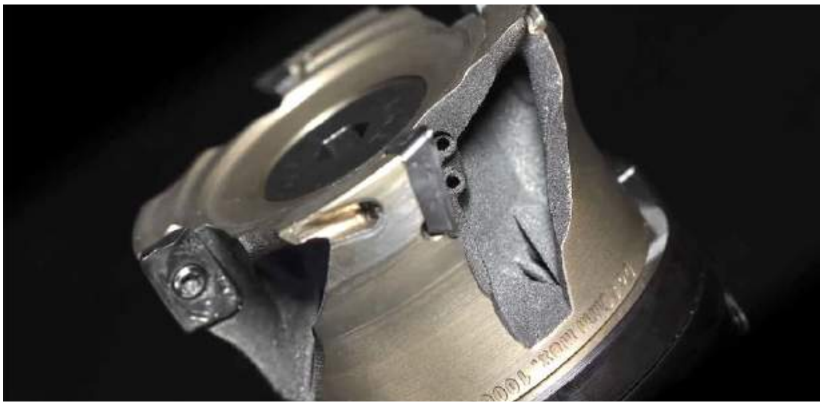
According to Dr Adrian Keppler, EOS CEO, "The establishment of complete digital production platforms is a major goal that we are aiming to achieve in the coming years. It's not just about providing the right 3D printing solutions, but about evaluating, planning, setting-up, and optimising AM production cells to leverage all the advantages and possibilities of digitalisation."

www.eos.info

New Sandvik Coromant tool features additively manufactured cutter body

Sandvik Coromant, Sweden, has introduced a lightweight metal cutting tool, the CoroMill 360®, which incorporates a metal additively manufactured cutter body. According to the company, the use of AM enabled the tool to be produced at a lighter overall weight, helping to minimise vibration.

The CoroMill 360 provides a solution for the generation of features like deep cavities which can be compromised by vibration, leading to slower production, shorter tool life and poor surface finish. Combined with the company's Silent Tools™ milling adaptors, the optimised tooling combination subdues vibration to help maximise productivity and process security in demanding applications involving long overhangs.



The CoroMill cutter body is additively manufactured (Courtesy Sandvik Coromant)

The CoroMill 390 is reportedly capable of performing long-reach face milling, deep shoulder and side milling, cavity milling, and slot milling. Thomas Wikgren, Manager Product Application Management, Sandvik Coromant, stated, "When designing our new lightweight CoroMill 390, material has been tactically removed to create the optimal cutter design for minimising mass."

"This is called topological optimisation and it makes the cutter more compact and significantly lighter than a conventional version, thus helping machine shops to boost the productivity of their long-overhang milling operations," he continued. "Moreover, a shorter distance between the damper in the adaptor and the cutting edge improves performance and process security."

www.sandvik.coromant.com

Linde and Liebherr-Aerospace collaborate to optimise AM aluminium aircraft components

The Linde Group has collaborated with Liebherr-Aerospace Toulouse SAS, France, part of the Liebherr Group, Switzerland, in a project set to optimise the benefits of Additive Manufacturing for aluminium aircraft components. To date, the project has reportedly delivered definitive results in terms of improvement of product quality and production repeatability, with Linde's ADDvance® O_2 precision solution gas analysis technology reported to play a central role in the research.

According to Liebherr-Aerospace, it is keen to integrate the fabrication of AM parts into its established automated workflow to enhance manufacturing efficiency and reduce production surplus. As AM represented a new manufacturing approach for the company, a pilot project was launched in collaboration with Linde to develop aluminium components, including bleed air valves.

Liebherr-Aerospace installed its first metal AM system at its manufacturing centre in France, but initial tests indicated that oxygen levels fluctuated during the AM process. The variation in oxygen levels were seen to negatively impact the quality of the printed parts – particularly those made from aluminium alloys. Linde states that the solution was to implement its ADDvance O_2 precision technology to provide continuous analysis of the gas atmosphere. This technology can reportedly detect O_2 concentrations with high precision – as low as 10 parts per million (ppm) – without cross-sensitivity, the unit automatically initiates a purging process to maintain the atmosphere to the required purity.

After the atmosphere in the build chamber is purged, impurities can remain due to incomplete purging, via access through loose connections or within the metal powder itself. Small variations in oxygen content can impair the mechanical or chemical properties of alloys sensitive to oxygen. This can affect the composition of the end product, resulting in discolouration and even poor fatigue resistance.

"Linde has always played a pioneering role in the development of atmospheric gas technologies," stated, Pierre Forêt, Senior Expert Manufacturing, Linde. "That we were selected by Liebherr-Aerospace Toulouse to collaborate in this important project to advance the understanding of the role atmospheric gases play in Additive Manufacturing of critical aerospace parts, is further testament to our innovative capabilities."

www.linde.com
www.liebherr.com

F1 parts maker doubles productivity with the Russell AMPro Sieve Station

Progressive Technology Ltd, Newbury, Berkshire, UK, is reported to be using Additive Manufacturing in the manufacture of complex metallic components, primarily for the Formula One (F1) market. After initially entering the F1 market manufacturing low-tech products, Progressive Technology is now creating high-end components and servicing most of the teams on the F1 grid.

A full 24-hour shift pattern allows rapid turnaround of parts, and the company invests in the highest quality equipment to optimise its production process. The AM technology provides significant benefits when producing F1 components, reducing the R&D time required to produce new designs, with the biggest benefit coming from weight reduction. Metal AM powders such as titanium, aluminium and Inconel are commonly used to produce AM parts for F1 cars – to ensure their quality, therefore, all powders must be qualified before use, and the unused powder must be reclaimed and requalified after the build process is completed. Dave Cooper, Head of Additive Manufacturing Technologies at Progressive Technology, explained, "The quality of the powder is crucial as it dictates the material properties and is the only way to guarantee a high-quality product, giving confidence to our customers that we're ensuring the quality of materials used to produce the components for their cars."

Initially, the method used to process metal powders at Progressive Technology was said to be very time consuming, with high product wastage. To solve this problem, the company has now adopted an automated solution for powder handling, the Russell AMPro Sieve Station™ produced by Russell Finex Ltd, Feltham, Hounslow, UK. With the installation of the Russell AMPro Sieve Station, the company reports that it has been able to double productivity with only half of the labour it previously used. "The turnaround process between jobs used to take well over an hour," Cooper explained. "Using the AMPro has made this significantly shorter, as it makes the powder handling processes automated, allowing operators to focus on other key tasks such as preparing the machine for the next build. This has been a fantastic investment for us – speeding up our day-to-day process and improving our materials' quality – absolutely key when producing high-value parts."

Established in 1934, Russell Finex designs machines for the international market and supplies to over 140 countries. In addition to its head office in the UK, the company operates subsidiaries in Belgium, the USA, India and China, enabling it to effectively provide customer service and after-sales support.

www.russellfinex.com
www.progressive-technology.co.uk

Machine learning algorithm designs new alloy for metal Additive Manufacturing

A new machine learning algorithm developed by Intellegens, an artificial intelligence company based in Cambridge, UK, has been used to design a new nickel-based alloy for metal Additive Manufacturing, in a research collaboration between a number of commercial partners and the University of Cambridge's Stone Group. According to Intellegens, the use of the algorithm saved the team an estimated fifteen years of materials research and around $10 million in R&D costs.

The Alchemite™ deep learning algorithm was used to design the new alloy, intended for processing by Directed Energy Deposition (DED), by analysing existing materials information to identify a new nickel-based combustor alloy that could satisfy the performance targets needed to additively manufacture a component for application in a jet engine.

The development of new materials using conventional research techniques remains a lengthy and expensive process that typically involves a considerable degree of trial and error – and designing new alloys for DED is said to be particularly challenging. To date, DED has only been applied to around ten nickel-alloy compositions, which severely restricted the amount of data available to motivate further investigations.

Alchemite was said to have offered the alloy research team a way around this lack of data and a means of speeding up the overall material selection process. Capable of learning from data that is as little as 0.05% complete, Alchemite was able to link and cross-reference the data available; verify the physical properties of potential new alloys; and accurately predict how they would function in real-life application scenarios.

Following the application of Alchemite, and the identification of the most suitable alloy option, the research team led by the Stone Group embarked on a round of experiments to confirm the new material's physical properties. The characteristics that the team wanted the new alloy to possess spanned processability, cost, density, phase stability, creep resistance, oxidation, fatigue life and resistance to thermal stresses. Results showed that the new alloy was better suited to DED and the application in question than other commercial alloys available.

Gareth Conduit, Chief Technology Officer at Intellegens, and a Royal Society University Research Fellow at the University of Cambridge, explained, "With deep learning capabilities that can pinpoint property-to-property relationships very quickly, Alchemite was uniquely positioned to assist with this project. Using machine learning, Alchemite enabled the team to use a large database of thermal resistance measurements to guide the extrapolation of just ten data entries of alloy processability."

"From that information we were able to shortlist material combinations that were most likely to deliver the right characteristics. The results speak for themselves. Thanks to Alchemite, the team now has a new alloy at its disposal and has saved vast amounts of time and money on R&D," he continued.

"Worldwide there are millions of materials available commercially that are characterised by hundreds of different properties. Using traditional techniques to explore the information we know about these materials, to come up with new substances, substrates and systems, is a painstaking process that can take months if not years. Learning the underlying correlations in existing materials data, to estimate missing properties, the Alchemite engine can quickly, efficiently and accurately propose new materials with target properties – speeding up the development process."

www.intellegens.ai

Heraeus produces 'world's largest' amorphous metal component by AM

Heraeus, headquartered in Hanau, Germany, has produced what is thought to be the world's largest amorphous metal component using Additive Manufacturing, in cooperation with advanced materials specialist Amorphology Inc. The component, a gear wheel manufactured by Laser Powder Bed Fusion (L-PBF), was presented at Automate 2019, April 8–11, 2019, in Chicago, Illinois, USA.

In contrast to pure metals and conventional alloys, amorphous metals are characterised by an irregular, non-crystalline structure, and combine properties of extreme hardness, high yield strength and high elasticity within one material, which would not normally be feasible. Amorphous metals also offer good corrosion resistance, excellent wear resistance and the elasticity of polymers, have soft magnetic properties and are easy to magnetise and demagnetise. This combination of properties means that for many applications, amorphous metals may be superior to steel, titanium and other materials.

However, due to required cooling rates typically over 1000 kelvin/second for amorphous metals, only small parts have typically been possible using these materials. Using metal Additive Manufacturing, Heraeus was able to produce a part weighing 2 kg – including a weight reduction of 50% achieved by optimising the design, material and production process.

According to Heraeus, the ability to produce large components from amorphous metals opens up many new design possibilities for fields such as the automation and robotics industries.

www.heraeus.com
www.amorphology.com

£1.2 million DigiTool project aims to improve tool & die manufacture by AM

The University of Strathclyde's Advanced Forming Research Centre (AFRC) is collaborating with a consortium of six other companies on the £1.2 million DigiTool project, which aims to improve the lifespan and functional performance of dies used by the UK's tool and die sector by using Additive Manufacturing, adaptive machining and other technologies considered part of 'Industry 4.0'.

The two-year project is partly funded by Innovate UK, and project partners include Toolroom Technology Limited (TTL), Applied Tech Systems (ATS), Hybrid Manufacturing Technologies (HMT), INSPHERE Ltd and Kimber Mills International. The project's funding is said to represent the biggest investment in the UK's tool and die sector for more than forty years.

DigiTool's final aim is to provide organisations of all sizes with athe capability to remanufacture worn or damaged dies using advanced manufacturing technologies such as metal AM. Using new technologies and processes to remanufacture worn dies instead of replacing is expected to help firms save on costs and materials, while also improving sustainability.

The consortium is currently said to be exploring Additive Manufacturing and adaptive solutions for remanufacturing the damaged areas on dies using a retrofitted legacy machine tool. Scanning and metrology is used to discover worn areas, before Additive Manufacturing techniques such as Laser Metal Deposition (LMD) are employed to complete the remanufacture back to the desired die form.

Designed for easy integration within one digital platform, the DigiTool framework aims to provide an affordable solution for SMEs looking to adopt new technologies without purchasing a brand-new machine. Toolroom Technology Limited is leading the project, while the AFRC is managing Additive Manufacturing and other partners are delivering research on their respective areas of expertise, including metrology and scanning, adaptive machining and digital integration.

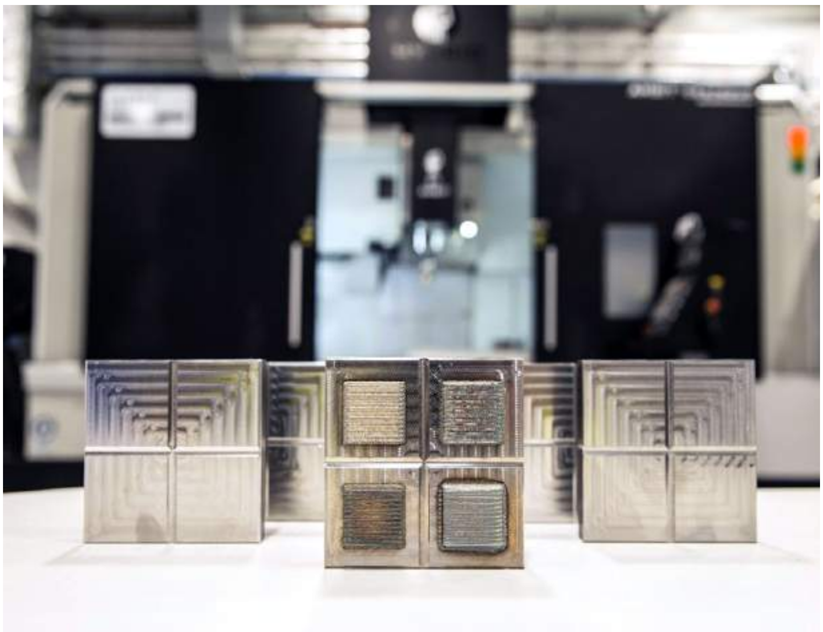
The new manufacturing methods will be combined in one platform at AFRC using its recently installed LMD Hybrid Machine, which combines AM and machining. Initial project trials have been carried out and the partners are now said to be analysing a die for a railway application from Kimber Mills, with plans to remanufacture and bring worn dies back into service.

Stephen Fitzpatrick, Team Lead for Machining and Additive Manufacturing at the AFRC, stated, "The consortium is all bringing different areas of expertise to the project, which is hoped to enhance competition across the industry through the uptake of innovation and new technology. Investment has been slow across the tool and die sector, which has made it difficult for organisations with limited resources to rethink their manufacturing process."

"Through our Additive Manufacturing digital framework, we'll provide these companies with access to new research, technology and insight at a low cost," he continued. "Many firms within the sector may already have a machine that can be retrofitted to integrate Laser Metal Deposition, allowing them to upgrade current assets and save the costs of purchasing a brand-new machine."

Robin Wilson, Innovation Lead & Catapult Relationship Manager, Manufacturing, Innovate UK, commented, "This is a forward-thinking project that can bring real benefits to the tool and die industry, helping traditional manufacturing businesses to embrace cutting edge digital technologies to boost efficiency and sustainability. The area of remanufacturing is a truly exciting one and we are delighted to support DigiTool and the diverse range of partners that are involved. We look forward to charting its progress."

www.strath.ac.uk



Parts produced on the AFRC's LMD Hybrid Machine, which combines additive and subtractive manufacturing (Courtesy University of Strathclyde)

The Aluminum Association releases the first material designation system for AM

The Aluminum Association, Virginia, USA, has released a materials designation system which it believes to be the first of its kind specific to the Additive Manufacturing industry. The 'purple sheets' will reportedly provide clear chemical designations for aluminium powder used in Additive Manufacturing and are the newest addition to the organisation's 'rainbow sheet' series, which provides alloy designations and chemical composition limits for various types of aluminium.

Representing aluminium production and jobs in the USA, the Aluminum Association provides global standards, business intelligence, sustainability research and industry expertise to member companies, policymakers and the general public. According to the organisation, the first registration to be granted will be for a high-strength aluminium alloy produced by HRL Laboratories, LLC, California, USA. The company will receive the registration number 7A77.50 for the aluminium powder used to additively manufacture the alloy and number 7A77.60L for the printed alloy.

"The purple sheets are a true game-changer for the aluminium industry," stated Jerome Fourmann, Global Technical Director at Rio Tinto Aluminum and chairman of the association's Technical Committee on Product Standards. "For the first time ever, a materials industry has developed a designation system specific to Additive Manufacturing, opening tremendous growth potential through standardisation."

A recent report by market research firm, SmarTech, Virginia, USA, projected that Additive Manufacturing using aluminium powder could grow to be a $300 million industry over the next decade. Key markets for aluminium powder in AM include aerospace, automotive, energy transmission and consumer products.

Heidi Brock, President & CEO of the Aluminum Association, commented, "For decades, the Aluminum Association's alloy and temper designation system has helped companies to gain wider acceptance in commercial applications – promoting the material's use in the marketplace. The purple sheets are the next chapter in that story as we look toward a future of aluminium in Additive Manufacturing."

The Aluminum Association is expected to publish its 'purple sheets' later this year. Individuals or organisations interested in having their product considered for inclusion in the inaugural publication of the material designation system can register via the association website

www.aluminum.org
www.hrl.com

MHI Machine Tool delivers its first Directed Energy Deposition system

Mitsubishi Heavy Industries Machine Tool Co., Ltd. (MHI Machine Tool), Tokyo, Japan, a group company of Mitsubishi Heavy Industries, Ltd., has delivered the first unit of its metal Additive Manufacturing machine to the Industrial Research Center of Shiga Prefecture, Ritto, Japan. The machine was developed under a research project of Japan's New Energy and Industrial Technology Development Organization (NEDO), with the participation of the Technology Research Association for Future Additive Manufacturing (TRAFAM).

The project's aim was to create a next-generation metal Directed Energy Deposition (DED) Additive Manufacturing system employing MHI Machine Tool's accumulated laser and positioning control technologies. By adopting a proprietary DED method in which metal powder is continuously fed by nozzles to the laser fusing point with high precision, a commercial model was achieved which is said to be capable of processing diverse metal materials at high speed.

Development of a prototype unit was completed in October 2017, and an entry model has now been launched that is dedicated to manufacturing prototypes of small parts. Using MHI Machine Tool's DED method, part production is said to be more than ten times faster than achievable using Powder Bed Fusion (PBF), and also to generate less waste material.

The use of DED also makes it possible to perform Additive Manufacturing on a part's surface by way of repair, to double-laminate different metal powders, and to manufacture large parts, and MHI Machine Tool stated that significant expansion of applications for the technology is anticipated through developments during the processing phase and through combined use with other machine tools.

MHI Machine Tool is currently developing monitoring feedback capability that will enable users of the new system to automatically monitor and stabilise the manufacturing status, as well as a gas shielding function necessary for manufacturing with the titanium alloys, etc, used in the aircraft and space fields.

The company stated that, in collaboration with the Industrial Research Center of Shiga Prefecture, it will now focus on marketing its new metal AM system within the manufacturing industry, as well as on developing new applications.

www.shiga-irc.go.jp/english/
www.mhi.com

Wolfmet sees potential of additively manufactured tungsten in medical imaging devices

A group of researchers at tungsten specialist Wolfmet, Manchester, UK, have developed a method to additively manufacture complex tungsten components for high-precision applications such as collimators and radiation shields in CT, SPECT, MR and X-ray imaging systems.

Because tungsten has a density around 1.7 x that of lead, as well as the highest boiling and melting point of any element found on Earth, giving it excellent radiation absorption properties, it is ideal for the production of components for X-ray imaging systems – however, these same properties also make it very difficult to work with.

Wolfmet states that by producing tungsten components using Laser Powder Bed Fusion (L-PBF) Additive Manufacturing, it is possible to produce complex parts in days and weeks rather than months, enabling the development of new parts which could dramatically improve imaging technology.

This technology is now being used to produce parts for use in Dosimetry, the measure of radiation during cancer treatment. In molecular radiotherapy treatment of thyroid cancer, it has traditionally not been possible to accurately measure the radiation absorbed by patients during the procedure. As a consequence, only limited information regarding the success of radiotherapy treatment has been available.

For the last six years, teams from the University of Liverpool's Department of Physics, and The Royal Marsden and Royal Liverpool University Hospitals have been working with Wolfmet to develop and assess an imaging system (known as DEPICT) to better measure the radiation dose; their aim is to provide a more accurate, personalised treatment of thyroid cancer.

Central to the imaging system's scanner is a collimator. This is a device which aligns the beams of radiation emitted from the patient so that they are directed onto a detector. The radioactive iodine is ingested by the patient in liquid or capsule form, and gamma rays are then emitted in all directions through the patient; yet only the rays which are aligned with the collimator's holes will make it through to the detector. The data received can then be viewed as an image on a computer screen.

Additively manufactured tungsten prototypes produced by Wolfmet (Courtesy Wolfmet)

Previously, lead was the preferred material for collimators. However, tungsten is more efficient at screening unwanted gamma beams. Additive Manufacturing now allows the production of collimators in tungsten, resulting in much clearer images of the radiation dose received by the patient.

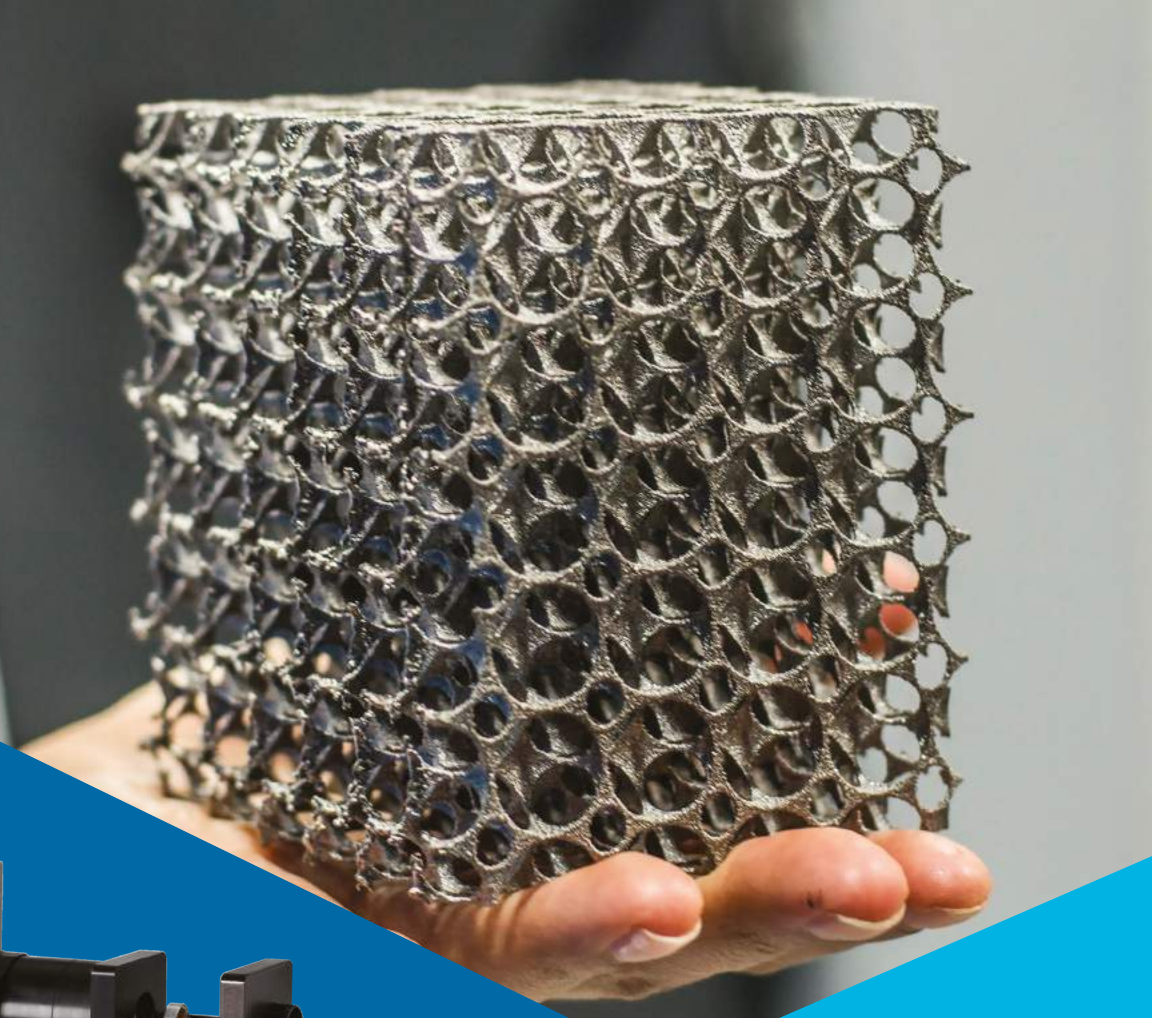
The implications could be significant; the ability to individualise treatments is expected to reduce healthcare costs by providing speedier and more efficient treatments. Importantly, it is hoped that this development will increase the success rates of cancer treatment, leading to improved quality of life and health for patients.

The same principles could mean huge advances in sectors outside healthcare. For example, airport and cargo scanners used to examine the contents of transport containers could be upgraded in the same way. These scanners often have tungsten grids which screen out stray X-ray beams to give a more accurate image; these grids are built up manually from many individual tungsten sheets, which could be replaced with additively manufactured alternatives.

Further, the geometric detail which can be incorporated into the tungsten, could now mean that increasingly complex components can be produced. In future, this could make it possible to manufacture handheld, lightweight medical scanners which can be used to examine individual organs and produce accurate imagery.

For more information contact Steve Jeffery, Business Development Manager, Wolfmet (stevejeffery@mimaterials.com).

www.wolfmet.com



€20 million IDAM project aims to integrate metal AM in automotive series production

Sponsored by the German Federal Ministry of Education and Research (BMBF), and coordinated by the BMW Group, IDAM is a research project with the aim of transferring metal Additive Manufacturing technology into an industrialised and highly automated process, specifically for the automotive industry. The consortium, consisting of twelve project partners including SMEs, large companies and research institutions, held its first meeting on March 27 in Munich, Germany.

With funding totalling over €20 million, the project titled 'Industrialisation and Digitisation of Additive Manufacturing for Automotive Series Processes' (IDAM) will run for three years. According to the project leaders, integrating metal Additive Manufacturing into conventional automotive production lines will enable them to replace costly and time-consuming processes, such as the production of moulds, as well as meeting a demand for product customisation at no extra cost.

Within the IDAM consortium, metal Additive Manufacturing is being implemented at both the BMW Group's Additive Manufacturing Centre in Munich, and GKN Powder Metallurgy's facility in Bonn, Germany. It is here that the IDAM team is qualifying metal AM technology for the specific requirements of producing identical parts as well as individual and spare parts. The team believes that it should be possible to mass produce at least 50,000 components per year, as well as over 10,000 individual and spare parts, using AM production lines.

The two modular and almost completely automated AM production lines, being established in Bonn and Munich, are expected to cover the entire process from component design to build to post-processing. Individual modules can be adapted to different production requirements thanks to the modular construction of the line and, if necessary, replaced. By taking an integrated view of the automotive production line into account, the project partners plan on reducing the manual share of activities along the process chain from around 35% to less than 5%. Additionally, the unit costs of additively manufactured metal components are expected to be more than halved.

The project is drawing on the expertise of the SMEs involved in the consortium for the design, provision and connection of the individual modules of the AM production line. These include the automation of interfaces between the individual process steps or, as part of the project, developing series-ready and modular production facilities for metal Additive Manufacturing.

Other modular process components, such as powder handling, monitoring and automated post-processing, are also being developed by relevant SMEs, while the research institutions supporting the project are developing tools for process control, digital twin and quality improvements, among others. These linked modules will be used in AM production lines under real conditions and on a large scale.

The partners involved in the IDAM research project include; Aconity GmbH, Concept Reply GmbH, Fraunhofer Institute for Laser Technology ILT, GKN Powder Metallurgy, Myrenne GmbH, Intec GmbH, Kinexon Industries GmbH, RWTH Aachen, Technical University of Munich, Schmitz Spezialmaschinenbau GmbH and Volkmann GmbH.

www.photonikforschung.de

This structurally optimised differential housing, jointly developed by GKN Powder Metallurgy and Porsche Engineering, is one of the growing new e-drive powertrain applications for metal AM (Courtesy GKN Powder Metallurgy)

Partners in the IDAM project at its first meeting in Munich (Courtesy BMW Group)

Titomic signs MoU to distribute Titanium Kinetic Fusion systems in Japan & South Korea

Titomic Limited, a metal Additive Manufacturing company based in Melbourne, Australia, has initiated a Memorandum of Understanding (MoU) with Osaka Titanium Technologies Co., Ltd., Amagasaki, Hyōgo Prefecture, Japan, and the Marubeni Corporation, Nihonbashi, Chuo, Tokyo, Japan, to distribute its Titomic Kinetic Fusion (TKF) systems in Japan and South Korea and supply aerospace-grade gas atomised titanium powders globally.

The TKF process applies titanium and titanium alloy powders onto a scaffold surface to rapidly produce titanium or titanium/composite products and parts. Due to the nature of the process, powder particles do not need to be of a uniform micron size, as is required in alternative AM techniques. Titomic states that the cost of this powder is approximately one fifth to one tenth that of traditional AM powders, resulting in components up to 50% cheaper.

The agreement with Osaka Titanium Technologies Co. and Marubeni is expected to help further Titomic's market development by enhancing TKF systems distribution, metal powder supply, and creating new market applications. According to Titomic, implementing these strategies will provide the company with an expanded global network for TKF system distribution and production run demand; a secured supply chain for metal powders required for high-value applications; and ongoing access to material science and next-generation titanium alloy powders for TKF systems.

"Titomic's partnering with OTC and Marubeni secures supply of the highest-quality aerospace-grade titanium powder, from a reputable global corporation, aligning with Titomic's development strategies in Aerospace and Defence," stated Jeff Lang, Managing Director at Titomic. "This partnership will enable the development of new titanium powder technologies which, when combined with Titomic's TKF automated production systems, drives new revenue opportunities through high-volume production of titanium parts for automotive and heavy industries."

Yusuke Yamamoto, General Manager at Marubeni, commented, "Marubeni has been supplying titanium raw materials to OTC for decades. We're very happy to have this opportunity to support OTC and Titomic in a new field of titanium powder. We believe the demand for TKF system and powder supply has significant potential in the future. We also believe we will have great success through combining Titomic's leading-edge technology, OTC's high-quality titanium powder and our network in the world."

Osaka Titanium Technologies' Managing Executive Officer, Yoshihisa Ohashi, added, "OTC is proud to announce our partnering with Titomic for supplying Titanium powder for the TKF system. We appreciate that Titomic identifies OTC as being such a high-quality producer of titanium powder with a long-history of being a global leading producer in high-quality titanium sponge. We are excited to be collaborating with such an innovative global leader of industrial scale, high-volume Additive Manufacturing as Titomic and are keen to create new commercial opportunities for titanium powder which can currently only be realised using the TKF process."

www.titomic.com

www.osaka-ti.co.jp

www.marubeni.com

EOS appoints Australian distributor for its Additive Manufacturing systems

EOS, Krailling, Germany, has appointed John Hart, a Melbourne-based company which supplies new machine tools, special products and factory automation, as the national distributor for its Additive Manufacturing solutions in Australia. Jack Wu, Sales Director for EOS APAC, commented on the agreement, "This partnership marks an important step for us in Australia as it will help us to jointly develop this market further towards a broader adoption of 3D printing."

"With learning curves and technology implementation accelerating, customers will be able to tap the full potential of Additive Manufacturing," he continued. "This technology will help customers to address their most demanding industry challenges which they cannot solve with conventional technologies and approaches today, as such enabling industry solutions that weren't thinkable before."

Mark Dobrich, John Hart's General Manager – Machine Tools, stated, "The addition of EOS to our product portfolio marks a milestone moment, not just for John Hart but for the Australian Manufacturing Technology sector, in that this will be the first partnership in Australia of a world leading additive machine technology company with a leading National Australian machine tool distributor."

"It is our belief that the Australian Manufacturing Industry has worked through the investigation stage of additive technology and is now preparing to enter the evaluation and adoption phases. The timing of this agreement places John Hart at the forefront of this technology and provides us with an opportunity to take a leadership position in the development and adoption of the technology with the Australian Manufacturing Industry, further enhancing our mantra of providing world class solutions."

www.eos.info

www.johnhart.com.au

Zenith Tecnica and HPSNZ collaborate on AM equipment for para athletes

Zenith Tecnica, Auckland, New Zealand, has collaborated with High Performance Sport New Zealand (HPSNZ), Auckland, New Zealand, to provide titanium additively manufactured prosthetics for para athletes preparing for the Tokyo 2020 Paralympics. Zenith Tecnica specialises in the design and manufacture of parts from titanium using Electron Beam Additive Manufacturing (EBAM). HPSNZ is a sporting technology company which works with National Sporting Organisations (NSOs) to provide high-performance sporting equipment and solutions.

The prosthetics were produced for Holly Robinson, who has already broken the world record in the F46 Women's Javelin with a throw of 45.73 m at the 2019 Australian Track & Field Championships, and Anna Grimaldi, who won Gold in the Women's Long Jump T47 and 4th Women's 100 m T47 at the Rio 2016 Paralympics. Through working with Duncan Anderson, the Hardware Engineer at HPSNZ, Zenith Tecnica was able to develop and produce advanced, tailored prosthetics for the two athletes.

It is hoped that the additively manufactured prosthetics will provide Robinson and Grimaldi with an advantage over the competition as they prepare for the Tokyo 2020 Paralympics. According to HPSNZ, the AM titanium equipment will open up training methods and exercises to the para athletes which would have previously been impossible due to the limitations of their former off-the-shelf prosthetic solutions.

Peter Sefont, Production Manager at Zenith Tecnica, stated, "Zenith Tecnica offers a freedom of design to a lot of engineers, so we are not constrained to classical manufacturing methods like machining and casting. It allows us and the engineers to do whatever we want."

"This is a piece of equipment that would enable them to train like an able-bodied person; granting the use of both arms with a full range of movement, achieving a full body balance," explained Raylene Bates, High Performance Coach at Athletics New Zealand.

Dr Stafford Murray, Head of Innovation at HPSNZ, added, "Zenith Tecnica 3D printed the new attachment for Holly and Anna to use in the gym. It's providing them with something different that you can't buy off the shelf, that enables them to be the best that they can be."

Both para athletes will be competing in the 2019 Oceania Area and Combined Events Championships in June, which it is hoped will provide the ideal opportunity to demonstrate how the use of Additive Manufacturing has benefited their performance ahead of the Tokyo 2020 Paralympics.

www.zenithtecnica.com

https://hpsnz.org.nz

Thyssenkrupp to establish Additive Manufacturing TechCentre hub in Singapore

Thyssenkrupp AG, Essen, Germany, is set to establish an Additive Manufacturing TechCenter Hub in Singapore in order to provide its engineering services to customers based in Asia Pacific. The Singapore facility will serve as the regional hub for the company's Mülheim TechCenter and aims to unlock the potential of AM for customers in Singapore and across the Asia-Pacific region.

According to Thyssenkrupp, Additive Manufacturing in Asia Pacific is expected to grow to more than $5.5 billion by 2025. The Research, Innovation and Enterprise 2020 or RIE2020 Plan of Singapore, which is the country's roadmap for research and development, includes Additive Manufacturing as one of the key enablers that will support the country's push for leadership in advanced manufacturing and engineering.

"Thyssenkrupp has always been at the forefront when it comes to innovation in engineering," commented Dr Donatus Kaufmann, Member of the Executive Board of Thyssenkrupp AG and responsible for Technology and Innovation. "We have made great strides with our Additive Manufacturing TechCenter in Germany. Establishing a hub in Singapore now reflects our commitment to bring our transformative innovations closer to the Asia Pacific region to meet our customers' needs."

The TechCenter Hub in Singapore, which is is supported by the Singapore Economic Development Board (EDB), together with the existing TechCenter in Germany, will focus on innovations around Additive Manufacturing solutions in metal and plastic technologies for customers in automotive, capital goods, chemical, mining and other heavy industries.

"Thyssenkrupp's Additive Manufacturing TechCenter Hub is an exciting addition to Singapore's growing ecosystem of Additive Manufacturing technology providers. We are delighted that Thyssenkrupp has chosen to anchor the centre in Singapore. Thyssenkrupp will be well-positioned to leverage our diverse manufacturing base and strengths in Industry 4.0 to serve the needs of customers in Asia Pacific," stated Lim Kok Kiang, Assistant Managing Director, Singapore Economic Development Board.

www.thyssenkrupp.com

PyroGenesis increases titanium powder production

PyroGenesis Canada Inc., Montreal, Quebec, Canada, a designer, developer and manufacturer of plasma atomised metal powder, plasma waste-to-energy systems and plasma torch products, reports that it has now produced titanium powder on its new NexGen™ Plasma Atomization System with production rates in excess of 25 kg/h. According to the company, these increased production rates were achieved with lower operating (OPEX) and capital (CAPEX) costs, while maintaining all of the characteristics demanded by the metal Additive Manufacturing industry, such as oxygen content, flowability, density, etc. Of note, this increased production rate was achieved at lower OPEX per hour, resulting in significant cost-per-kilogram savings.

"A limiting factor in titanium adoption in the marketplace has been its cost," explained Massimo Dattilo, VP of PyroGenesis Additive. "By lowering the cost of a typically expensive product, NexGen has opened the door to other markets and applications which, until now, found titanium to be too expensive to utilise. We expect that the NexGen price reduction will drive an increased adoption of PyroGenesis' powders into new markets and applications where the higher cost of plasma atomised powders was typically restrictive."

The increased production rate and lower cost of powder production on the NexGen unit is also expected to make it possible for PyroGenesis to produce new materials, via plasma atomisation, that have typically been cost restrictive. "As a result of NexGen's game-changing advantages, there is now an opportunity for the Additive Manufacturing industry to start experimenting with other materials which can now be produced economically with the NexGen Plasma Atomization System," Dattilo added. "Essentially, NexGen™ will allow PyroGenesis to convert low-value materials to high-quality powder that, until now, have been deemed to be too expensive to produce."

"In addition to a significant reduction in OPEX, the NexGen technology also boasts significant CAPEX reductions," stated P Peter Pascali, President and CEO of PyroGenesis. "The CAPEX reductions occur on two fronts: (i) the reactor itself has been simplified compared to conventional plasma atomisation resulting in lower fabrication costs and, (ii) given the increased production rate, the number of reactors and associated service equipment required has been reduced by up to a factor of four."

"This is a clear advantage over anyone using our legacy technology," he continued. "We are now in a rush to incorporate these advantages into our current production process before it is frozen during audits by aerospace clients. The production process is typically frozen by an aerospace end-user as a condition for contracting powder long-term."

www.pyrogenesis.com

Renishaw enables metal AM of Removable Partial Dentures

Metal additively manufactured Removable Partial Dentures produced by Renishaw (Courtesy Renishaw plc)

Renishaw, Gloucestershire, UK, has collaborated with Egan Dental Laboratory, Yorkshire, UK, a specialist in chrome cobalt and prosthetics, to fully digitise the design and manufacture of Removable Partial Dentures (RPDs), also known as chromes. The move to digital techniques is said to have halved the time required to produce a chrome framework and resulted in the production of stronger, more accurate, yet thinner RPDs.

Egan Dental Laboratory was established in 2002 and, collectively, its team has over seventy-five years of experience in the dental industry, supplying dentists with chrome frameworks, from one-tooth dentures to implant-supported prostheses. Being aware of the trend in crown and bridge dentistry towards a fully digital workflow, the company approached Renishaw to develop a robust Additive Manufacturing process for RPDs.

"We worked with Renishaw to develop an Additive Manufacturing process where every RPD produced is superb. We are now at a stage where every chrome framework is a perfect fit first time," stated Gill Egan, Managing Director of Egan Dental Laboratory. Prior to working with Renishaw, the company was using traditional methods to manufacture and design its prostheses, such as the lost wax technique.

Using this manual process, it took technicians two hours to complete each cast chrome framework. Lost wax casting is also prone to error because, when casting metal by hand, the cobalt chrome material used in RPDs shrinks on cooling. The technician must make models based on this principle, using expansion liquid so that when the metal shrinks during casting, the resulting framework still fits.

An additional issue with casting by hand is that the denture is constrained by manufacturing limitations which make it difficult to achieve a thin cross section. Attempting to do so often results in the deformation of the prosthesis. Errors can also be introduced if the molten metal doesn't enter the mould cleanly, causing frames to be incomplete, and there is also a risk of porosity if the molten metal is overheated, which can cause the introduction of excessive carbon – leading to structural weaknesses.

In order to develop a consistent internal work-flow for the Additive Manufacturing of RPDs, Egan Dental Laboratory partnered with Renishaw. The two companies worked together for over a year to develop a process suitable for every possible RPD. During the process, the laboratory transferred designs to Renishaw, which then produced the dentures and adapted AM system build parameters based on feedback.

Egan Dental Laboratory believes the most accurate method by which to produce RPDs is Additive Manufacturing. "The new process takes just forty minutes of manual work; less than half the time of the casting process," commented Egan. "The dramatic reduction in labour required means we could double the laboratory's productivity, as well as providing a cleaner, safer environment for our staff. I have also been able to use the additional time to develop new products, give lectures and share my experiences of digital dentistry with the rest of the industry. Another benefit for the laboratory is that with Additive Manufacturing there is no risk of carbon or miscasting and a reduced risk of porosity.

"As well as the immense saving in time, the laboratory is now able to produce RPDs that are lighter, stronger and more flexible than hand-cast dentures," she continued. "This is better for the patient, as they have a lighter, more comfortable fit. We've also had dentists report that they are experiencing less fracturing of the clasp and that when their patients come back for check-ups, the RPDs have held their shape and the clasp does not require tightening."

Chris Dimery, Sales Manager, Medical Dental Products Division, Renishaw plc., stated, "Around 95% of metal partial dentures are cast. This traditional process results in thick, bulky chrome frameworks that are not ideal for the dentist or the patient. Because of this, the industry is searching for alternatives. Additive Manufacturing enables metal RPDs to be smaller and more discrete. Additively manufactured chrome frameworks are exactly what the market needs: better for the surgeon, patient and dental laboratory."

"Working with Renishaw has been amazing," Egan added. "We have developed a process and a product that brings RPDs into the digital revolution and I urge the rest of the dental industry to grab digital technology with both hands. As an industry we must move forward – Additive Manufacturing provides the ideal platform for us to achieve this."

www.renishaw.com
www.egandentallab.co.uk

Electric Superbike Twente works with K3D to develop additively manufactured cooling shell

Electric Superbike Twente, Enschede, the Netherlands, has collaborated with K3D, part of The Kaak Group, Terborg, the Netherlands, to develop and produce one of the first additively manufactured components for the motorcycle racing industry. Like the first superbike produced by Electric Superbike Twente in 2018, the component, an electric motor for the company's second generation superbike, will be water cooled.

Feitse Krekt, Technical Manager of this year's Electric Superbike Twente team, stated, "The cooling shell of the first superbike consists of multiple parts, which were quite hard to produce using conventional production methods like turning and milling. For these production methods, lots of material was needed and therefore the end product turned out to be quite heavy."

"Also, the cooling performance was somewhat disappointing," he continued. "Because of the turning process, the wall thickness needed to be higher than optimal, and we were unable to cool the electric motor as efficiently as possible. Therefore we had less power than desired and sometimes needed to slow down to not overheat the electric motor."

"With this year's second generation superbike we wanted to optimise and redesign as many parts as possible. We saw that the cooling shell could be improved a lot by making use of Additive Manufacturing, for its advantages in functional integration and lightweight production. When looking for a production partner, we found K3D," Krekt further added.

Electric Superbike Twente and K3D's additively manufactured cooling shell (Courtesy Electric Superbike Twente)

"We were contacted by Electric Superbike Twente in the early stage of their design phase, which gave us the opportunity to guide them in their design for Additive Manufacturing," commented Jaap Bulsink, CTO of K3D. "We are very experienced with 3D metal printing and are always looking for opportunities to share this knowledge, especially when we are able to do so in such an awesome project as building an electric superbike."

The design of the cooling shell also benefitted from the geometric freedom offered by Additive Manufacturing. Bulsink explained, "The part has an optimal cooling performance due to the thin walled design with internal channels on the right spot. This was only possible with 3D metal printing where you have optimal freedom of design. On top of this, the part had been designed for minimal weight. The part was printed right the first time and is very accurate and can be used directly without any post-processing."

Once assembled, the Electric Superbike Twente team will reportedly test the superbike's performance, including the cooling system. "With innovations like this, it is always exciting to see if and how it works out, but we are already convinced that this 3D metal printed cooling shell is an utterly awesome piece of technology," concluded Krekt.

www.electricsuperbiketwente.nl
www.k3d.nl

Fourth ASTM International Symposium on Structural Integrity of Additive Manufactured Materials & Parts

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Two Additive Manufacturing research facilities to open in the Philippines

The Department of Science and Technology (DOST) of the Philippines has inaugurated the country's first Additive Manufacturing research facility and begun the construction of a second. The first facility to be opened by DOST is the Additive Manufacturing Research Laboratory (AMREL), based at Bataan Peninsula State University, which is said to be equipped with the latest Additive Manufacturing technology.

The AMREL facility will reportedly focus on the research and development of new materials, testing and characterisation of materials, rapid prototyping, tooling, manufacturing, training, education and empowerment, and design and analysis of parts and systems.

DOST's second research facility is the Additive Manufacturing Center (AMCen), for which the groundbreaking ceremony took place at the Metals Industry Research and Development Centre. Two DOST agencies are expected to lead the overall management of AMCen: the Industrial Technology Development Institute (DOST-ITDI) will develop new materials for Additive Manufacturing, while DOST-MIRDC will lead advanced prototyping.

During the ceremony, Fortunato de la Peña, DOST Secretary, emphasised the importance of partnerships with different agencies – national government organisations, non-government agencies, private companies, and academia – in optimising the programme objectives.

Dr Enrico Paringit, DOST-Philippine Council for Industry, Energy, and Emerging Technology Research and Development (DOST-PCIEERD) Executive Director, is also optimistic on the prospects of Additive Manufacturing in the Philippines with the launch of the two facilities. "We are launching two centres for 3D printing research and development and we, in DOST-PCIEERD, are privileged to be part of this game-changing initiative. The Additive Manufacturing research industry will open the doors to previously unimaginable possibilities, and every single 3D printed product will unfold more innovations. Soon, how we create things will be different from what we're used to," he stated.

"With the recent trends in the Industry 4.0, advanced Additive Manufacturing will support our independence from many imported items as well as sustain our development. It will also serve as a buffer with regards to the economic effect of importation, inflation, and dollar fluctuation while enhancing the technical support of the government to the industry," stated Dr Rowena Cristina Guevara, DOST Undersecretary for R&D.

www.pcieerd.dost.gov.ph

Metal Additive Manufacturing enables Sandvik's 'smash-proof' guitar

Sandvik's 'smash-proof' guitar

Sandvik AB, Sweden, has manufactured a 'smash-proof' guitar for Swedish metal guitarist Yngwie Malmsteen, using milling and metal Additive Manufacturing technologies. The guitar is said to be the world's first all-metal, unbreakable guitar, and is the result of a company-wide project at Sandvik to demonstrate how sustainable technologies can be used to make objects which are both highly precise and extremely durable.

At the beginning of the project Henrik Loikkanen, Machining Process Developer at Sandvik Coromant, viewed a number of videos of Malmsteen smashing guitars to understand what happens during the process. "We had to design a guitar that is unsmashable in all the different ways you can smash a guitar," he stated.

A major challenge for the 'smash-proof' design was the need to manufacture an extremely complex design, due to the need for high strength at low weight, enabling the guitar to be held comfortably while performing. To tackle this requirement, Sandvik chose to additively manufacture the titanium body of the guitar using Laser Powder Bed Fusion (L-PBF).

Amelie Norrby, an AM Engineer who participated in the guitar project, stated, "Additive Manufacturing lets us create lighter, stronger and more flexible components with internal structures that would be impossible to mill traditionally. And it's more sustainable because you only use the material you need for the component, minimising waste."

Tomas Forsman, a research and development specialist at Sandvik, stated that he believes the guitar project and the collaboration it required illustrates the ways in which Sandvik's wide range of expertise and experience can solve unique challenges, even faced with short timeframes. "Collaborating like this is a key for the future," he commented. "Our customers' challenges continue to grow more and more complex. We need to bring our expertise to work hand-in-hand with our partners and customers and keep inventing new ways of meeting those challenges."

When the guitar was complete, Sandvik gave it to Malmsteen to play. The guitarist debuted the guitar at a club in Florida, USA, and failed to smash it – instead damaging the equipment and surfaces he attempted to break it against!

www.home.sandvik

Nexxt Spine develops AM spinal implants using MTS test systems

Nexxt Spine, Noblesville, Indiana, USA, has used material test systems created by MTS Systems Corporation, Eden Prairie, Minnesota, USA, to further develop its additively manufactured porous titanium spinal implants. Nexxt Spine is an independent medical device company which designs and manufactures spinal solutions for patients with debilitating spinal conditions.

According to Nexxt Spine, as the world's population ages, spinal surgery is becoming more commonplace. Along with the deterioration that comes with natural ageing, spinal tumors or trauma can cause decayed, diseased or collapsed discs that are immensely painful and need to be repaired. The company is reportedly addressing these concerns by using MTS material test systems to develop bone healing spinal implants.

"We've immersed ourselves in the Additive Manufacturing space completely and positioned our future business focus as pioneers in the design and development of spinal fusion implants that incorporate interlaced micro-lattice architectures with the goal of promoting osteoconduction, osteointegration and bony fusion," stated Alaedeen Abu-Mulaweh, Nexxt Spine's Director of Engineering. "Given the highly nuanced nature of these intricate microgeometries, the MTS testing platform has been our go-to solution for quantifying and tailoring the associated biomechanical performance attributes from day one."

MTS is a global supplier of test systems and industrial position sensors. The company provides testing and simulation hardware, software and service solutions to enable customers to improve their design, development and manufacturing processes.

Dr Jeffrey Graves, President and CEO of MTS, commented, "MTS' expertise in creating systems for testing biomedical devices and simulating in-vivo conditions, combined with leadership in developing testing techniques for additively manufactured products, brings a unique set of knowledge to this type of testing application."

MTS is pleased to support medical device manufacturers in their quest to design innovative products that improve health and well-being," he continued. "In this case, MTS material test systems are helping Nexxt Spine find better ways to repair spines and improve quality of life for spine surgery patients."

www.nexxtspine.com
www.mts.com

Titanium AM spinal cage produced by Nexxt Spine (Courtesy Nexxt Spine)

Metal AM implants replace the smallest bones in the human body

It is thought that a pioneering surgical procedure using metal additively manufactured middle ear bones, developed by Prof Mashudu Tshifularo, head of the Department of Otorhinolaryngology in the University of Pretoria (UP) Faculty of Health Sciences, in South Africa, may make it possible to cure conductive hearing loss, a middle ear problem caused by congenital birth defects, infection, trauma or metabolic diseases.

The surgery, which can reportedly be performed on any patient, including newborn infants, replaces the ossicles – the three bones that make up the middle ear – with titanium additively manufactured ones. On March 13, 2019, Prof Tshifularo performed the transplant for the third time on a patient born with an underdeveloped middle ear, replacing the hammer, anvil and stirrup ossicles, the smallest bones in the human body, with titanium implants.

"By replacing only the ossicles that aren't functioning properly, the procedure carries significantly less risk than known prostheses and their associated surgical procedures," he explained. "We use titanium for this procedure, which is biocompatible. We use an endoscope to do the replacement, so the transplant is expected to be quick, with minimal scarring."

The surgery also aims to simplify the reconstruction of ossicles during middle ear procedures, such as ossiculoplasty and stapedectomy, in order to increase the chance of success with minimal intrusion trauma. In addition, Prof Tshifularo's procedure is said to reduce the chance of facial nerve paralysis, which can occur if the facial nerve that passes through the middle ear space is damaged during traditional surgery.

www.up.ac.za

Angus 3D reports early success of its AM services using Markforged Metal X

Andy Simpson, Managing Director, Angus 3D Solutions, holds a part produced on the Metal X system (Courtesy Angus 3D Solutions Limited)

Angus 3D Solutions Limited, a Scottish Additive Manufacturing start-up based in Brechin, Angus, UK, has reported early success in its new Additive Manufacturing service, using what is reported to be the UK's first commercially available Metal X system. The system was purchased with a grant of £175,000 from Zero Waste Scotland's Circular Economy Investment Fund – part of the Resource Efficient Circular Economy Accelerator Programme, supported by the Scottish Government and the European Regional Development Fund.

The Metal X system produces metal parts using a process Markforged refers to as Atomic Diffusion Additive Manufacturing (ADAM), in which metal powder bound in plastic is deposited a layer at a time to form the part geometry, then debound and sintered. It is believed that the only other Metal X systems in the UK are owned by Formula One teams and university laboratories, which do not allow them to be used externally.

Using the Metal X system, Angus 3D stated that it can offer new metal AM capabilities to the UK market, at up to ten times cheaper than would be possible using some alternative metal AM technologies. The binding of the metal powder in a plastic matrix also eliminates some of the safety and environmental concerns associated with AM technologies which use loose metal powder.

So far, Angus 3D stated that it has used the Metal X to additively manufacture lightweight custom parts for a bicycle business and components for a new product design for an oil & gas company, as well as to remanufacture obsolete components for a local textile manufacturer to help maintain production and reduce breakdowns. It's also producing test pieces for a Formula 1 team looking for help carrying out performance analysis on parts.

The majority of the parts produced so far have been for companies in Scotland, but Angus 3D reported that it has seen an increase in enquiries from companies in England due to the limited commercial availability of the binder-based technology in the UK. Angus 3D believes that its ability to provide AM services using the Metal X will advance the development of a circular economy in the Scottish region by allowing parts which would previously have been scrapped due to obsolescence to be put back into service through reverse-engineering– wherein their design is replicated using a 3D scanner and produced using the Metal X.

For example, an oil & gas company which had been scrapping electrical connections due to minor parts no longer being available has now begun to reverse-engineer and manufacture unavailable parts with Angus 3D, allowing the connectors to be put back in service and saving nearly £20,000, as well as reducing material waste. Speaking on this development, Andy Simpson, Managing Director of Angus 3D, stated, "I'm naturally delighted to get this world-leading piece of kit into production, as it will help our clients and Scotland's manufacturing industry develop the circular economy.

"Scotland has an impressive manufacturing history," he added. "To maintain and further develop this we must embrace the latest Additive Manufacturing technology and make it accessible, as well as encourage the next generation to look at manufacturing as a career choice. We're doing this by bringing the latest Additive Manufacturing technology to Scotland and the UK and making it accessible to all industries and individuals. This machine enables us to better support inventors, designers, SMEs and manufacturers in Scotland and beyond."

www.angus3dsolutions.co.uk
www.markforged.com

AddLab to become K3D-AddFab as it scales for industrial AM

AddLab, an open innovation centre for metal Additive Manufacturing launched in Eindhoven, the Netherlands, in 2013, has been renamed K3D-AddFab as it scales for industrial AM. The facility is jointly operated by partners KMWE, NTS-Group, Machinefabriek De Valk and K3D, who stated that they will scale the shared facility for the series production of AM components for high-tech equipment and aerospace.

As well as K3D-AddLab, K3D operates a Printing Technology Center (PTC) in Terborg, the Netherlands, and has reportedly produced over 45,000 metal additively manufactured parts at the PTC using a MetalFAB1 system from Additive Industries. Additive Industries will also provide process and application development support at K3D-AddLab, with a MetalFAB1 system set to be installed at the centre's new facility on Brainport Industries Campus, Eindhoven.

"We are proud to be able to take our unique collaboration in industrial Additive Manufacturing to the next phase and scale for series production of high-tech equipment parts and aerospace components. The K3D-AddFab team will be integral part of the K3D network of 3D Printing Centers allowing for load balancing, volume sharing and materials pooling," stated Luuk Wissink, CEO of K3D.

"Within K3D-AddFab we will jointly work on our development projects for the high-tech industry and aerospace customers like Airbus. The co-location on BIC allows us to combine additive technologies with our core-business in subtractive processes like milling and turning," added Edward Voncken, CEO of KMWE and Chairman of Brainport Industries.

Jan-Cees Santema, Sales Director Europe of Additive Industries, commented, "For us K3D-AddFab will be the testbed for distributed manufacturing in demanding markets as well as an extra training and demonstration centre around the corner from our headquarters. In a close partnership we will be able to accelerate learning that started when we opened AddLab almost six years ago."

www.additiveindustries.com

From left to right: Hans Reutelingsperger (NTS), Paul Neggers (NTS), Jaap Bulsink (K3D), John Hagelaars (Machinefabriek de Valk), Edward Voncken (KMWE), Luuk Wissink (K3D), Jan-Cees Santema (Additive Industries), Ilko Bosman (Additive Industries) and Daan Kersten (Additive Industries) (Courtesy Additive Industries B.V.)

Lincoln Electric acquires Baker Industries ahead of planned metal AM business launch

Lincoln Electric Holdings, Inc., Cleveland, Ohio, USA, has acquired Baker Industries, Inc., Detroit, Michigan, USA, and its related assets. Baker is a privately held provider of custom tooling, parts and fixtures, primarily serving the automotive and aerospace markets. Baker is said to have extensive in-house design and manufacturing capabilities, including machining, fabricating, assembly and Additive Manufacturing. Its operations are AS9100D certified and Nadcap accredited.

The Baker organisation is expected to complement Lincoln Electric's automation portfolio and its new metal Additive Manufacturing service business, planned to launch in mid-2019. Drawing on Lincoln Electric's core competencies in automation, software development and metallurgy, the new metal AM business will manufacture large-scale metal parts, prototypes and tooling for industrial and aerospace customers.

"We are pleased to welcome Baker Industries to Lincoln Electric and to our automation portfolio's new Additive Manufacturing platform," stated Christopher L Mapes, Chairman, President and Chief Executive Officer. "Additive Manufacturing is a key strategic growth area in automation, and Baker's expertise and capabilities will assist in scaling our Additive Manufacturing services and expand our presence in attractive aerospace and automotive end markets."

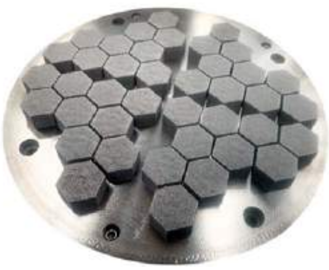
Lincoln Electric's automation revenue is approximately $500 million in annualised sales with the addition of Baker Industries. The terms of the transaction were not disclosed.

www.lincolnelectric.com

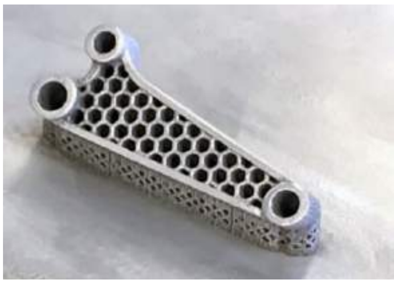
Aurora Labs MCP technology offers high-speed titanium and highly-dense aluminium parts

Aurora Labs, Bibra Lake, Australia, has reported using its Multi-level Concurrent Printing (MCP™) technology to produce a number of complex 10 mm high titanium parts on a 200 mm build plate in just 20 minutes. The company also reported that its MCP Additive Manufacturing process was successfully used to produce high-density aluminium parts.

Aurora Labs is an industrial technology company that specialises in the development of metal Additive Manufacturing systems, powders and AM parts. The company's Rapid Manufacturing Technology (RMT) production process is reportedly capable of achieving print speeds of up to 113 kg/day using its Multi-level Concurrent Printing system. In the MCP process, the system prints multiple layers simultaneously in a single pass. By printing on multiple levels at once, Aurora's machine is said to overcome key speed limitations in the Additive Manufacturing process.



Aurora manufactured these titanium hexagonal shapes in 20 minutes (Courtesy Aurora Labs)



An aluminium part produced with the company's Alpha RMT machine (Courtesy Aurora Labs)

In testing, the titanium hexagonal shaped parts were used as an example of the technology's ability to manufacture complex shapes at high speeds. "This as an exciting test for us, following on from our result in February that achieved 3D print speeds of 113 kilograms per day," stated David Budge, Aurora Labs' Managing Director. "This outcome will give our partners and future customers confidence that we have an Additive Manufacturing solution that can deliver the Holy Grail of rapid 3D printing, which is looking to revolutionise the production of parts in a whole range of applications."

Further positive results were reported during the first test run of Aurora's prototype Alpha RMT machine. The system manufactured an aluminium part at a density of around 99%. "This is an early stage result and we are expecting to achieve further significant manufacturing improvements," Budge continued. "Aluminium is in high demand for a range of high-value applications such as the automotive, aerospace and heat exchanger industries where consistent quality and meeting tight specifications is required."

www.auroralabs3D.com

General Dynamics Land Systems and GE Additive focus on combat vehicle AM components

GE Additive has been awarded a contract by General Dynamics Land Systems, a division of General Dynamics, located in Sterling Heights, Michigan, USA, for the qualification, production, post-processing and inspection of metal AM components.

General Dynamics Land Systems is reportedly developing applications for AM on its combat vehicle platforms and has chosen GE Additive to help accelerate incorporation; the companies are currently working together to identify applications in which AM can provide value through weight reduction, performance optimisation and lead time reduction. The company recently worked with GE Additive to transition a titanium cable guard to production in order to replace an 18-piece welded steel component, yielding an 85% weight saving compared with the existing part. The cable guard will reportedly be the first additively manufactured metal production part on a US ground combat vehicle.

Teams from General Dynamics and GE Additive are expected to focus on detailed process development activities to ensure a seamless transition from prototype to production. This will involve creating a standardised build plate orientation, as well as support structures and quality control plans, to deliver an efficient and repeatable production process. The companies stated that the cable guards will be additively manufactured for production on GE Additive's Arcam EBM Q20plus systems, which are said to be well suited to titanium alloys because the process takes place in a vacuum at elevated temperatures, eliminating residual stress and providing superior material properties.

"General Dynamics is always looking for innovative technologies to enhance our products, and Additive Manufacturing holds real promise in the near term. We'll continue teaming with leading suppliers such as GE Additive as we uncover additional applications for this exciting technology," stated Jason Deters, a specialist in Process & Technology Development at General Dynamics.

www.ge.com/additive
www.gdls.com

Siemens and Interspectral collaborate on 3D visualisation tool for metal AM

Siemens' gas turbine business in Finspång, Sweden, has entered into a collaboration with Interspectral, Norrköping, Sweden, a provider of custom tools and software for interactive 3D visualisation, to develop a 3D visualisation tool specifically for metal Additive Manufacturing. The tool, AM Explorer, has been in development since 2017 as an R&D project supported by innovation initiative Visual Sweden, and now makes the transition into product development.

Andreas Graichen, Head of Additive Manufacturing Center of Competence at Siemens, explained, "To improve and ultimately industrialise the [Additive Manufacturing] process you need to capture, explore and understand large amounts of heterogeneous data from the manufacturing process and increase domain knowledge. There is a need for a tool that generates true insights and new knowledge from the data."

"Based on our core visualisation technology we are designing an intuitive tool that will support interactive exploration and collaboration," stated Thomas Rydell, Business Developer & Co-founder, Interspectral. "Using AM Explorer, Siemens will learn more from the data that they collect, increase domain knowledge and minimise trial and error."

AM Explorer is expected to make it easier for engineers to gain insights into the Additive Manufacturing process and communicate challenges and solutions with stakeholders. CAD files, data from sensors and cameras, simulations, and metrology systems such as laser scanners and CT scanners, can be fused and visualised using the same tool.

Further, engineers will be able to filter, navigate, explore and analyse the data in an intuitive way. This is expected to enable them to detect anomalies and trace why and where in the manufacturing process they appeared.

"The collaboration with Siemens represents the beginning of a new and very exciting market segment for Interspectral," added Rydell. "The project is a great example of how our 3D software platform can bring value to companies working with complex 3D data and digital twins."

"We believe 3D-visualisation, including AR and VR, will be a key component in the industrialisation of additive manufacturing and tools such as the AM Explorer will be one part of the solution in our Additive Manufacturing roadmap at Siemens," concluded Graichen.

www.siemens.com
www.interspectral.com

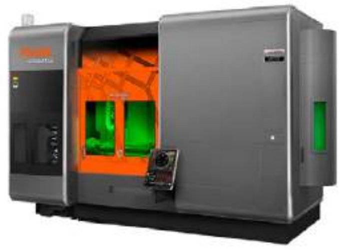
Mazak launches new facility in Florida to enhance customer support network

Mazak Corporation, the US arm of Japan's Yamazaki Mazak, is set to expand its customer support network by launching a new facility in Orlando, Florida, USA. The Florida Technical Center will reportedly serve manufacturers of all sizes across the state, including Florida's 'space coast', Tampa and Jacksonville regions, and will include the company's hybrid metal Additive Manufacturing solutions alongside its conventional manufacturing tools.

The Florida facility will provide access to the latest advanced manufacturing technologies from the company, as well as sales, service, application and training support. It is expected to open in the third-quarter of 2019 and comes shortly after it established its latest technical centre in the San Francisco Bay/Silicon Valley area of California, USA.

Mazak reports that for Florida manufacturers involved in the aerospace, medical, high-tech and other industries, the centre will serve as a source for the tools and knowledge required to increase the output of their existing work forces and reduce time spent training new, less experienced employees. According to Perry Leonor, Mazak Sales Manager for Florida, the new facility will allow manufacturers to experience live demonstrations of Mazak's most advanced technologies, including its Hybrid AM machines.

The company's hybrid systems include the Integrex i-400 AM range, which in addition to Additive Manufacturing technology feature in-built high-precision milling, machining and laser marking tools, and the VC-500 AM range, which combines full 5-axis machining with AM technology for high accuracy and finish.



Mazak's hybrid systems include the Integrex i-400 AM range, which in addition to Additive Manufacturing technology feature in-built high-precision milling, machining and laser marking tools (Courtesy Mazak)

"Our technology centers and technical centers are designed with customer success in mind and are built around the various manufacturing needs of each region," stated Dave Kennedy, General Manager of Mazak's Southeast Technology Center, located in nearby Suwanee, Georgia. "Customers not only want innovative machine technology, but also a partner that is close by that will work with them and provide the means to help overcome all their manufacturing challenges whether technology, application or training related."

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United Technologies: Pioneering new possibilities for Additive Manufacturing in aerospace

United Technologies Corp (UTC), through its Pratt & Whitney and Collins Aerospace businesses, has a long history of innovation in aerospace engineering. As Venkat Vedula, Executive Director of UTC's Additive Manufacturing Center of Expertise (AMCoE), and Vijay Jagdale, the centre's Principal Engineer, explain, this tradition is today being continued through the corporation's cutting-edge Additive Manufacturing activities. This report highlights, with the support of an in-depth case study, the centre's core areas of activity and UTC's vision for the future of AM.

From the propeller that powered Amelia Earhart's non-stop flight across the Atlantic, to the space suits worn by generations of US astronauts and the communications equipment that captured the footage of the first step on the moon, United Technologies Corp (UTC) and its businesses have over decades helped to define the aerospace and defence industries. Today, with more than 110,000 aerospace employees stationed globally at over three-hundred sites, UTC continues to drive innovation in commercial and business aviation, intelligent defence solutions, helicopter systems and spacecraft design and production. The company's portfolio also powers communications, navigation and surveillance technology for the world's leading aircraft companies.

As part of United Technologies, Pratt & Whitney and Collins Aerospace Systems represent the enterprise's deep commitment to aerospace innovation. Both businesses have a long history of manufacturing ingenuity, and each played a critical role in building the modern air transportation network. Now, as new technologies fuel rapid advances in the aerospace industry, UTC is building on its legacy of innovation with cutting-edge Additive Manufacturing initiatives. For over three decades, UTC and its business units have been using AM to prototype polymer and non-metallic parts. But more recently, recognising the vast potential of metal AM, the company has ramped up its efforts through the creation of UTC's Additive Manufacturing Center of Expertise (AMCoE) in East Hartford, Connecticut, USA (Figs. 1-2).

"UTC companies helped build the second industrial revolution in the early decades of the 20th century,"

Fig. 1 UTC's Additive Manufacturing Center of Expertise (AMCoE) in East Hartford, Connecticut, USA, is responsible for accelerating the adoption of AM across UTC's engineering and manufacturing organisations

Fig. 2 UTC's AMCoE is primarily focused on achieving certification for key AM processes, deploying a design-for-additive toolchain and training UTC's engineering and operations teams on both AM design and manufacturing

said John-Paul Clarke, Vice President of strategic technology at UTC. "As we build the next industrial revolution, additive could be a game changer in manufacturing. Our AMCoE is a mechanism for driving a critical mass capability across the enterprise."

Accelerating the adoption of Additive Manufacturing across the enterprise

While each business unit under the UTC umbrella has its own path on the UTC AM roadmap, the AMCoE is a cross-divisional organisation that aims to bring the creative minds in materials science, mechanical design, diagnostics and machine learning together to solve the toughest challenges. Launched two years ago, the AMCoE is responsible for accelerating the adoption of AM across UTC's engineering and manufacturing organisations. The initiative is focused on three key goals: achieving process certification for key AM processes, deploying a design-for-additive toolchain and training UTC's engineering and operations teams on both AM design and manufacturing. Together with ongoing efforts at individual UTC business units, the initiative will demonstrate new engineering and operations capabilities to produce cost-competitive additively manufactured parts across a range of materials and functions. The current focus is on nickel-based superalloys, titanium, aluminium and engineered plastics for brackets, fuel nozzles, complex manifolds and other components.

Most recently, UTC broke new ground in its AM efforts through the successful design, full-scale build and testing certification of a conformal heat exchanger, which this article will explore in greater detail. "Until now, manufacturing has been constrained by what's possible," stated Venkat Vedula, Executive Director of UTC's AMCoE. "But with additive, if you can imagine it, you can build it. In partnership with America Makes and the Collins Aerospace additive team, the conformal heat exchanger demonstrated that Additive Manufacturing opens the door to novel designs that allow us to truly optimise for performance."

Changing thinking, opening new markets

While the AMCoE is a catalyst for scaling AM operations across the enterprise, it's hardly UTC's first or only foray into the field. Since the 1980s, Pratt & Whitney has additively manufactured more than 100,000 prototypes, hundreds of which supported the development of its PurePower® Geared Turbofan™ (GTF) engine range. In 2017, the company took the major step of entering additively manufactured parts into

Fig. 3 This fully additively manufactured fuel nozzle for land-based industrial gas turbines for power generation applications was developed by Collins Aerospace. It is produced with just four components – compared with the seventeen components necessary for a legacy standard fuel injector shown in Fig. 4

production for its PW1500G Geared Turbofan engines, which were used exclusively by Bombardier for its CSeries aircraft family, now branded as the Airbus A220.

"Additive Manufacturing isn't just driving improvements in performance and quality, it's changing the way we design and even think about manufacturing challenges," explained Jesse Boyer, Technical Fellow at Pratt & Whitney. "Each additive project we undertake generates insights and creates opportunities for the ones that come next." Building on its decades of work in this area, UTC has already begun to realise new market opportunities, thanks to AM. For example, at Collins Aerospace, a fully additively manufactured industrial fuel nozzle (Fig. 3), produced with just four components – compared with the seventeen components necessary for a legacy standard fuel injector (Fig. 4) – opened up new possibilities for the business in the

Fig. 4 The conventionally manufactured fuel nozzle showing the volume of raw material required for its production

Fig. 5 The AMCoE features AM production equipment from a range of manufacturers

diesel segment. The AM fuel nozzle also yielded notable advantages, such as 75% shorter lead time, 10% weight reduction, 70% fewer operational steps and 80% less raw material.

"Additive Manufacturing gives engineers so much flexibility to solve our customers' challenges," commented Paula Hay, Executive Director of Additive Design and Manufacturing at Collins Aerospace. "The fuel nozzle solved a technical problem and enabled us to reach a new customer market the older product couldn't serve. As we drive toward the future, we're looking at the next level. How can we really take advantage of additive to create new designs that bring the biggest benefits?"

Next-level manufacturing for next-level aerospace technology

As the next generation of aircraft technology becomes more sophisticated, it seems clear that getting the most out of Additive Manufacturing – with new designs and novel concepts – will become more important than ever. Inspired by that challenge, United Technologies recently partnered with industry accelerator America Makes to develop a heat exchanger produced using Laser Powder Bed Fusion (L-PBF) for the Department of Defense and Air Force Research Laboratory (AFRL) [1]. New head-up displays, onboard electronics and other avionics, as well as engine advances, will create increasingly aggressive cooling requirements for thermal management systems. As a result, heat exchangers will need to meet a more advanced level of performance in the same or more constrained space.

The UTC-led team, which included UTC's AMCoE, the United Technologies Research Center (UTRC), Collins Aerospace, Pratt & Whitney, Stratonics and 3DSIM, set out to achieve several goals:

- Establish a quantitative link between key product characteristics and the manufacturing process parameters required for repeatable and reliable fabrication
- Address key risks and gaps in AM processes, including in-situ defect detection, non-destructive inspection and thin-fin manufacturing capabilities
- Demonstrate an additively manufactured heat exchanger and value proposition relevant to the Department of Defense and AFRL

"Heat exchangers play a critical role in the thermal management systems that remove heat generated from advanced electronics and more efficient jet engines," stated Brian St Rock, Project Manager, America Makes / AFRL project, UTRC. "But even though they must handle greater demands, performance improvements have been hindered by the limitations of traditional manufacturing. This project gave us an opportunity to experiment with conformal shapes that let us put performance first."

The proposed benefits of AM in a heat exchanger application

Traditional heat exchangers are rectilinear, box-like forms created with metal roll sheets that are brazed and welded together in a multi-step process that is often associated with low yield. Because the heat exchanger must fit into constrained, non-rectilinear spaces on aircraft, sometimes wrapped around the engine core, these linear segments are connected using transition headers to make a curved conformal shape. But the addition of these bridge-like components adds volume and weight and can create efficiency losses.

Conformal heat exchangers with curved sides and without the transition headers will improve thermal performance and flow distribution while reducing volume by around 10%. But manufacturing such heat exchangers through traditional methods is economically unfeasible and operationally arduous. Additively manufactured heat exchangers, on the other hand, promise to more effectively use overall volume by eliminating welding lines and distribution headers, thereby unitising the structure and improving yield, as well as reducing lead time for new products. They also improve thermal performance and flow distribution through complex fin topologies and spatially varied geometry. Localised geometry modifications, such as fillets, can also reduce stress concentrations and improve fatigue life.

A preliminary optimisation and benefit assessment conducted by UTC suggested that with an advanced additively manufactured heat exchanger design, a 40% improvement in precooler UA per unit volume (the product of the overall heat transfer coefficient and the heat transfer area) could be achieved. That would correspond to a 29% improvement in cooling capacity or an 11% decrease in the amount of engine bleed needed to drive the thermal management system.

Fig. 6 AM components developed by UTC reviewed in the AMCoE

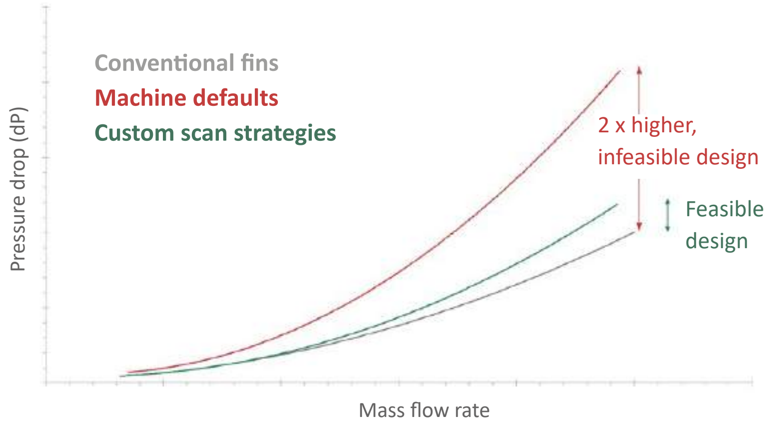

Fig. 7 Machine default parameters result in infeasible designs with 2 x pressure drop, custom strategies make them feasible

Limitations of the typical AM approach

Around 150 different process parameters can influence AM, from power to scan speed to build orientation. In a typical AM process, engineers assign a uniform set of parameters (also called 'defaults') to an entire component. But existing AM technology is not without its limitations. When it comes to producing a heat exchanger, merely switching from traditional manufacturing to out-of-the-box AM actually more than doubles the volume of the part, largely because default AM scan strategies generate fins that are 0.25 to 0.4 mm thick with a surface roughness of 7.6 to 25.5 micron, depending on build orientation. That is significantly greater than traditionally manufactured fins, which are 0.1 to 0.15 mm, with a surface roughness of 0.1 to 0.4 micron. When the fins are too thick and rough, the pressure drop exceeds the requirement. Indeed, it can be two-to-ten times higher than with smooth conventional fins.

While roughness can help increase heat transfer, depending on the fluid, its impact on the pressure drop is more significant. This is a highly critical trade-off and, if the roughness issue is not properly addressed, the resulting AM heat exchanger will not perform as needed (Fig. 7).

Fig. 8 An Inconel 625 additively manufactured heat exchanger developed by UTC and its project partners

Cutting a new path

To achieve the aggressive goals of the project, which touched various aspects of the AM value-chain, UTC assembled a multi-disciplinary team of experts with backgrounds in product engineering, design, AM, process modelling, in-process sensing and post-processing. UTC also embraced an approach that was systematic, model-guided, performance-driven and feature-based. This strategy enabled them to drive new Additive Manufacturing build strategies, develop a robust AM process and, as a result, create an effective heat exchanger (Fig. 8).

"This project provided freedom and required creativity, which made it a fascinating undertaking," commented Vijay Jagdale, Principal Engineer at the UTC AMCoE and lead investigator on the project. "We had to ask, 'What are the critical features of the heat exchanger that are driving performance? And what is the response needed at the feature level?' That thought process led us to focus on the fin thickness, its surface roughness and leak-free parting sheets."

Recognising the constraints of existing AM technology, UTC internally developed a product performance prediction tool to conduct the trade-off analysis between surface roughness and pressure drop and provide the necessary manufacturing targets. "The industry is still developing post-processing techniques to achieve the desired surface finish reliably and repeatably, as well as thermal post-processing to control defects," Jagdale continued. "Many a time, this can add up to be a significant portion of the additive product cost. We set out to minimise post-processing required to achieve surface roughness targets in the as-built configuration, as well as avoid the Hot Isostatic Pressing (HIP) process. This required taking calculated risks and pushing the limits of the technology through novel build strategies."

One of the team's critical innovations was to divide the geometry of the desired heat exchanger into various sections, including fins, parting sheets and headers. From there, they worked together, sample by sample, to use process models, in-situ process monitoring and process-mapping approaches to identify the optimal build strategies and parameters for each specific section (Fig. 9). Given that existing commercial AM toolchains and build set-up programs do not allow for the level of customisation required, UTC developed many new tools and approaches to enable the AM machines to, ultimately, create the desired end product.

"We took on more risk than some of our team members were accustomed to," Jagdale stated, "but we were comfortable, because our hypothesis was supported by physics-based models and a rigorous experimentally-validated scale-up approach."

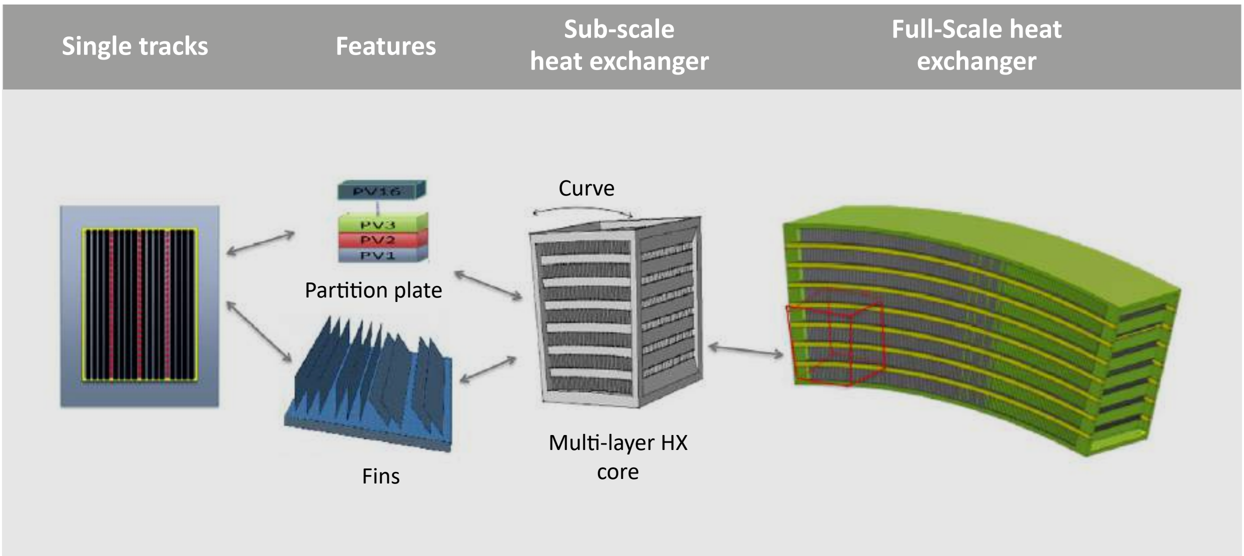

Fig. 9 Performance-driven feature-based approach guided systematic process and part development

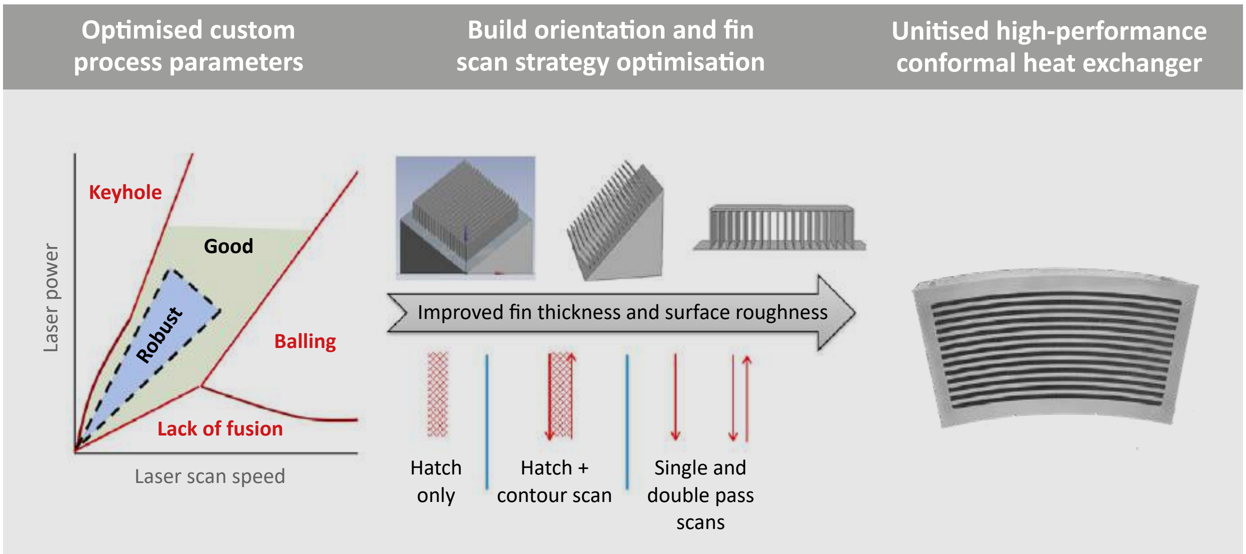

Fig. 10 Use of physics-based models and custom scan strategies enabled best feature-based response and rapid scale-up to high=performance heat exchanger

Fuelling innovation through physics-based modelling

UTC's physics-based model takes important process inputs into account, including key powder feed-stock characteristics, machine and laser level characteristics, thermo-physical material properties and key scan strategies, and then predicts a feasible process space in terms of laser power (P) and scan speed (V). It can also help classify process zones according to how defect-prone they may be, from predicting lack-of-fusion defects and balling to identifying conduction-dominated 'good' zones and keyhole regions of higher energy intensity (Fig. 10).

Once the model identifies 'good' zones, it is possible to then superimpose other variables, such as feature resolution, residual stress, distortion, microstructure and surface roughness, to narrow down the process parameter selection as a function of a particular feature and its performance needs. This physics-based model enabled the UTC-led team to rapidly develop a feasible process space, use select experiments to validate the process map and use these feature-based parameters for heat exchanger development.

This approach to modelling also helped empower the team to abandon the traditional linear waterfall approach to manufacturing, in which product engineers hand over directions to designers, who in turn deliver digital CAD files of 3D models to manufacturing operators, stated Jagdale: "Usually designers, product leads and manufacturing teams work in siloes, barely speaking to each other. For this project, we were collaborating and iterating continuously."

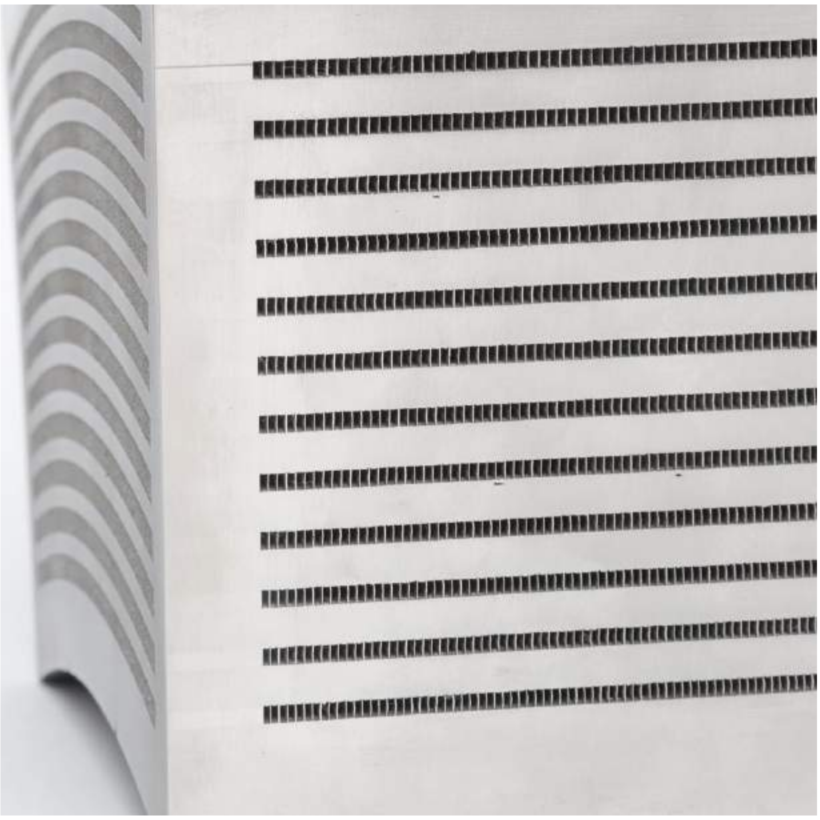

Fig. 11 Detail of the Inconel 625 alloy heat exchanger showing detail of the thin fins

A rigorous, repeatable approach for AM heat exchanger manufacturing

The team's willingness to test new boundaries and ways of working ultimately paid off. When the programme comes to a close this summer, they will have not only developed a high-performance conformal heat exchanger, but a systematic, repeatable methodology for manufacturing it. Compared to one produced conventionally, UTC's heat exchanger achieves about a 20% increase in heat exchanger effectiveness for the same volume. As the team continues to refine its proprietary parameters and scan strategies, as well as incorporate advanced heat exchanger topologies, it expects to move even closer to the over 30% reduction in volume suggested by its initial analysis.

So far, this approach has reportedly been demonstrated successfully on machines provided by three different OEMs. While this first project focused on the Inconel 625 alloy, the UTC team is also developing aluminium alloy heat exchangers internally. The machine and material-agnostic build strategies approach was assembled with material-specific parameters to enable an orders-of-magnitude reduction in product scale-up time.

Along with establishing a prescriptive methodology for the additively manufactured heat exchanger, the team also developed a comprehensive set of process data that enabled valuable links to be made – from acceptance test anamolies to indications identified in a CT scan, to the appearance of that indication on the in-situ process sensor during the build. These data-driven connections have the potential to support a digital thread for the entire Additive Manufacturing process and ensure the appropriate parameters are guiding its development.

New applications for conformal techniques

While the new heat exchanger itself is a valuable outcome of the project, the team's new ability to successfully build a conformal component is expected to open the door to a broader range of opportunities for Additive Manufacturing at UTC. "The fact that we were able to do things conformally is a huge piece of the puzzle," stated Hay. "That really creates new possibilities for us." For example, now that the team has demonstrated that it can additively manufacture parts robustly and utilise feature-based scan strategies, UTC can advance novel concepts in designing flow passages that improve efficiency in thermal management systems.

"now that the team has demonstrated that it can additively manufacture parts robustly and utilise feature-based scan strategies, UTC can advance novel concepts in designing flow passages that improve efficiency in thermal management systems..."

And further, Hay said it brings UTC closer to unlocking the true value of Additive Manufacturing. Replacing existing, traditionally manufactured parts with AM parts can deliver some advantages. But, she emphasised, the real potential is leveraging the design freedom offered by AM.

Fig. 12 The team at UTC's AMCoE is working on the full range of challenges that face the industry, from certification and regulation to future materials, end-to-end design tools and cutting-edge data analytics

Ready for takeoff

The motivating factor in all of UTC's work in AM is the enterprise's planned shift from development into production. The company has built up a strong base of materials knowledge and process-related best practices through years of prototypes and proof-of-concept projects. Now, it is focused on working through the certification and regulatory agencies that will help scale production. Part of that focus requires enhancing internal knowledge of its AM processes to enable it to overcome machine-to-machine variations and truly standardise part production. Another part of that means working with external partners so that the industry is aligned with itself and the regulatory bodies responsible for certification and approvals.

Hay noted that the heat exchanger project, conducted with America Makes and other partners across the industry, is a good example of the kind of collaboration the industry needs in order to move forward. Given that so many groups, from peer companies to academic institutions to AM associations, are working toward similar goals, she said it only makes sense for everyone to work together. "We're driving toward the adoption of additive," said Hay. "But we can't do it alone. Additive is ready for takeoff. There's no stopping what it can do."

On the horizon

In the coming years, UTC's AM initiatives, including the AMCoE and the United Technologies Research Center, will continue to explore new developments in materials, design, and data analytics. In addition to sharpening its understanding of materials systems commonly used today, the company is working to identify future materials that could advance industrial manufacturing. Controlled microstructures and custom alloys, for example, are expected to play bigger roles as the field pushes technology to new limits.

Building end-to-end design tools for AM that capture the entire value-chain, from mechanical design to analysis to post-processing, is another key priority for the enterprise. New technologies and new ways of working mean engineers need better tools for guiding decisions, managing workflow, validating cost assessment methodology and, in general, making 'smarter' choices with the new platforms.

"One of our key challenges is that we don't have design tools that offer end-to-end toolchains," commented Vedula. "The industry needs tools that can optimise the process from concept and design all the way through to production." Applying cutting-edge data analytics insights to Additive Manufacturing is also a critical target. For example, UTC is developing an automated, robust data-harvesting process that will establish a data path from initial part material feedstock to final characterisation. The goal is to assimilate unstructured and pre-aggregated data into a database environment that facilitates trend generation and reporting. It is also using machine learning methods to enhance the build quality of additively manufactured parts and develop a deeper understanding of the AM process.

Furthermore, the team is currently looking at the development of 'smart' parts, developed by embedding sensors in additively manufactured components. While industry peers are also pursuing Additive Manufacturing solutions, UTC believes that it is carving its own approach to accelerating AM development and deployment. With more than ninety years of manufacturing experience and over 430 unique patent families in AM technologies, the company is uniquely qualified to integrate AM technology into the design process. Its combination of physics-based models and in-process monitoring is unlocking an in-depth understanding of the process's capabilities and limitations, which will advance adoption through the certification of material and machine combinations. In short, this heat exchanger project demonstrates how UTC's holistic approach to AM balances the drive to get AM parts to production quickly, while achieving or exceeding aerospace quality standards.

"Its combination of physics-based models and in-process monitoring is unlocking an in-depth understanding of the process's capabilities and limitations, which will advance adoption through the certification of material and machine combinations"

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References / notes

[1] This material is based on research sponsored by Air Force Research Laboratory under agreement number FA8650-16-2-7230. The U.S. Government is authorised to reproduce and distribute reprints for Governmental purposes notwithstanding any copyright notation thereon.

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Additive Manufacturing at HP: A new ‘centre of excellence’ supports the move to volume production

On June 12th, HP Inc. formally opened its new 3D Printing and Digital Manufacturing Center of Excellence at its campus in Barcelona, Spain. Metal AM magazine’s Emily-Jo Hopson attended the event and here reports on the 14,000 m^2 facility’s opening and the company’s rapid rise in the world of Additive Manufacturing. She reveals how, whilst the company is not traditionally associated with equipment for industrial manufacturing, many of its core technologies directly lend themselves to a new generation of metal Binder Jetting systems.

From June 11–13, 2019, HP Inc. welcomed members of the global press and analysts to the opening of its new 3D Printing and Digital Manufacturing Center of Excellence at its campus in Barcelona, Spain. Serving as a global hub for HP’s Additive Manufacturing and Large Format Printing businesses, the Barcelona campus employs some 2300 staff, among them more than 700 research and development engineers, and supports twelve of HP’s diverse businesses across ten buildings. On average, the campus’s R&D staff are credited with filing more than one hundred patents per year.

The new 3D Printing and Digital Manufacturing Center of Excellence comprises what HP’s campus staff call ‘Building 10’, and is solely dedicated to R&D activities in Additive Manufacturing, supporting both HP’s well-established polymer AM Multi Jet Fusion business and the development of its new Metal Jet technology and applications. Housing roughly one-hundred Additive Manufacturing machines, the opening of the centre coincided with HP’s 80th anniversary year since its founding by two friends in Palo Alto, California, USA, and marks a strong commitment to the future of the company’s business in digital manufacturing technologies.

Spanning 14,000 m^2, the centre marks not only HP’s investment in the development of its business, but also shows a considerable commitment to sustainability, producing more than 110 kW of photovoltaic power through a large canopy of solar cells,

Fig. 1 Exterior view of HP’s 3D Printing and Digital Manufacturing Center of Excellence in Barcelona, Spain (Courtesy HP)

Fig. 2 The 14,000 m^2 centre marks not only HP's investment in the development of AM, but also a commitment to sustainability, producing more than 110 kW of photovoltaic power through a large solar cell canopy (Courtesy HP)

integrating rain water reuse facilities for irrigation and sanitary purposes, as well as making use of natural light optimisation and eco-friendly construction. At a company level, HP stated that its goal is to use 100% renewable energy in its global operations over time, with a target of 60% by 2025.

Throughout the event, HP Barcelona's management team was keen to impress upon its guests the importance of the new centre's opening within the wider context of HP's history. The launch provides a significant expansion to the company's existing R&D capabilities in Corvallis, Oregon, USA; Palo Alto, California, USA; San Diego, California, USA; Vancouver, Washington, USA; Barcelona, Spain; and Singapore. Upon its opening, it already unites hundreds of experts in systems engineering, data intelligence, software, materials science, design and digital manufacturing in what is believed to be the world's largest ever concentration of Additive Manufacturing specialists in one location.

"HP's new 3D Printing and Digital Manufacturing Center of Excellence is one of the largest and most advanced 3D printing and digital manufacturing research and development centres on earth," stated Christoph Schell, President of 3D Printing and Digital Manufacturing at HP Inc. "It truly embodies our mission to transform the world's biggest industries through sustainable technological innovation. We are bringing HP's substantial resources and peerless industrial 3D printing expertise together with our customers, partners and community to drive the technologies and skills that will further unleash the benefits of digital manufacturing."

Specifically designed for active collaboration across HP's engineering and R&D groups, customers and partners, the new facility integrates flexible and interactive layouts, co-development environments and fleets of the latest HP metal and plastic Additive Manufacturing systems to drive rapid and agile product development and end-to-end solutions for its customers. Partners such as GKN Powder Metallurgy, Siemens, BASF, Volkswagen and others across the automotive, industrial, healthcare, and consumer goods sectors will continue their collaborations with HP on new AM and digital manufacturing innovations at the centre.

An in-depth look at the HP Metal Jet

Being historically focused on computing and 2D printing solutions, HP's background in Additive Manufacturing is relatively short, having announced its intention to move into the space in 2015, launching its first Multi Jet Fusion system for polymer AM in May 2016 and establishing its HP 3D Printing brand in 2017.

Fig. 3 The new 3D Printing and Digital Manufacturing Center of Excellence supports both HP's well-established polymer AM Multi Jet Fusion business and the development of its new Metal Jet technology (Courtesy HP)

By 2018, the company was ready to expand its portfolio of polymer AM systems and, in 2019, the focus has been on accelerating and verticalising this portion of the business. The wealth of experience and customer faith HP has built up over this short period is considerable, and it now claims that its Multi Jet Fusion customers are producing, on average, ten million plastic parts a year.

Following HP's entry into polymer AM, it did not take long for speculation to begin on whether the printing giant would ever make the leap into metal Additive Manufacturing, and in October 2017, Stephen Nigro, then HP's President of 3D Printing (since retired), revealed the development of a metal AM approach which he called "a major step for HP 3D printing aspiration." This approach was, of course, Metal Jet, HP's take on Binder Jetting.

The first Metal Jet system saw its official launch less than a year later in September 2018, at the International Manufacturing Technology Show (IMTS) in Chicago, Illinois, USA. HP also announced during the launch partnerships with GKN Powder Metallurgy, the world's largest Powder Metallurgy components producer whose operations include a major Metal Injection Moulding plant in Bad Langensalza, Germany, as well as extensive metal powder production facilities, and US-based MIM pioneer Parmatech.

These were the first companies to integrate the new systems at their facilities for parts production, enabling their customers to benefit from the capabilities and production volumes offered by Binder Jetting, and providing vital feedback to enable HP to develop and finalise its design.

In Barcelona, attendees were for the first time able to see Metal Jet systems in action in HP's Process and Applications Development Lab. In a presentation by Tim Weber, Global Head of 3D Metals for HP, the machine and its technology were reviewed in-depth. Setting the Metal Jet apart from other Binder Jet solu-

"The wealth of experience and customer faith HP has built up over this short period is considerable, and it now claims that its Multi Jet Fusion customers are producing, on average, ten million plastic parts a year."

Fig. 4 A polymer AM system at HP Barcelona. The company uses the same printhead technology in every single printer it produces, enabling them to be produced quickly and at a low cost (Courtesy HP)

tions on the market, Weber stated, is HP's use of its well-established PageWide inkjet technology, optimised over the course of its thirty years in 2D printing and installed across all of the company's 2D and 3D printers, and its over ten years of expertise in latex technology.

Tried and tested printhead technology

As a manufacturer of digital (2D) printers, Weber stated, HP is number one or two globally in almost every price category, from \$100 to \$10 million. "We build 25 million printers a year," he stated, "and use the same printhead technology in every single product. So we have the ability to make them, make them quickly and make them at incredibly low cost." This means, he explained, "I can double or quadruple up my nozzles for redundancy, for productivity and to improve the system very cheaply. If they break, they're very easy to replace." Decades of design optimisation and the low-cost of installing multiple, high-density inkjet nozzles per machine is reported to enable the Metal Jet system to achieve jetting speeds of around fifty times faster than HP's competitors.

A unique latex-based binder system

The advanced latex chemistries developed by HP lend significant benefits to the binder itself. Originally developed for use in signage and having the ability to adhere to glass, vinyl, or metal, Weber describes HP's proprietary long-chain polymer latex glue as "the world's best binder for gluing metal powder together."

By using its proprietary latex glue, HP is reportedly able to use twenty times less binder than typically employed in MIM, resulting in a green part chemistry of < 1% binder by weight. "This allows us to skip the debinding step," Weber explained, "which enables us to produce larger parts, due to the open pore structure for when you do remove the binder."

Driving productivity and cost-effectiveness

With its stackable build chamber of 430 x 320 x 200 mm, the system offers the capacity to additively manufacture hundreds (if not thousands) of parts in a single batch. The first materials available for use with the Metal Jet system are 17-4PH and 316L stainless steels, with finished parts said to deliver isotropic properties that meet or exceed ASTM and MPIF Standards for tensile strength, yield strength and elongation. Weber stated that the company's goal is to make low-alloy steels – "the workhorse of the automotive industry" – available for its Binder Jet process.

In addition to productivity, a major focus throughout the ongoing development of the Metal Jet system has been on cost-effectiveness. "When we started the investigation and HP was getting into this, we recognised that to build this business it was not just about prototyping, it was about manufacturing," stated Weber. "In order to get into manufacturing, one thing that is absolutely key is economics. If you don't have a cost-effective part, you are not going to get into manufacturing unless it's a very high value application."

HP has designed the Metal Jet system for cost-effectiveness in two key ways: by using 'off-the-shelf' Metal Injection Moulding powders, available at much lower costs than existing metal AM powders, and by developing a system which will be available to purchase for less than

Fig. 5 HP's Tim Weber, Global Head of 3D Metals, shares insight into the advantages of the company's Metal Jet technology (Courtesy HP)

$400,000, in a market where the majority of metal AM systems carry price tags of $500,000 +. "If you combine off-the-shelf powder with a low-cost printer with this kind of productivity, you end up with a cost-effective solution that will enable folks to get into manufacturing even before beginning to take full advantage of what 3D printing brings to the table," Weber stated.

Strategic alliances driving development in the right direction

Of course, the focus cannot be placed wholly on speed and affordability, both of which mean little without a quality output. While Weber believes that HP is the world's best printing company, he admitted, when explaining the decision to partner with Volkswagen, GKN Powder Metallurgy and Parmatech for the development and customer testing of its Metal Jet systems, that "we don't know much about making metal parts, we don't know much about making automobiles, and we don't know much about how to produce metal powders."

Since forming these partnerships, HP has produced and installed multiple Metal Jet machines and has already begun to make progress on its production service, developing applications for customers including and beyond Volkswagen. "Typically, that might be a two-year development cycle from the point of conception to the point you want to go into production," Weber stated; "you iterate, you go back and forth. But this partnership allows us to do this with our partners, with a clear path into manufacturing as we develop the final product."

"We are learning a ton with our partners," Weber commented. "The final product is going to be a lot more robust, a lot more 'sealed up' relative to regulations, and a lot more ready for automation and factory integration. If we hadn't made these partnerships, if HP had done it alone from the beginning, this product wouldn't be half as good."

Guido Degan, Senior Vice President Additive Manufacturing and Business Development at GKN Powder Metallurgy, and Sven Crull, Volkswagen's Head of Design for New Manufacturing Technologies, joined Weber for a panel discussion during the opening event in Barcelona.

GKN Powder Metallurgy consists of GKN Hoeganaes, GKN Sinter Metals and GKN Additive and provides metal powders, conventional PM components and Additive Manufacturing across thirty-four global locations. The company produces some 300,000 tons of metal powder annually – considerably more than the 2,000 tons of metal powder currently produced for the Additive Manufacturing market worldwide – as well as 20 million precision Powder Metallurgy parts per day. As a producer of both metal

Fig. 6 Christoph Schell, President of 3D Printing and Digital Manufacturing at HP Inc., spoke to guests about the importance of the entire digital manufacturing ecosystem to the wider adoption of AM

AM powders and parts, the company has much to gain from the scaling up of the AM metal powder market and has previously made substantial investments in the industrialisation of Additive Manufacturing, notably as the first automotive supplier to begin series production using metal AM. In the first half of 2019, it began to supply its first customers with industrial-grade AM parts using the HP Metal Jet.

While GKN Powder Metallurgy is one of many manufacturing businesses with a stake in metal Additive Manufacturing, and certainly not the only one with the ability to supply AM parts to its customers, Degan expressed his belief during the partner panel that the sheer scale of its operations, combined with its in-depth expertise, puts the company in a unique position for scaling new manufacturing technologies. "We have more than three thousand customers around the globe, we know what they want, and we know how to influence materials," he stated. "We offer the whole value chain from materials design to manufacturing services." Now, he stated that GKN's focus is on scaling metal AM technology for true production, with a focus on the automotive and other industrial sectors.

Asked why GKN Powder Metallurgy chose to pursue this goal in partnership with HP, Degan explained that, while the company had already gained experience in laser-based Additive Manufacturing technologies, it had considered Binder Jetting as being 'a bit out there.' However, when approached by HP and after a visit to the company's Corvallis facility, Degan stated that it became clear that HP was approaching metal AM at the right scale and with the right mindset. "For us, as a mass production manufacturer, it was this mindset that was the biggest motivation to say yes to a great partnership."

Volkswagen's Crull discussed the partnership with HP from the same perspective of scale, stating his belief that the scaling up of metal AM for production will only be successful if processes and parts are developed in parallel. One key reason for this which Crull spoke of is the importance of regulations in automotive parts manufacturing. By developing the Metal Jet process with key target industry regulations in mind, in partnership with Volkswagen and major automotive supplier GKN, all three companies hope that HP can build trust within highly-regulated industries for as smooth a transition as possible from prototyping to production.

"We don't know anything about AM technology or the behaviour of AM parts in a car," Crull explained. "It's much harder to push technologies into the market which are not designed for it." It makes sense, then, to design the Metal Jet as an automotive-ready production technology, while at the same time designing automotive parts which are ready for production by AM.

"One of the reasons HP chose partners like GKN and Volkswagen is because we're getting into a space where we know nothing about the regulations," Weber added, "and we want to work with folks who are at least knowledgeable about what the current regulations are. This is also why we're working toward meeting those regulations that exist rather than creating special new ones for our technology."

An end-to-end solution for the rapid acceleration of metal AM

This holistic view of AM's acceleration and industrialisation was echoed throughout the event. Earlier in the programme, Christoph Schell spoke to guests about the importance of the entire digital manufacturing ecosystem to the wider adoption of AM.

Through providing ongoing support to its Multi Jet customers, and through continuing collaborations

Fig. 7 Stainless steel demonstration parts manufactured using HP's Metal Jet technology

with universities and research institutes, HP has gained a thorough understanding of the AM value chain. It has come to understand that to accelerate the transformation from a small-scale prototyping technology to a production-ready solution, HP must make available to its customers an ecosystem which can provide end-to-end solutions, a digital manufacturing network and digital manufacturing integrations; productivity, quality and performance in the machines it provides; a robust architecture of data intelligence and software solutions; in-house materials innovation, and customer support.

By integrating with partners with the capabilities to provide support at all levels of the digital manufacturing ecosystem, as well as developing those aspects it can in-house and providing extensive support through customer experience centres such as Barcelona, HP believes it holds the keys to allow AM to make major inroads from prototyping into industrial applications. As a company with proven experience of rapidly scaling new technologies in a changing industry – it was already producing millions of 2D printers before the year 2000 – HP may have the resources at hand to buck the much-bemoaned trend of slow time-to-market for new metal Additive Manufacturing technologies.

When the HP Metal Jet was officially announced at IMTS 2018, the company forecast wide commercial availability coming in 2021, with select availability set for 2020, but in his welcome address in Barcelona, Christoph Schell revealed that the project is currently running ahead of its planned product cycle. "I'm very optimistic about the HP Metal Jet," he stated. "We're already starting to quote some customers on their needs, even with the product not being on the market yet."

One thing was made clear through numerous comments and slides during the event: HP's management believes the company holds "the winning hand" for the development and production of industrial Additive Manufacturing solutions. While no new technology can expect a seamless transition into the marketplace, it will be interesting to see what impact HP's unique background, extensive alliances and in-house expertise will have as Metal Jet finds its place in the increasingly competitive Binder Jet market.

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Powder removal: The Achilles heel of powder bed-based metal Additive Manufacturing

The broader industrial-scale use of powder bed-based metal Additive Manufacturing is resulting not only in improvements in process performance and material properties, but also in a growing scrutiny of the process by regulators, risk managers and legal departments. One key area of their focus is powder removal, the step in the production chain where there is perhaps the greatest risk to worker and plant safety as a result of dust exposure. Joseph Kowen reviews the current status of this topic and reports on how leading producers are addressing what is often described as the Achilles heel of metal AM.

AM is becoming increasingly industrial in nature. Much has been written about various aspects of this trend, and it is reasonable to assume that the process of industrialisation is now well underway. This is particularly true in metal AM, as regular readers of this magazine will know. Now, as AM emerges as a serious manufacturing method, regulators, risk managers and legal departments have begun to take note; what was sufficient for parts manufactured infrequently or in small quantities is not sufficient for manufacturing parts in the higher quantities that industrialisation demands, and new questions are being asked of the technology that were never addressed before.

Attendees at the Additive Manufacturing Users Group (AMUG) Conference in Chicago in March 2019 will have noted that a number of presentations at the event were concerned with issues peripheral to the AM process itself. For example, speakers took a deeper dive than previously into subjects such as safety and the fire and explosion hazards associated with common materials used in AM.

While safety and health issues apply generally throughout the Additive Manufacturing segment, metal AM is attracting the closest attention. One reason is that improvements in process performance and material properties have resulted in a broader use and application of the technology. Another reason is growth: metal Additive Manufacturing is growing faster than non-metal. The *Wohlers Report 2019* states that, while unit sales of all industrial systems increased by 17.8% in 2018, metal systems unit sales grew by 29.9% during the same period. Finally, metal AM is inherently more complicated, challenging and potentially dangerous than polymer AM, so health and safety issues are less easily deferred or ignored.

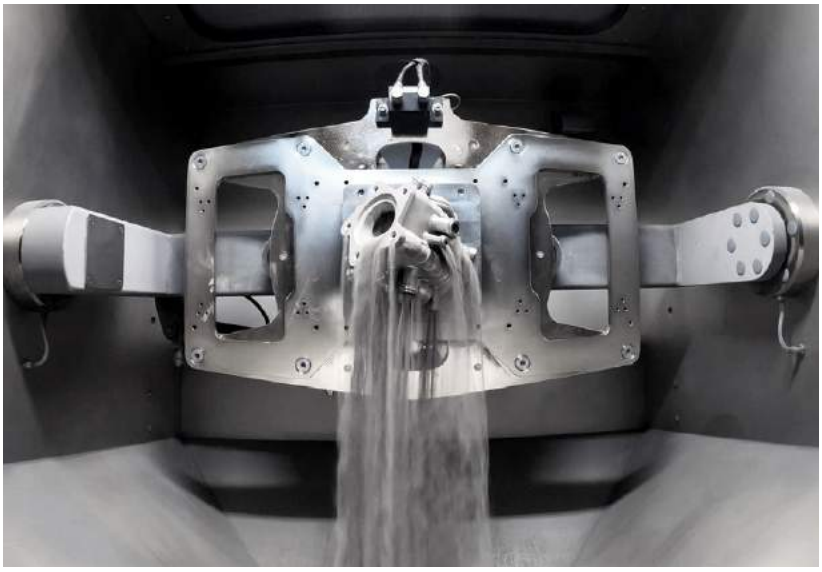


Fig. 1 Automated powder removal in progress in a Solukon SFM-AT800

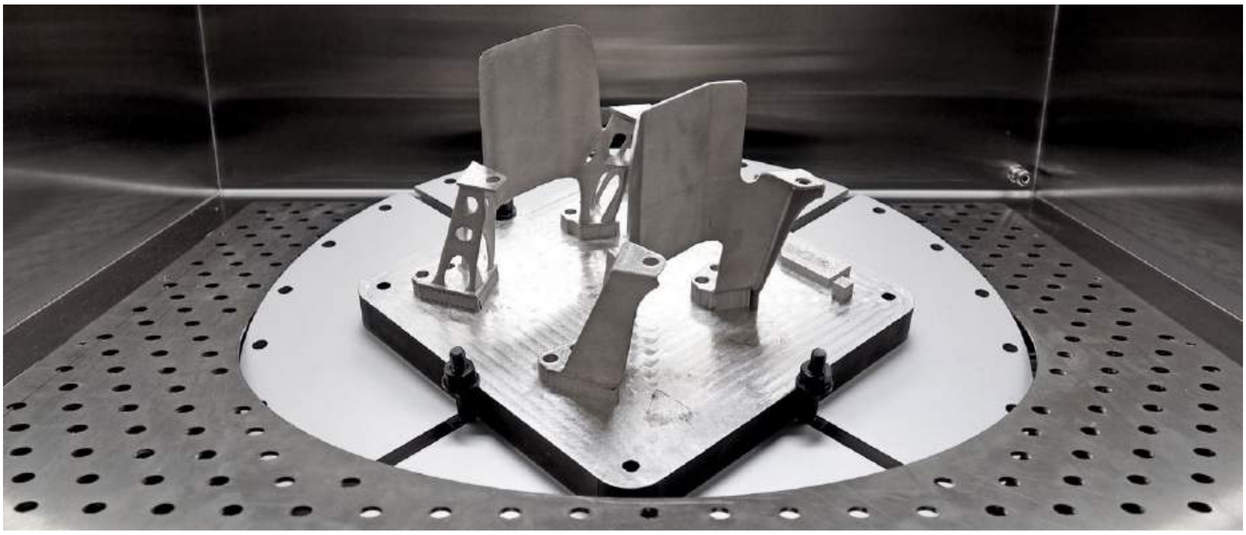


Fig. 2 Internal view of PowderShield system (Courtesy of Inert Corporation)

Fig. 3 Inert PowderShield system (Courtesy of Inert Corporation)

The predominant metal AM technology in the market today is Powder Bed Fusion (PBF). Since PBF systems work on the basis of the fusion of fine metal powder, one of the key issues in the industrialisation of this process is the removal of powder from AM parts after they come out of the machine. Depowdering might be referred to as 'the Achilles heel' of metal powder bed-based AM, and occurs at the moment of birth of a part. In our article in the Spring 2018 issue of *Metal AM*, we looked at some of the pain points faced by users of PBF systems, listing the issues of explosion risk, occupational health, labour costs, powder recovery, cleaning quality and process repeatability. To these we can add the growing need to avoid mixing of powders of different kinds, which is a particular concern in segments such as aerospace. A backdrop to these operational issues is a growing trend towards regulation and standardisation, which pushes manufacturers to think more carefully about their manufacturing processes, both at the level of requirements for the part itself (such as cleanliness and process repeatability) and at the level of the facility in general (contamination, occupational health and explosion risk).

What should a good metal powder removal system contain?

While some machine manufacturers implement some level of powder removal and management inside their systems, or in peripheral equipment offered by them, these solutions do not address all of the problems associated with powder removal. Put more simply, current approaches by systems manufacturers to vacuuming and processing excess powder from the build plate inside the machine or external to the machine are insufficient to remove enough powder either for reasons of safety, or for achieving the desired level of cleanliness. None rise to the level of a full-blown powder removal system. To appreciate this, one needs to understand the key functions of a good powder removal system:

- **Vibration of the build plate to dislodge stubborn powder**
  Variable frequency and intensity to match the part's size and geometry and for the avoidance of damage to delicate or thin-walled parts
- **Rotation of the build plate**
  The higher the degrees of freedom of rotation, the greater the possibility of reaching and cleaning hard-to-remove powder inside support structures or internal channels
- **Inert gas capability**
  Needed to process reactive metal powders, such as titanium and aluminium, to avoid explosion risk
- **Programmability and automation**
  Offers repeatable cleaning cycles and reduced manual effort
- **Compressed air or gas to assist in the cleaning process**
  But only within an airtight environment, to avoid blowing particulate matter into the atmosphere.
- **Access for large parts (if relevant)**
  Easy crane loading from the top of the system, or back entry for robot-loading system integration

Currently, there are two main suppliers of dedicated, standalone depowdering systems on the market. Solukon Maschinenbau GmbH of Stadtbergen, Germany, has developed the SFM range of powder removal solutions in a number of sizes and configurations. Inert Technologies of Amesbury, Massachusetts, USA, is a supplier of gas management solutions in a number of industrial applications and has recently entered the AM market with the PowderShield system dedicated to metal powder removal.

Feature	Inert PowderShield	Solukon SFM-AT800
Table size	533 mm diameter	800 x 400 mm
Maximum build plate weight	50 kg	300 kg
Vibration	Yes	Yes
Adjustable vibration frequency	Unknown	Yes
Programmable vibration	No	Yes
Rear or top access for loading build plate	No	Yes
Inert gas capability	Yes – in all systems	Yes – optional per customer need
Programmable cleaning cycle	No	Yes
Motorised axes of movement	None	2 axes
Maximum rotation/tilt (y axis)	45 degrees	360 degrees
Glove access, blow off gun	Yes	Yes
UPC-UA control	No	Yes
Robot loading	No	Optional

Table 1 The main features of two standalone depowdering systems

How do these systems stack up against the key functions of an ideal depowdering system? Table 1 compares basic features of the top-of-the-line systems from the two established suppliers.

In the final analysis, the choice of a powder removal strategy will depend upon the needs of a particular manufacturer. Removing powder from a 20 mm height build of dental parts is far different from that of a large heat exchanger with complicated internal channels. Not all systems will need inert gas capability, which will only be required if the system is running a reactive metal powder. So how are leading Additive Manufacturing practitioners dealing with the removal of powder?

> *"...the choice of a powder removal strategy will depend upon the needs of a particular manufacturer. Removing powder from a 20 mm height build of dental parts is far different from that of a large heat exchanger."*

Powder removal in practice: stories from the shop floor

With more than a year of further industry development behind us since our earlier article, we decided to take a look at how powder removal strategies are now being implemented on the shop floor. We have focused on companies that have sought and implemented industrial solutions for powder removal after having encountered either all or some of the pain points mentioned. While the information gleaned from conversations with these companies is anecdotal, it serves to shed some light on how companies on the front lines are dealing with powder management and removal.

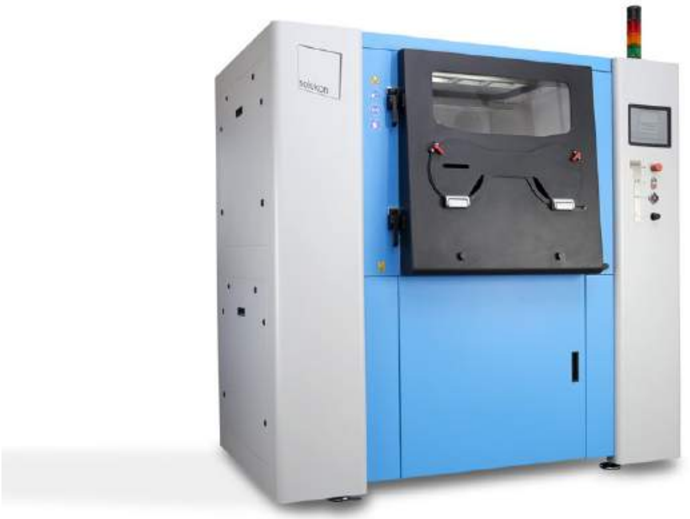


Fig. 4 Solukon SFM-AT800 (Courtesy of Solukon Machinenbau GmbH)

Voestalpine Additive Manufacturing

Voestalpine Additive Manufacturing, based in Düsseldorf, Germany, is a unit of the Austrian Voestalpine metals and capital equipment group and, among other things, a manufacturer of metal powder. It operates a number of different metal AM machines, and provides Additive Manufacturing and design services to units within the group and externally. The company has a range of expertise in using the unique features of AM to manufacture parts that cannot be made using traditional manufacturing techniques, such as tooling with conformal cooling channels, as well as in the redesign of legacy parts for mechanical systems to create more reliable or better performing designs by AM.

Until Voestalpine acquired a Solukon SFM-AT800 depowdering unit (Fig. 4), powder was removed using a glovebox with a one-axis rotating turntable, where an operator armed with compressed air toiled at length to accomplish the task by hand (Fig. 5). The challenge that the company faced using this method was that of getting powder out of complicated internal channels in AM parts; since intelligent design for AM is one of the specialty services that the company provides, it required a more sophisticated way to remove powder from these intelligently designed parts. Currently, production runs for each part are not large.

The company has clear and developed policies for occupational health and safety. It is well aware of the challenges of managing powder and protecting employees from exposure to it. The initial interest in upgrading its powder removal strategy was driven by the need to remove powder from internal channels. Safety issues are seen as important, but take second place in its considerations. While it acknowledges the benefits of automation and reduced manual labour costs, it has yet to quantify the savings. This is partly due to the fact that it is, as yet, not producing parts in large enough production runs.

"The company has clear and developed policies for occupational health and safety. It is well aware of the challenges of managing powder and protecting employees from exposure to it."

GE Additive

GE Additive operates a Customer Experience Center in Garching, near Munich, Germany. The principal purpose of this centre is to serve as a showroom for GE Additive Powder Bed Fusion products developed by the Concept Laser and Arcam units acquired by GE in 2016. The centre is not an operating entity in the normal sense. However, it serves a broader purpose of educating about the latest developments in the industry, albeit through the prism of its own products. It also offers consulting services and sees a wide variety of parts. The centre also aims to address issues peripheral to the manufacturing systems themselves, and powder removal is therefore an important part of its activities in industrial applications.

As with the majority of AM machine producers, the Concept Laser product line does not address powder removal in a meaningful way. Operators of these systems remove the bulk of the excess powder by vacuuming it from inside the build space after the build is completed and cooled. As such, deep cleaning of a part still has to be addressed in a peripheral process after the build is removed from the machine.

A factor that carries a lot of weight at GE Additive is for operators to have access to the parts, which is frequently difficult due to their increasing size. A large build plate is often cumbersome and, if it needs to be repositioned to free powder from enclosed channels, this can be a difficult and time-consuming manual operation. So, the ergonomics of the depowdering system are an important factor. Accessibility also saves time, which the GE team noted was an important factor. Reproducibility of the process is also significant. Capturing excess powder for recycling is a factor, but the company has not quantified the benefits of this.

GE Additive acknowledges that the risk of leaving powder inside internal cavities is high if powder removal is not approached in an organised and industrial way, and has installed a Solukon SFM-AT800 unit to address these issues. Overall, the automated solution brings so many advantages that the company stated that it "cannot be compared" to the manual process that was employed previously.

Israel Aerospace Industries

The MBT division of Israel Aerospace Industries, located in Lod, Israel, is a manufacturer of aeronautical and space systems. The company established an Additive Manufacturing centre in 2016, at which it currently operates a single metal AM system producing parts in aluminium and is in the process of acquiring a second. Due to the nature of the aerospace business, the AM centre specialises in building parts designed for lightweight aerospace applications. Quantities are currently low, but are expected to increase as capacity is built up and design for AM takes hold among engineers.

The company has a highly developed protocol for occupational safety and health, with employees wearing protective coats at all times and masks when moving build plates out of the machine. The overriding factor in seeking a depowdering solution was minimising powder contact for employees, especially the downstream workers who receive the part for post-processing after powder is removed. Since other departments are ill-equipped to deal with powder issues and lack personal protection equipment, it was important for the company to make sure that a part leaving the AM centre would be as clean as possible.

A second objective for investing in intelligent powder removal equipment was an order for a complicated AM part with a very deep internal cooling channel. The expected demand for this part is "in the 100s", so it made sense for the company to identify a solution to removing the powder that was more organised and repeatable. The initial design for the part included powder extraction points. After the powder was removed, the holes were plugged in a separate manufacturing operation.

Fig. 5 Manual depowdering cabin at Voestalpine prior to replacement with automated depowdering system (Courtesy of Voestalpine)

The company installed a Solukon SFM-AT800 depowdering unit to manage powder removal optimally, but also with the aim of enabling powder removal from the cooling channel without the need to plug holes. The company expects to build many more parts that will take full advantage of the complicated geometry that AM-designed parts can contain. It has a high awareness of design for AM issues, and is inculcating among its engineering staff how best to design parts that maximise the geometric possibilities offered by the technology, while at the same time understanding issues such as support minimisation and powder removal. With an automated powder removal tool at their disposal, they expect to make the most of the possibilities that metal AM has to offer. As the system has been installed only recently, the company is still experimenting with the best parameters for the cleaning cycle. What is clear, though, is that an optimised cleaning cycle for a particular design, or for parts in general, is easily repeatable.

Fig. 6 Automated part cleaning at Toolcraft (left) and Solukon SFM-AT800-S system in operation at Toolcraft (right) (Courtesy of MBFZ toolcraft)

MBFZ toolcraft

MBFZ toolcraft runs one of the more sophisticated AM operations in Germany. The company is a manufacturer of parts for a range of customers across a number of industries and is located in Georgensgmünd, Bavaria. Toolcraft operates ten metal AM systems from three different suppliers, offering four different metal powders. The predominant brand on its floor is Trumpf, with whom it has been in close collaboration as a beta tester of new Trumpf systems. It has also invested in the Trumpf powder removal station, which it uses to remove the bulk of unfused powder from the cylindrical building box.

Like most leading metal AM system operators, Toolcraft complies meticulously with standard powder management practices. Its facility is spotless and preliminary unpacking takes place in a separate space insulated from the area in which the AM machines are operated. The complete absence of dust from the factory environment is remarkable given the volume of powder that is processed by its AM equipment; employees are also equipped with the highest level of personal protection equipment (PPE).

"Like most leading metal AM system operators, Toolcraft complies meticulously with standard powder management practices. Its facility is spotless and preliminary unpacking takes place in a separate space insulated from the area in which the AM machines are operated..."

Driving Toolcraft's interest in dedicated depowdering technology was the realisation that it was impossible to remove all the powder from AM parts. Since the Toolcraft team already understood that powder was a risk, it sought a solution that would improve its powder removal results without sacrificing safety. If powder remains unremoved in a part, it may come out at a later stage, such as when the part is cut off the build plate, leading to risks in downstream operations. If powder is left inside parts, it will complicate later operations such as heat treatment, or reduce the quality of the part.

Toolcraft acquired a Solukon SFM-AT300 at the beginning of 2018. At end of 2018, the company became the first beta tester of Solukon's advanced SFM-AT800-S system (Fig. 6). This system offers an advanced capability to rotate the build plate into any position in two axes through the use of two endless rotating servo motors. This makes it possible to move the part into any position and along a path that mimics the design of internal channels that contain powder that needs to be removed. In collaboration with Solukon, Siemens is now developing software that detects internal channels in the part within the CAD file and calculates the necessary algorithm for rotating the part in the SFM-AT800-S to improve and speed up powder removal.

Overall, the Toolcraft team found that operating a depowdering system has given them much better cleaning results that could not have been achieved manually. Actual results are dependent on the part complexity and the amount of support structures. The average lot size for parts produced in the facility is ten, although some projects entail up to 1,000 parts per year. The company has not quantified the labour cost savings due to the variability of the parts produced, but it takes a holistic view of the operations and recognises that the new process is better. The team also pointed out the advantage of recovering powder that might otherwise be lost, although here also the company has not quantified the savings.

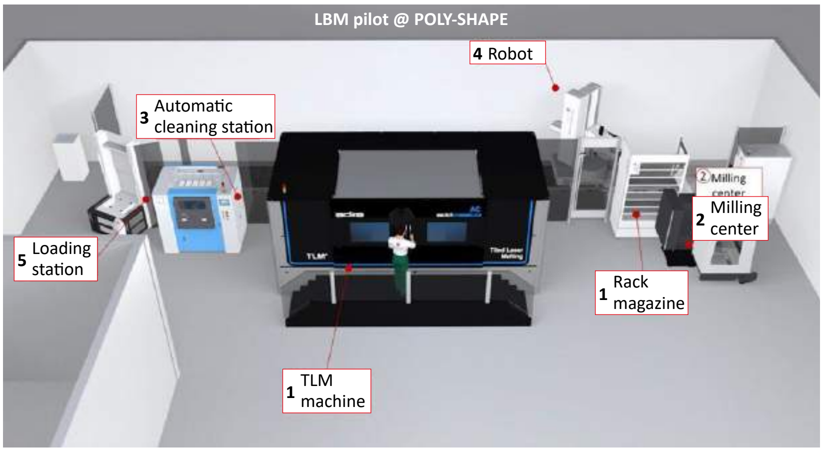
Material Solutions

Materials Solutions is an engineering and manufacturing service provider specialising in AM, based in Worcester, UK. Siemens acquired a majority stake in the company in 2016, and invested €30 million to expand its manufacturing operations, leading to the opening of a new facility in December 2018. The facility is expected to hold up to fifty metal AM systems at its full capacity (Fig. 7).

To meet the part cleaning needs of the facility, the company acquired four Solukon depowdering units. Before acquiring these systems, it employed home-grown solutions. For small build plates, bulk depowdering occurred inside the manufacturing unit. Vibration units were used, but with static positioning. Larger build plates were lifted and vibration was applied by using a motor or by hammering on the plate.

Since the acquisition of dedicated depowdering technology, the depowdering process has been simplified and made safer. As a large operator of systems, the company appreciates the ability to program and repeat cleaning cycles. While it has not scientifically measured the time savings, it estimates them to be on average around 50%. Since the process is automated, staff can be deployed to other tasks while the cleaning cycle runs automatically, resulting in further savings on labour costs.

Fig. 7 A digital render of Materials Solutions' facility in Worcester, UK that includes three Solukon depowdering systems (Courtesy Material Solutions/ Siemens)



1 - SLM machine (Adira Addcreator)
2 - Milling center (Haas 3-axis VF-2)
3 - Cleaning station (Solukon AT800)
4 - Robot (Erowa ERD 500)
5 - Loading station (Erowa ERD 500)
6 - Rack magazine (Erowa ERD 500)

Fig. 8 Layout for the HyProCell automated AM cell (Courtesy of HyProCell Project)

Future developments

And what of the future? There are already pioneering projects that are taking powder removal to the next level of automation through the integration of downstream processes into a manufacturing cell. One such example is a project called HyProCell. Based in France, the project is supported by a consortium comprising thirteen entities in seven European countries. Among other things, the cell contains a metal AM system, a depowdering system and a robot to transfer the build plate from the machine to the depowdering unit without the need for manual interven-

Update on requirements for performing a dust assessment

The National Fire Protection Association in the United States is a trade association which produces codes and standards for fire prevention. A number of new requirements were introduced by NFPA 652 that have not previously been included in commodity-specific standards. NFPA 652 requires that a Dust Hazard Analysis (DHA) be performed for all operations that generate, process, handle or store combustible dusts or particulate solids. Under the latest version of the standard introduced in 2019, a DHA must be performed by September 7, 2020. The standard specifies that the facility owner or operator is responsible for determining if the handled materials are combustible or explosive and, if so, characterising their properties for the DHA.

According to Dust Safety Science, in 2018 there were 272 recorded dust fires and explosions worldwide, resulting in 113 injuries and 17 fatalities. About 10% of the incidents involved metal dust. With the proliferation of metal AM systems, in which powder is a central resource of the process and not simply a byproduct, authorities and insurance companies are hoping that increasing regulation and awareness will avoid an increase in the incidence of metal dust-related incidents.

tion. The depowdering component of this cell, a Solukon SFM-AT800, is equipped with UPC-UA-control, an automatic clamping system and a specially designed sliding backdoor for robot access. This pilot project offers a glimpse of an automated AM workflow, of which powder removal is an essential and challenging step.

Conclusions

Conversations and questionnaires on the subject of powder removal have delivered interesting information and insights into how some companies view powder removal. These conversations, however, are far from being a 'study' with statistical findings on operators' attitudes to the issue. Depowdering solutions, of which there are a small number, are still relatively new. The approach of companies operating metal AM systems to date has been ad hoc and inconsistent, based on the experience and intuition of the specialists who run the machines.

While companies have in most cases adhered to powder management protocols out of concern for risks to health and safety, until recently they lacked the tools to approach the issue in a systematic and automated way, relying on manual cleaning skills acquired over years of practice. Reliance on human factors is not a sustainable strategy as metal AM ramps up; experienced powder removal experts are not in endless supply.

As these companies acquire more experience in dealing with the challenges of powder removal, we can expect greater clarity as to quantifiable efficiencies that automated depowdering can deliver. The most significant factors that appear to trigger a decision to adopt smart depowdering technologies are safety, occupational health and the need to remove powder from hard-to-reach areas of the part.

Human exposure to metal powders is a relatively clandestine risk, the health effects of which may only become apparent years into the future. On the other hand, fire and explosion are more tangible and immediate risks. Their occurrence is not a theoretical matter. On October 12, 2018, a dust fire broke out in a Seattle plant belonging to Nucor Steel Corporation. Fire fighters who rushed to the scene reported that the cause of the fire was "titanium dust from a printer." The Seattle Fire Department was reported as saying that the titanium dust was "a known ongoing issue." One can only hope that this is not a sign of things to come in the AM industry. The warning signs are there, even though some machine operators have yet to recognise them. As the industry matures, we can expect that a better awareness of the risks of powder among AM users and providers will take root, as will improved procedures and equipment to mitigate the dangers.

Acknowledgements

Special thanks to Nigel Bunt of Intelligent AM for assistance in the preparation of this article.

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Defining your digital future: The path to industrial digitalisation in Additive Manufacturing and beyond

Terms such as Industry 4.0, the Digital Thread and the Digital Twin have become familiar buzzwords in manufacturing, but many such terms barely make sense to IT experts, let alone AM professionals. In the crowded and jargon-heavy landscape of solutions for digitalisation, articulating future AM software trends can help offer clarity and confidence in IT investments and give insight into the data-driven future of manufacturing, believes Authentise's Andre Wegner, who shares his vision of the route to developing an effective digital factory with *Metal AM*'s Emily-Jo Hopson.

Authentise, based in Mountain View, California, USA, has come a long way from its roots in security and intellectual property protections for AM to establish itself as a leading software and service provider driving the development of connected, modular and open workflow tools for industry. Founded in 2012 by Andre Wegner, a frequent author and speaker as well as Chair of Digital Manufacturing at the nearby Singularity University, the company's workflow solutions aim to tie all data generated during the AM process together and leverage that data to reduce effort and increase productivity, repeatability and traceability. Application of the technology is no longer limited to the Additive Manufacturing industry, but is regarded as a model for the intelligent digitalisation of manufacturing as a whole.

Drawing on the expertise of a team of subject matter experts which includes management consultants, engineers, solution architects and product design officers, Authentise has the knowledge and experience to determine the greatest threats and opportunities posed by digital manufacturing, and understand its impact across the manufacturing segment. To address these threats and opportunities, the company offers specialised software solutions to facilitate the effective digitalisation of manufacturing workflows.

In order to effectively tie the stages of the AM process together, a significant degree of Authentise's efforts have focused on the development of partnerships and integrations with major machine vendors, CAD vendors and business tool developers to enable the gathering and consolidation of all data in the

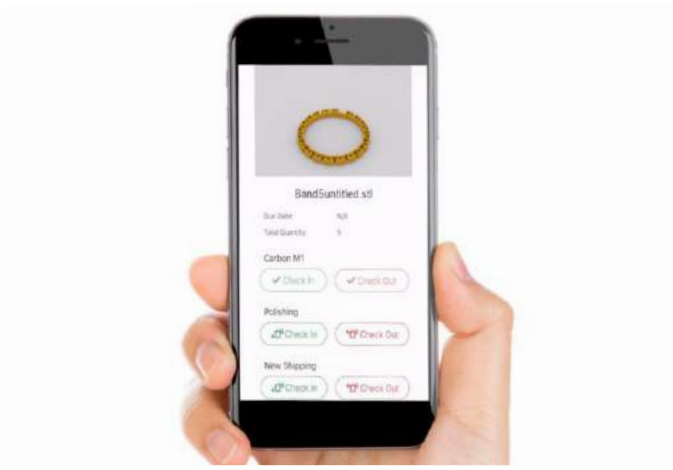

Fig. 1 As Additive Manufacturing moves from prototyping to the production of functional series components, new solutions are needed that can help companies access, and make sense of, the huge volumes of data generated

Fig. 2 Andre Wegner, founder and CEO of Authentise

manufacturing process. This can then be leveraged to optimise workflow. Among those applications available as part of the company's modular 3DIAX workflow management tool are multiple third party systems – many of them competitors – selected to ensure that users have easy access to best in class systems without the need to learn and understand new interfaces. They include mesh healing tools by Materialise, Autodesk and MX3D, shape search technology by Siemens, file conversion and serialisation solutions by Prototech and more. Even though Authentise has developed its own machine learning-based quoting software, users of the platform can also access estimates by Prosper, an Israeli startup, and can thus easily switch provider at any time. Over the last year, a series of significant announcements have offered further insight into how the company's development strategy is unfolding. Late last year, a partnership with Autodesk was announced on an integration that makes it possible to use Autodesk Netfabb®, a leading brand in software for Additive Manufacturing design, seamlessly within 3DIAX. This integration means that geometries can be loaded directly into Netfabb from Authentise at the press of a button, and files edited in Netfabb exported back into Authentise's suite just as simply, enabling the development of an integrated workflow which includes quoting, CAD editing, version control, scheduling and real-time data-driven monitoring.

"... a significant degree of Authentise's efforts have focused on the development of partnerships and integrations with major machine vendors, CAD vendors and business tool developers to enable the gathering and consolidation of all data in the manufacturing process."

More recently, Authentise agreed to a multi-year collaboration with Microsoft which will enable it to utilise Microsoft Azure, a cloud computing service for building, testing, deploying and managing applications and services through Microsoft-managed data centres, and integrate Authentise's solutions into Microsoft Flow, Microsoft's workflow automation platform. The integration with Flow gives operators direct access to Authentise's system via the Microsoft Flow Gallery, and allows them the opportunity to create their own process automations regardless of the level of their coding knowledge. Flow also allows operators to connect Authentise's data with third party applications such as Microsoft Office 365, Quickbooks, text messaging, email and more, by simply dragging and dropping the operations into place. In doing so, they can create custom alerts, dashboards and other workflow automations to further increase transparency and efficiency in their Additive Manufacturing operations.

Authentise recently received United States Patent and Trademark Office (USPTO) approval on its patent, 'System, Method and Program Product for Digital Production Management.' The patent shows how streaming designs or machine code directly into manufacturing devices (down the PLCs that control the individual movements within the machine, eventually) can help not only to protect the intellectual property of the part but also enable remote integrity control (by monitoring the

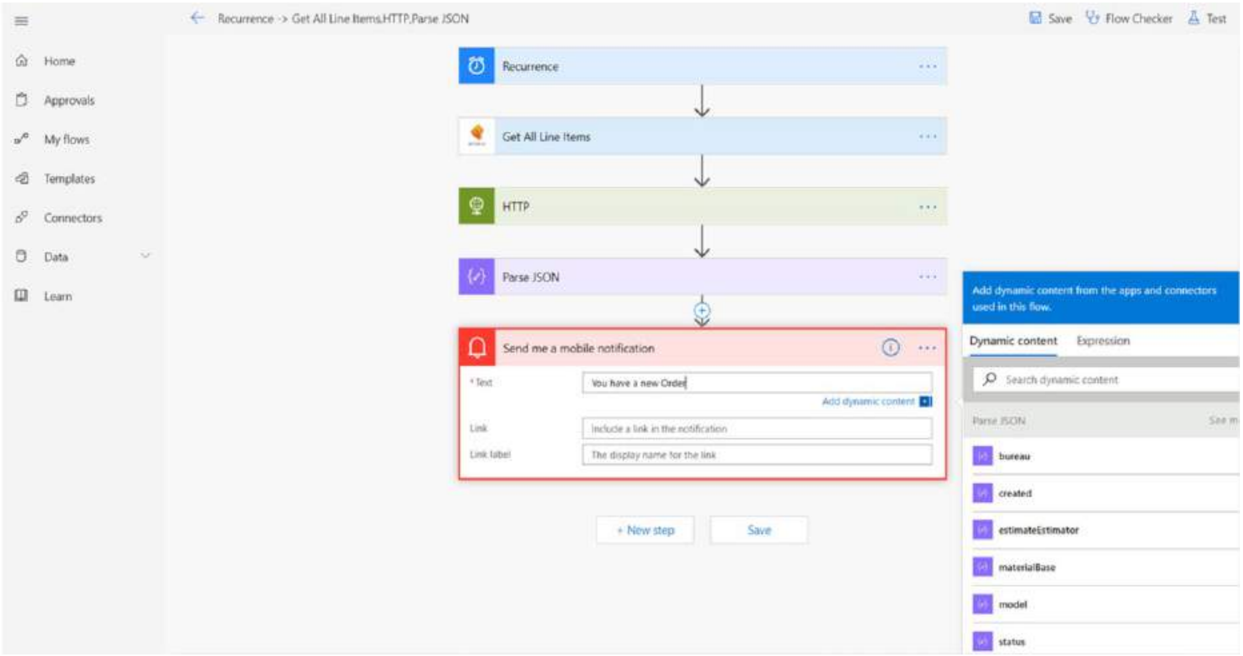

Fig. 3 Authentise's solutions were recently integrated into Microsoft Flow, Microsoft's workflow automation platform, as part of a wider partnership agreement

feedback remotely) and close the loop completely by making remote in-process amendments, such as integrating watermarks in the object once it has been verified that the part was produced correctly.

This technology is available in the company's data-driven Additive Accelerator workflow management solution and, while Wegner stated at the time of the announcement that Authentise is, "in the technology game, not the patent game," the company believes that the patent "shows a path for the future of manufacturing," adding: "We see this patent as a shining ad to the industry as to where the technology is moving. To get there, we have to work together with others. To work with others, we have to show them there's value in it. That we think there's enough value to file a patent."

Making sense of today's AM software trends

Recently, Wegner shared his thoughts with *Metal AM* magazine's Emily-Jo Hopson on the future of manufacturing in the digital age, and on the ways in which he believes that articulating future AM software trends can help offer certainty in IT investments and insight into the data-driven future of the manufacturing industry. Terms such as Industry 4.0, Digital Thread and Digital Twin have become familiar buzzwords in manufacturing, but many of them, according to Wegner, barely make sense to IT experts, let alone AM professionals, who are typically more focused on identifying applications, characterising materials and optimising production.

What IT experts such as Authentise can offer, however, is an understanding of current realities and the experience to know where trends are heading. Using this experience to crystalise a vision for digitalisation can help manufacturers – not just in AM, but in a number of fields – plan how to structure their IT investments today, as well as providing guidance on how to relate to data and software in the years to come.

> *"... solutions are generated in far greater numbers than a human would be capable of outputting in such a short period of time, with the most advantageous solution selected, setting the precedent for future iterations."*

Drawing on his background both in the Additive Manufacturing industry and the academic field of future studies, Wegner highlighted three key long-term trends he sees in software and data for AM.

1. Generative design from initial idea to the finished part

Generative design has become increasingly important in Additive Manufacturing in recent years. In this iterative design process, a program generates a number of outputs in order to meet set constraints. While in concept generative design can be practised by a human with nothing more than pen and paper, the term is mostly used to refer to a specific kind of CAD, in which an artificial intelligence automatically generates these outputs, enabling designers to explore a very large number of possible permutations of design solution to meet a particular problem.

As new programming environments and scripting capabilities make it relatively easy for designers to implement their ideas via generative design, this process is becoming ever more important, especially in fields such as AM where new design freedoms are available which would not be possible with conventional manufacturing methods. Generative design solutions are now being incorporated in CAD packages offered by major software companies such as Autodesk and Altair.

However, there is still progress to be made until generative design is fully established as a usable, everyday solution for the digital factory, Wegner noted, stating that, "The promise of generative design has so far resulted in little more than demo reels. Optimising areas of more limited constraints such as support, orientation and nesting will be the first step for these algorithms and is already saving operators time." While much remains to be done to get to a fully automated design process, he believes that the determination with which the technology is being pursued at Autodesk, Altair and beyond shows that companies are taking its disruptive potential seriously. "With resources at our disposal, and decades of learning from simulation, model-based design and associated fields backing us, we can talk confidently about where the generative trajectory leads us," he explained. "A future in which a part might be shaped by digital constraints from consumers, the environment, manufacturing processes and beyond, only to be assembled into its final geometric shape at the very last moment."

2. Seamless workflows

"It is no exaggeration to say that users are upset with the current glut of software tools they must use to make parts work," Wegner noted, "particularly at the high end of additive: simulation, support optimisers, engineering tools, materials databases, toolpath generators, workflow, in-process monitoring tools and others. The list goes on. Each tool has a separate interface, often by widely different companies with significant licence fees attached. Knowing which to pick and learn is a challenge, especially when a new, better tool might be just around the corner."

Wegner believes that this is a problem of the industry's making. "Because the industry grew out of the prototyping realm, it had different priorities, and layering production on top in an immature market is causing a mess," he continued. "It's informative to see how other industries, such as 2D printing, solved this situation: while each printer used to require its own software interface, which often led to widely different results, those processes have now been standardised. In additive we've seen similar trends: mesh healing used to be an error-prone, manual step that was part of every print. Now most models come to us watertight straight from CAD."

"Since the fragmentation of software solutions in AM is a major point of frustration, Wegner believes a continuation of the trend to remove manual steps is very likely..."

Since the fragmentation of software solutions in AM is a major point of frustration, Wegner believes a continuation to integrate process steps, often from separate providers, while eliminating manual steps, is very likely. "Orientation and support, for example, could be radically simplified to the point where they are generated on the fly as the part is being produced, instead of a separate part of the workflow," he predicted. "Same goes for scanning strategies or toolpath in general. Simulation and resulting compensation are already moving towards automation. This won't happen overnight – in the beginning, only the simplest parts will be able to skip manual steps."

"In addition to helping to reduce frustration and workload for operators, seamless workflows have the additional advantage of providing a platform to test new solutions for each stage without having to learn a new tool. Providers can simply integrate their new algorithm in the back end and allow the user to test their capabilities with zero switch cost," he added.

3. Better quality through data

As the consolidation of tools used to prepare parts for production increases, forming a 'digital thread' from concept to completion, so too increases the availability of process data for each part; generated by machines, operator actions, design changes, material genealogy and more. Companies such as Authentise are using these data to drive further process automation, but, according to Wegner, this is only the beginning. "Early work at Oak Ridge National Lab and beyond indicates that process data can be used to verify the quality of the final part without, or with limited, testing," he explained.

"Given that testing can make up a significant part of the final production cost and that testing tools themselves are reaching their limits as additive

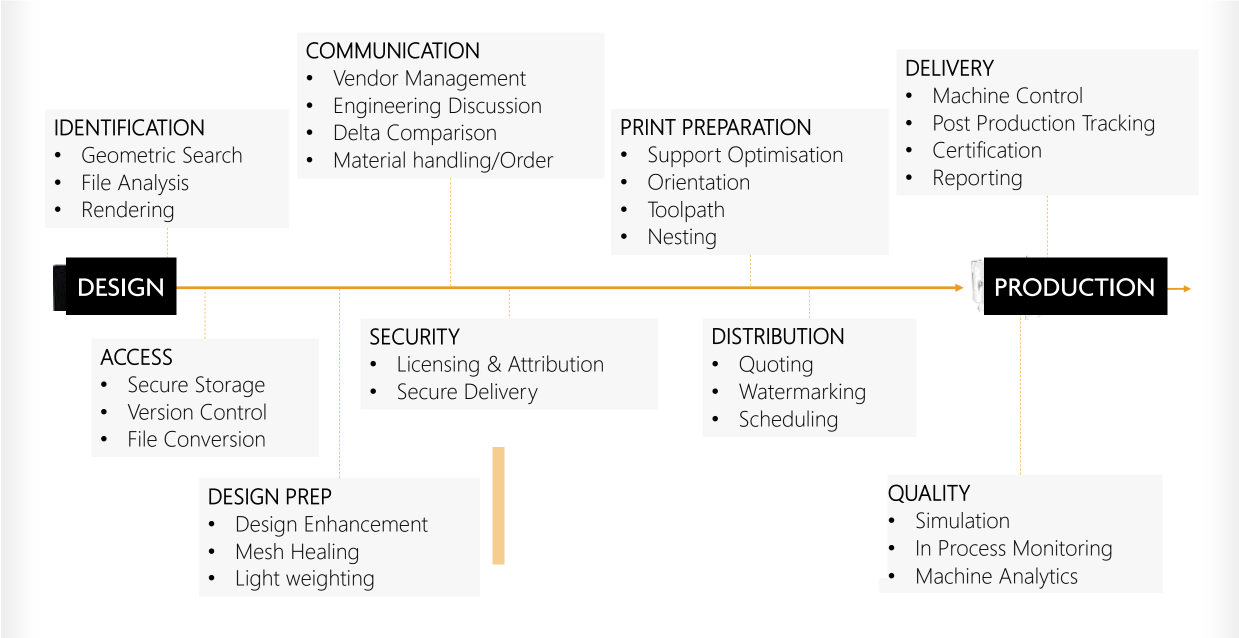

Fig. 4 Some of the key areas in the metal AM process chain where software and data integration will be an advantage

machines evolve, the need for such tools is self-evident," he continued. "If we want to go beyond the current scenarios and further enable distributed spare parts production, these tools become even more valuable. Efforts from companies such as Dimanex and Spare Parts 3D will quickly reach their limits: remote quality assurance will be required to fulfil the potential additive holds as a supply chain disruptor."

"Identifying these trends is not easy," Wegner stated. "If it were, we would all be off picking stocks. Nor is the process meant to be exclusive. Drawing out these trends is not some mythical process aimed at discovering one truth, but a series of conjectures that should be frequently revisited." However, the lessons learned by observing the trends described at Authentise have been, according to Wegner, that IT investments in AM must remain open to change, must be built on data, and must be focused on the operators.

Drawing on these three principles enables Authentise to understand what needs to be built, and its clients to build an infrastructure they can be sure of in the future as well as in the present. We asked Wegner to propose his steps to action for manufacturers as they begin the process of digitalising their workflow.

Starting the process of digitalisation: backbone deployment

The most straightforward way for companies to begin the process of digitalisation is, according to Wegner, to start deploying a system which can act as a 'backbone' for their future endeavours. "The backbone captures data from the process, leverages it for automation and gives your business the opportunity to connect disparate actions and data themselves," he explained. What precisely forms this backbone is dependent on the field; in design, the backbone is a Product Lifecycle Management (PLM) tool, which manages the entire lifecycle of the product from inception, through engineering design and manufacture, to the service and disposal of manufactured products. In manufacturing operations, it is more likely to be a Manufacturing Execution System (MES) such as Authentise's Additive Accelerator.

However, as Wegner noted, "This step often requires time – our deployments range from four to six months; people – a part-time project manager – about quarter-time for deployment phase depending on the size of your business – usually helps deliver the project smoothly; patience - this is still early days, and you and your vendors are not going to get everything right first time; and money." Understandably, not everybody has all of these resources at hand, so the following steps may be more applicable.

Design

"Getting everybody around the table to understand your vision is often the most complex and critical task, yet frequently overlooked," Wegner stated. "We have found that simple workshops can help give everybody involved – from IT to legal, operators and managers – the ability to participate in the vision. Giving everybody a stake in it strengthens your vision, makes it practicable and helps overcome hurdles as they come up during your deployment."

Indeed, as part of its process, Authentise often organises and facilitates these design workshops, which begin by identifying the company's process at a high level before looking at the challenges and opportunities it presents, what can change and what role can be played by data, quality assurance and other elements in that process. The second part of the workshop then maps out action steps based on the input provided. "Whether you work with Authentise to organise such a workshop or do so yourself – it's a relatively limited time and resource commitment which gives any subsequent project a far higher chance of success," Wegner commented.

Connect

"Many additive operations we visit have yet to connect their machines," Wegner noted. While this may seem an obvious step to some, he added that the number of machines which are not connected comes as no surprise. "Machine suppliers have done very little to incentivise connectivity – only a few have an open API and there are barely any tools outside of Authentise's own suite that can use that data with immediate return on investment. Nevertheless, the simple act of connecting devices is a foundational element to any effort to digitise manufacturing operations. Data access can speed up efforts in parameter development, quality assurance, first article development and more."

Once the decision has been made to connect machines, connectivity itself is relatively easy to establish. Authentise offers a connectivity module which enables its solutions to connect to multiple different machine types at once, including EOS, SLM Solutions, Stratasys, HP and more. Once the connection is in place and the machine data are unlocked, manufacturers can decide who sees it and for what purpose, "instead of being beholden to machine operators as they and others try to get you to share your data," Wegner explained. "We've also found that the newly unlocked data visibility tends to spark creativity among those operating machines: Can I get an alert when O_2 levels increase? Can print time reports go into a CSV file? Simple questions asked by your operators and answered by data access may yield significant increases in productivity and repeatability."

Empower

The fact that these questions tend to come from machine operators is worth noting, and brings us to a point on which Wegner has often spoken: the importance of empowering operators in the process of digitalisation. "In truth, the heart of digitisation is about giving the operators what they need to help each one complete their tasks more efficiently and move on to higher value tasks. Often the tasks that need automating seem benign: people might be frustrated about having to walk over to the machine to check on the status. That action might cost the operator 30–60 min/day and lead to lack of transparency elsewhere, costing your business."

"In truth, the heart of digitisation is about giving the operators what they need to help each one complete their tasks more efficiently and move on to higher value tasks."

In a background essay published at the time of the Microsoft integration on the advantages of operator-driven automation, Wegner highlighted how putting process automation into the hands of workers could help to counteract the "confrontational relationship" some operators have with technology, fuelled by fears and discussions of automated systems as a 'replacement' for workers. Instead of pitting workers against technology, he stated, the industry can benefit from "uniting them in collaboration with it."

"High-handed talk of 'replacing' workers displays a radical misunderstanding of future needs," he stated. "World markets, driven by fast information flows and instant access to digital products, demand a level of agility that manufacturing companies can scarcely imagine, let alone deliver. We need to drastically reduce the time and cost to deliver ideas to market, and be able to adjust production in real time to correspond to shifts in demand. We can only accomplish this if we move away from the planning framework currently used and towards a model of inherent and constant change."

"There are dozens of tools available that make it easier for relatively untrained individuals to deliver their own automations – from connectors such as Microsoft Flow, or webcams to monitor builds, to deploying rugged sensors such as BlueMotion, all the way to implementing your own collaborative robots as ModBot enables," he told *Metal AM* more recently. "Often, these opportunities are available with relatively little budget. All you have to do is to provide support and let those that know their tasks inside out take over. It's KANBAN on steroids: the added benefit will be that you see higher engagement of your workforce alongside productivity gains."

"Of course, you can't solve all your problems this way," he noted. "Sometimes you need a strategic project to drive solutions up. Think of it in terms of the 80/20 rule: Your workforce can complete 80% of your digital journey without you ever having to be involved, so you can focus on the 20% that truly needs your attention."

Final thoughts

It should be understood that many of Wegner's points are applicable not just to Additive Manufacturing, but to manufacturing as a whole. But while much of AM's industrialisation is reliant on ramping up the technology's abilities to match or beat conventional solutions in terms of quantity, speed and scale, and on enabling it to fit into the contemporary factory as an integrated production solution, Wegner believes that the development of an effective digital factory for all industrial production methods has much to gain from following Additive Manufacturing's lead.

"Operational improvements tied to data remain a rarity in manufacturing solutions dominated by dashboards (a colourful way to entertain managers) and predictive maintenance (an insurance product)," he stated. "Operators don't see real, hands-on relief materialise despite all the news of AI breakthroughs they keep hearing about. Authentise aims to change that, and Additive Manufacturing is the best platform to do so. Additive Manufacturing is more data rich (HP's 3D Printing CEO, Christoph Schell, said recently that one of their prints can generate up to 4 TB of data), and less encumbered by legacy processes than its peers."

"That's not to say that it's inherently different," he continued, "it's a manufacturing process – but that it's a fertile learning ground, full of professionals willing to experiment. This helps it be both a sandbox for new solutions, and ensure that they are not too dissimilar from the needs in high-value, discrete manufacturing as a whole."

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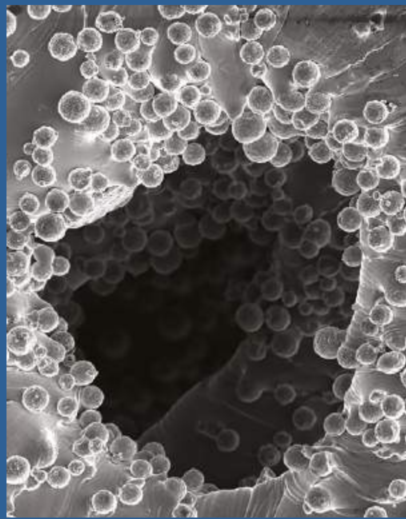

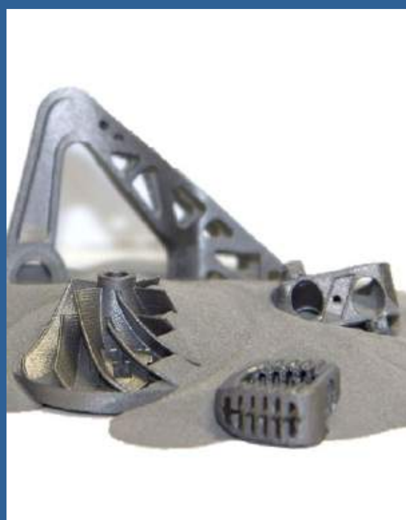

DfAM insight: How to choose candidate products for AM production applications

With the right training and experience, a design engineer can quickly make an informed decision on whether a production part might be suitable for Additive Manufacturing. For the rest of us, some basic rules can be applied to understand if a product is a good fit. Here, Ray Huff and Terry Wohlers outline six questions that should be asked before going down the AM route for series production, and present a selection of successful real-world application examples that illustrate the issues raised.

Using Additive Manufacturing for the production of metal parts can reduce time and cost, provide more manufacturing flexibility, and potentially improve product performance. Often, news reports suggest that a wide range of products can be made using AM. However, one must consider the inherent and sometimes hidden costs and other considerations of producing metal parts by AM, while knowing how to identify products that are a good fit. It is important to explore the benefits of metal AM and how to identify if or when they apply to your products before beginning production.

How to identify candidate parts

Is the product complex?
Part complexity is difficult to quantify, but it is relatively easy to explain and conceptualise. Parts that include a combination of undercuts, internal channels, organic contours, lattices, and the like, may be considered complex (Fig. 1). Parts with a greater number of these types of features are increasingly complex.

If a part is simple enough to be machined in a single operation on a 3-axis CNC machine, it isn't usually a good candidate for metal AM. This is something that Associate Consultant and Head Instructor Olaf Diegel explains in the Design for Additive Manufacturing (DfAM) courses he leads for Wohlers Associates. Such parts, in most production volumes, will not support a case for AM.

Parts of high complexity become much more expensive using conventional methods of manufacturing, yet they can be affordable using AM. If a part requires two or more opera-

Fig. 1 These taps from DXV by American Standard show levels of design complexity that can only be achieved by Additive Manufacturing

Fig. 2 Titanium alloy bracket produced using metal PBF being fitted to a section of the Airbus A350 jetliner (Courtesy Airbus)

tions on a 4-axis CNC machine, it may be a candidate for AM. Other considerations, such as the material type and its availability and cost, are also a part of the decision-making process.

A single part may not be complex, but consolidating two or more parts into one could lead to more complexity. It is possible to digitally consolidate many parts into a single part, resulting in an assembly that is produced in its entirety by AM. In this case, the benefits of AM extend to a reduction in joints, welds, and possible weak points, as well as part numbers, inventory, assembly, labour, maintenance, and certification paperwork. When taking all of these benefits into account, AM can become a compelling method of production.

Can a product be designed to take advantage of AM's benefits?

To make AM feasible for production, it is often necessary to design – or redesign – parts for AM. Part consolidation, as discussed, is one example of this. Learning to join two parts in a way that reduces material, maintains or increases strength and avoids stress concentrations comes with learning the principles of DfAM, coupled with practice.

DfAM knowledge costs time and money in hands-on learning and experimentation, but the benefits are far-reaching. Weight reduction, product performance and other benefits can offset the added costs of designing parts for AM. Over time, it becomes more natural to identify and design parts and assemblies for AM.

An example of the long-term benefits of DfAM is reducing the mass of a part. Lightweighting a part through DfAM can reduce the amount of material in production and also lower long-term operating costs, particularly in the transportation industry. Reducing weight by half a kilogram on a commercial jet can save many thousands of dollars in fuel savings over time. It is also possible to design parts for less expensive materials, such as by using an aluminium alloy instead of titanium.

Will AM reduce material waste?

Adding material to produce a part is typically more material-efficient than removing it by milling or some other operation. With AM, material is only added where it is needed, resulting in a low-waste operation. The need for support structures is an exception, but good design can keep these to a minimum for certain parts. A reduction in waste adds up even more when processing high-value materials.

Can AM be used to reduce lead time?

AM does not require any tooling to build a part, which can save a significant amount of time and money. Good methods of DfAM can help minimise the need for post-processing of the part. These factors can lead to fast production of relatively low volumes of parts, compared to conventional methods. Reducing lead time can have a

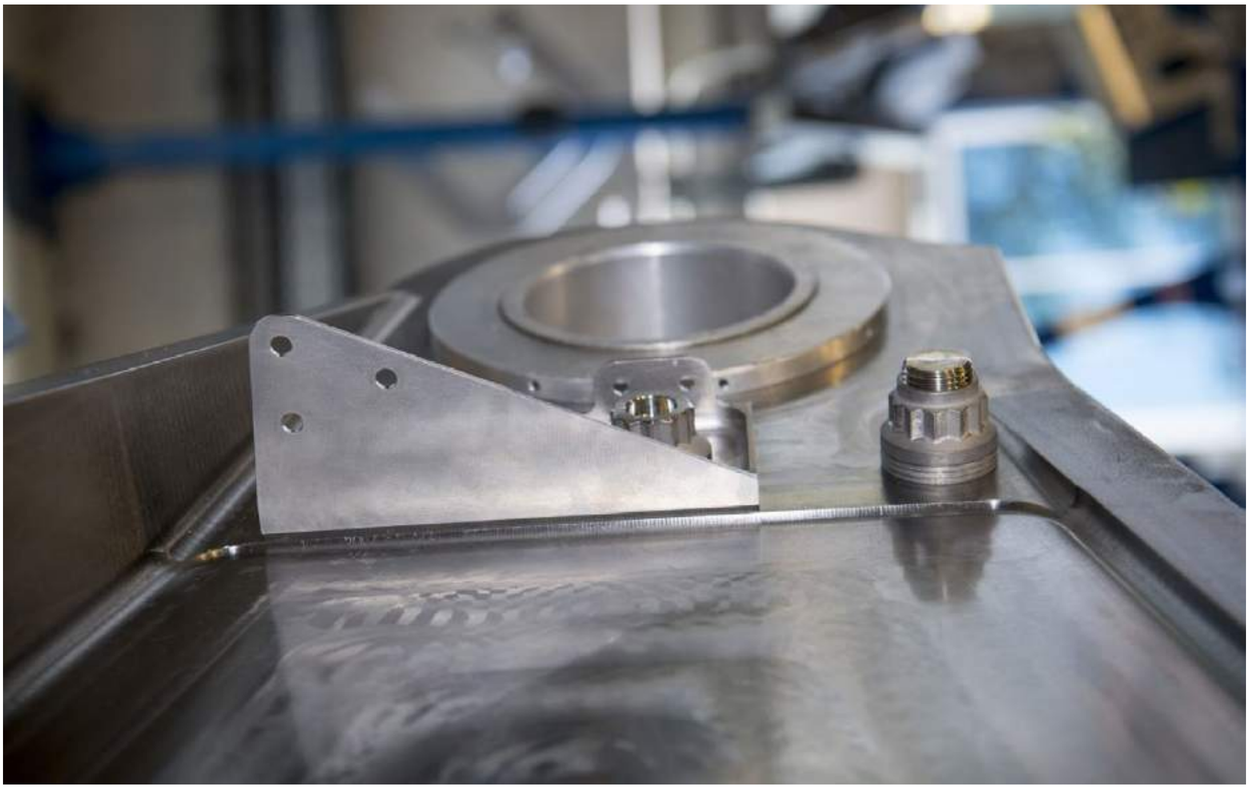

Fig. 3 Detail of the titanium alloy bracket shown in Fig. 2 (Courtesy Airbus)

big impact on a product's time to market, with products sometimes entering the field in record time. Design updates, corrections, and changes can be inserted into production very quickly. The production of assembly tooling for conventional methods of manufacturing can be produced quickly using AM and at a much lower cost. This is an excellent application of AM that is often overlooked.

Is your part made in low volume or with high product variation?

AM shines most in low production volumes, including volumes of one. These are production runs in which the cost of tooling per part would be very high using conventional methods. Medium-volume production is becoming an option with relatively small parts, enabled by fast processes and automation. Some AM technology, such as metal Binder Jetting, promises fast build speeds, though such methods are still a distance from the mainstream.

Would as-cast material properties meet product requirements?

In most cases, metal Powder Bed Fusion (PBF) produces parts comparable in surface finish to cast parts. Plan to machine and finish all mating surfaces and other features with critical dimensions. The material properties of parts made by metal PBF usually exceed those of cast parts and can be close to wrought properties. For aerospace parts, Hot Isostatic Pressing (HIP) is usually required to eliminate porosity. Metal PBF machines typically produce parts with a density of 99% or better.

Examples of using metal AM for series production

An expanding number of companies have learned, often by trial and error, the criteria for selecting candidate products for production by AM. The more they do it, the easier it becomes. The following is a sampling of what has been produced to date in a range of industry sectors.

Titanium brackets in aerospace serial production

Airbus began testing metal AM parts several years ago, demonstrating flyable titanium parts as early as 2015. After testing part production using metal PBF in combination with post-machining, Airbus identified a titanium bracket that would benefit from the process in serial production for the A350 (Figs. 2-3). The titanium alloy bracket entered serial production in 2017.

Why did this part succeed in serial production? Although very simple, it benefitted from AM's material saving capabilities. It was made of a relatively high-cost material, making material savings in production very relevant to the cost of production. The material is commonly used in aerospace, so properties were predictable without a mountain of testing and qualification. Even with limited DfAM modifications, the material savings and well-understood material made the bracket a good choice for AM.

Fig. 4 BMW uses metal Additive Manufacturing to produce mounting brackets for its i8 Roadster (Courtesy BMW)

Fig. 5 Titanium brake caliper produced by Bugatti using metal AM (Courtesy Bugatti)

Convertible top mounting brackets

In 2018, BMW announced that it was using metal AM to produce mounting brackets for its i8 Roadster (Fig. 4). The brackets are produced in an aluminium alloy on PBF machines. BMW designed the bracket using topology optimisation, resulting in the characteristic organic look of an optimised metal AM part.

The part is lighter than its plastic injection moulded counterpart, yet much stiffer, thus providing superior support to the roadster's soft convertible top. The part was not only optimised for stiffness and material savings, it also stands upright during the build, allowing the company to concurrently produce many of the parts on a single build plate with minimal support material. These factors enable the metal AM part to outperform the conventional version.

Brake calipers

In January 2018, Bugatti announced the production of a titanium brake caliper using metal AM. At the time of the announcement, the caliper was believed to be the largest in the automotive industry, and the largest functional titanium part made by AM (Fig. 5). While these claims were worthy of note, they would mean little if the part were not also economical to produce by AM.

In collaboration with Fraunhofer Research Institute for Additive Manufacturing Technologies (IAPT), Bugatti used DfAM to make the brake caliper 40% lighter and stronger than its conventional aluminium counterpart. For Bugatti, this alone was enough to make a case for the new design. As a premium automotive application, the caliper is a low-volume, high-value part. Producing it by AM presented interesting cost and performance benefits.

Braille handrail covers

Deutsche Bahn has been exploring AM for production applications since 2016. The company used AM in the production of more than 1,000 individual handrail signs for its train stations (Fig 6). Each handrail includes text in German and braille.

To individualise each sign, an app was developed that employees used to submit handrail production requests from their smartphones. The company reported as much as a 50% cost savings using this novel approach to production.

Formula 1 parts

AM's impact on the supply chain is a tremendous advantage to companies nimble enough to take advantage of it. CA Models reported a lead time reduction from six weeks to six days – a reduction of 85% – when using AM to produce a double-water inlet/outlet component for a Formula 1 car. The part is complex in shape and needed to be hollow for fluid flow (Fig. 7). The company optimised the build orientation and added material, digitally, to faces that would require post-machining in preparation for producing it by AM.

Fig. 6 Handrail produced by metal AM with text in German and braille (Courtesy Deutsche Bahn)

What will your winning application be?

As shown, metal AM offers many benefits for production components. Applying one or more of them can help make the case for using AM. Applications where several benefits apply could be a winning solution, resulting in cost and time savings to a company. Learning to spot the opportunities is key and is best accomplished by learning the rules of DfAM as they apply to production parts. No single metal AM process or material will be right for all applications, so knowing the available options is key to not getting stuck in a single mindset. With metal AM, the value is in knowing when and how to apply the technology.

Fig. 7 Double water inlet/outlet produced for a Formula 1 car (Courtesy CA Models)

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VBN Components: Additive Manufacturing delivers a new generation of wear-resistant carbide parts

Sweden's VBN Components AB has successfully combined the design freedoms offered by Additive Manufacturing with innovative process and material developments to create a new generation of high-strength, carbide-rich tool materials. These unique, patented alloys are transforming tool and wear component performance across a range of applications, from gear cutting hobs to food processing and the mining sector. Isabelle Bodén reports on the company's development and the unique properties of its products.

In the midst of the 2008 financial crisis, the foundation was laid for what would become VBN Components AB, based in Uppsala, Sweden. Uncertainty was high at a time when many manufacturing companies had more cancellations than actual orders. However, VBN saw the opportunity to turn the business for wear-resistant high alloy steel products on its head by using Additive Manufacturing to produce high-strength, carbide-rich tool steel materials. Conventional wear-resistant steel materials have a broad range of established industrial uses, from gear cutting to applications in mining, plus a wide range of other industries where exceptional hardness is required, but where shape and material performance are often restricted by the limits of conventional manufacturing technologies.

"Our strength at the time was a broad experience of industrial processes, but these were complex and were associated with extended lead times. There was a significant limitation to what materials a mechanical engineer could choose – all of this we wanted to change," stated Ulrik Beste, CTO and one of VBN's founders. As a result of the work undertaken by VBN, a new generation of high alloy materials has been developed, along with an innovative Additive Manufacturing process based on Electron Beam Powder Bed Fusion (EB-PBF).

In the Autumn of 2014, VBN issued new shares and received a large investment which enabled it

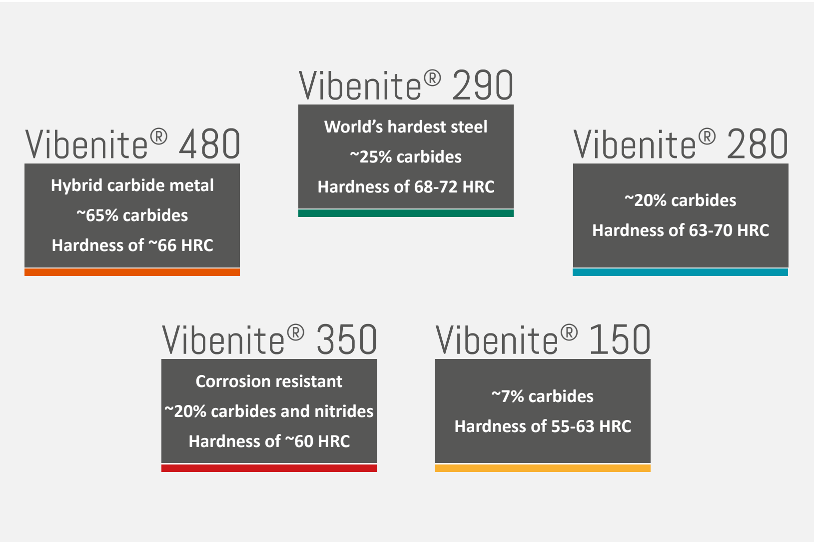

Fig. 1 The current range of Vibenite materials, with their carbide content and hardness values

Fig. 2 Industrial applications manufactured with Vibenite materials

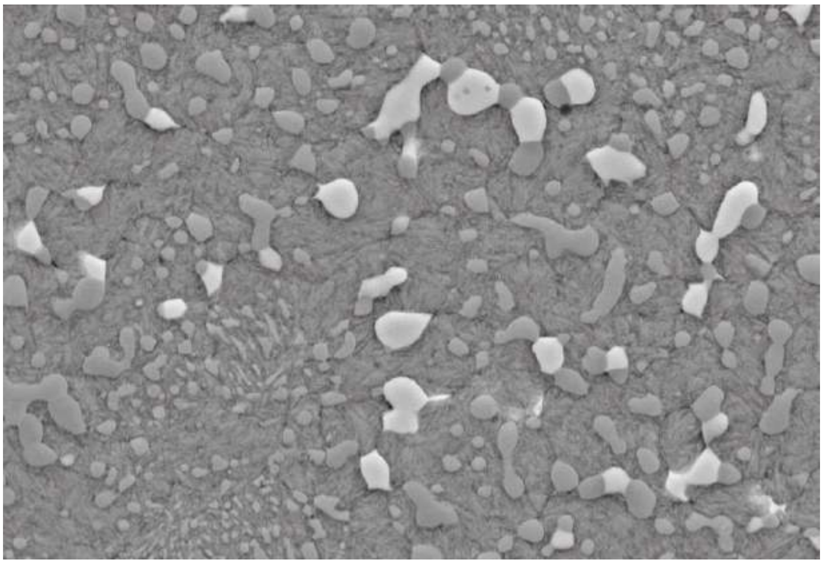

Fig. 3 The presence of small-sized, evenly distributed carbides in the material's matrix are one of the reasons for Vibenite's enhanced performance

to rapidly establish a new, modern facility in the Libroбäck area of Uppsala, beginning production in December 2014. At the plant, VBN began manufacturing wear-resistant high alloy steel parts by AM, using its trade mark registered Vibenite® range of high-alloyed PM High Speed Steels to manufacture cutting tools, wear parts and other components with complex geometries (Fig. 2).

The company sees itself as continuing the long Swedish tradition of metalworking innovation by developing new and novel materials and processes. Its Vibenite products are unique in their compositions and offer exceptional wear resistance. Their enhanced properties are achieved through VBN's patented Additive Manufacturing process, which achieves 100% density. All products are made using gas atomised metal powder and are, therefore, classified as Powder Metallurgy materials. The presence of small-sized, evenly distributed carbides in the material's matrix are one of the reasons for the improved performance (Fig. 3).

Today, VBN produces industrial tools and components for companies which are among the most prominent in their fields, and offers its technology on the basis of license agreement. While the first stage of an application's production always takes place in-house at VBN's facilities, once the client has approved the properties offered by the Vibenite materials, a license agreement may be arranged to enable the customer to implement VBN's patented production process AM-HSS™ at its own production units for a specific application. VBN would then continue to give comprehensive support on how to additively manufacture these unique materials.

"After our company's first patent, describing the process of making extremely clean and low-oxygen-content materials, we felt that we were onto something big," says Martin Nilsson, CEO and one of the founders of VBN. One

Fig. 4 A gear hob from VBN Components with double tool life-time and half cycle-time.

key aspect of the Vibenite range is that the technology allows the user to switch to a more wear-resistant material than is achievable with conventional manufacturing. When producing wear parts by Additive Manufacturing, the need for the initial forging and rolling of bar stock, and the following heavy machining, is no longer necessary. By eliminating most production and transportation steps, as well as optimising material usage, the reduction to environmental impact is enormous.

Both the performance and life-time of components increase with Vibenite materials; these properties are easily tested, states VBN, by simply building a full-specification prototype and running it. Superior material properties are not normally the main talking point in the Additive Manufacturing business, where the ability to manufacture previously unimaginable geometries is often promoted as the most significant aspect of the technology.

The Vibenite material range

Vibenite 350

The corrosion- and wear-resistant Vibenite 350 high alloy steel is ideally suited to products such as pump impellers, where there is a requirement for both complex shapes and high performance. Its high hardness of 60 HRC (680-700 HV) and high chromium content confer good wear and corrosion properties, and it is also highly suited to high-wear applications, such as in plastic moulding tools, pumps and pump housings, bearings and valve rings.

Vibenite 150

Vibenite 150 is a multi-purpose, wear-resistant PM high alloy steel with high toughness. It has a fine-grained Fe matrix with small, well-dispersed carbides and a hardness of 58-64 HRC (600-780 HV). It works well for functional prototypes, parts difficult to machine, tool holders, cold work applications with demands on both wear resistance and toughness, plastic materials processing tools and wear parts.

Vibenite 280

Vibenite 280 is an extremely wear- and heat-resistant Powder Metallurgy material with a very high content of fine, well-dispersed carbides. It is especially suitable for cutting applications such as gear hobs (Fig. 4), shaper cutters, power skiving cutters, as well as wear parts. However, it is also excellent as a hard, heat-resistant substrate material for PVD coatings in a wide variety of applications. Its hardness is in the range of 63-70 HRC (780-1000 HV), and it has proven to increase productivity for industrial tools, for instance in automotive powertrain production.

A number of gear-cutting hobs manufactured from this patented PM high alloy steel have been running at Volvo Construction Equipment, and have been compared

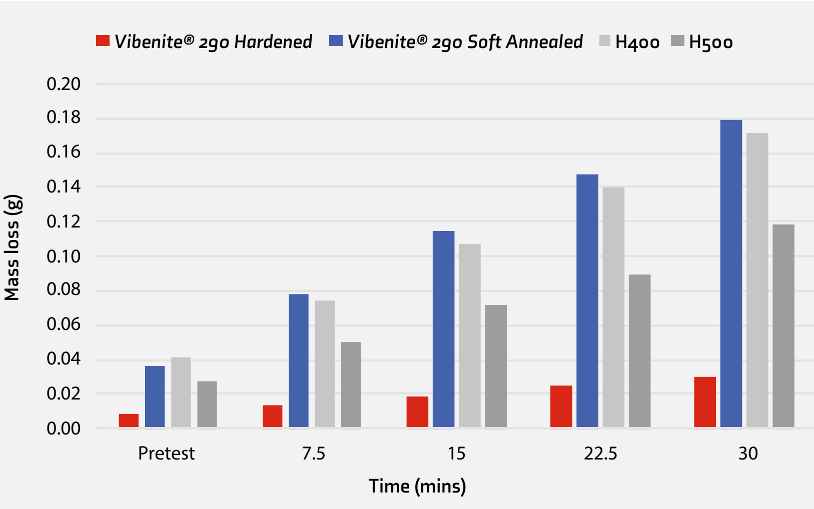

Fig. 5 Four materials in a CPOD test; wear rate in g as a function of time

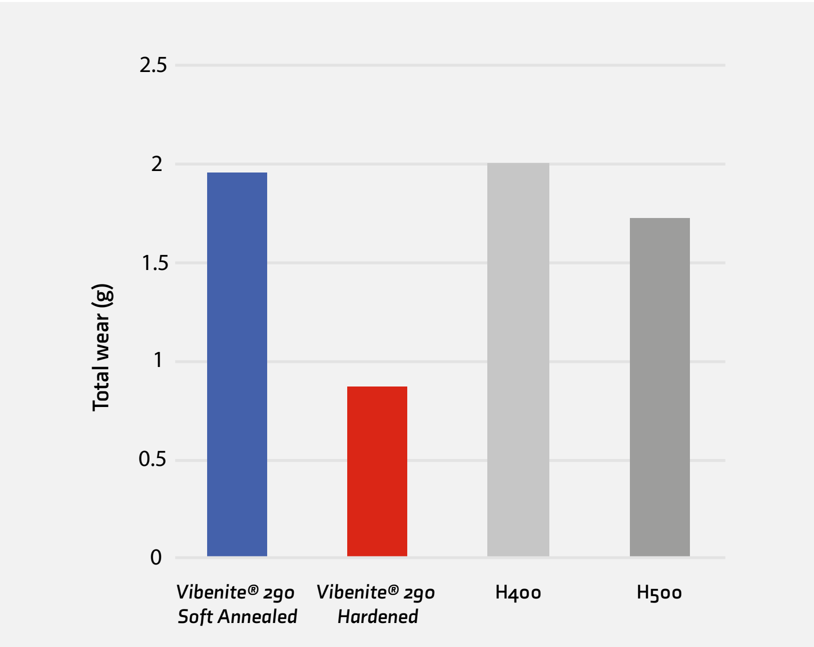

Fig. 6 Total wear in g in a high-speed slurry pot test

to standard hobs manufactured from conventional high alloy steel in real-world production. It was concluded that when the Vibenite 280 hobs are run with normal feed (cut with the same depth as the standard hobs), they last 2.2 times longer before needing regrinding. Moreover, the Vibenite 280 hobs can also be set to run with double feed (cut twice as deep) and still last two times as long as a standard hob before needing regrinding.

In a life-cycle cost analysis for 20,000 automotive gears per year, this translates to a reduction in total production cost per produced gear of 15–20%, thanks to the doubled service life of the Vibenite tool. Double cutting feed reduces costs by a further 15–20%, so the total reduced production cost per produced gear is 30–40%. Tool changes, which cause production stops and are often a source of broken tools, are consequently reduced by 50%. In addition, cycle time is improved by 100%.

Vibenite 290

In November 2017, Vibenite 290, tagged 'the world's hardest steel', was launched. It contains 25% carbides and comes in the hardness range of 68-72 HRC (940-1100 HV), which means it could never be processed using conventional technologies. New levels of material performance are reached and previously 'impossible' components are shaped. Applications include metal cutting and other high-wear applications.

Recently, Vibenite 290 was compared with two ordinary steel grades, H400 and H500, in two abrasion tests against rock. These tests were a collaboration between VBN Components and Robit Plc., carried out at Tampere Wear Center, Tampere University, Finland. The test methods used were Crushing Pin-on-Disc Abrasion (CPOD) and a high-speed slurry pot test (also called a dry-pot test).

To simulate wear against rock, Vibenite 290 was fully hardened to approximately 72 HRC, as well as soft-annealed to 50 HRC. H400 was hardened to approximately 43 HRC and H500 to approximately 51 HRC. The chosen reference materials are common for laboratory tests. Their hardness is quite close to the hardness of drill bits, but less alloyed and with higher ductility.

In the CPOD test, a sample was subjected to abrasion from granite gravel. The hardness ratio between the pin sample and the base plate determines if the sample is subjected to either two-body abrasion or the less wearing three-body abrasion. As the hardness ratio for fully hardened Vibenite 290 was 1.5, it was subjected to two-body abrasion. Soft annealed Vibenite 290, H400 and H500 had ratios of 1.1 – 1.15 and were subjected to three-body abrasion. Consequently, in comparison to the other samples, the wear rate for hardened Vibenite 290 is actually even lower than shown in Fig. 5. Despite being subjected to a tougher test, hardened Vibenite 290 showed only 25% of the wear rate of H500. Finnish Kuru granite was used as abrasive material in all tests.

In the high-speed slurry pot test, samples of Vibenite 290 and reference materials were rotated in granite gravel. To neutralise wear discrepancies at different levels, the samples were subsequently switched. Sample edges were then measured to determine mass loss.

In the high-speed slurry pot test, Vibenite 290 in hardened condition showed only 50% of the H500 wear rate. Vibenite 290 did not show any chipping in any test – a unique property considering the high hardness of the material (Fig. 6).

A new type of cemented carbide – a hybrid carbide

In December 2018, VBN Components announced that it had developed the capability to process cemented carbides, otherwise known as hardmetals, by Additive Manufacturing. This type of material has previously been considered impossible to print because of its high carbide content. VBN had already proven that the Additive Manufacturing of high alloy steel materials with high carbide content was possible with its Vibenite 280 and 290. However, its new Vibenite 480 contains around 65% carbides and is based on a powder produced by gas atomisation. Since it combines the best of two material worlds – PM High Speed Steels and cemented carbides – Vibenite 480 is referred to as a 'hybrid carbide'.

There is no mixing, drying, pressing or sintering needed, as in the traditional cemented carbide process. Moreover, this new type of hybrid hardmetal has a long-term heat resistance of 750°C, is corrosion resistant, and is magnetic. The material is aimed at applications where high alloy steel would normally be used, but where a switch to hardmetal could increase production efficiency and geometrical complexity. This could mean that metal cutting tools which today are manufactured by machining steel bars could be replaced by the hybrid carbide and run at faster speed, thanks to its higher heat resistance.

Fig. 7 An as-built Vibenite impeller

In addition to enabling the production of more complex shapes, Vibenite 480 is said to allow the production of much larger components in a single piece than is possible using conventional hardmetal manufacturing techniques. This adds to the number of possible usage areas and additionally offers new opportunities for the production of prototypes.

"We have learned an enormous amount on how to 3D print HSS alloys with high carbide content and we see that there's so much more to do within this area," stated Nilsson. "We have opened a new window of opportunity where a number of new materials can be developed."

"It is a particular kind of satisfaction to be able to offer our new hybrid cemented carbide to customers who have been asking for this for some time now. We are starting a new era in Swedish material history," added Beste. An application well-suited for the new hybrid carbide is, of course,

"The material is aimed at applications where high alloy steel would normally be used, but where a switch to hardmetal could increase production efficiency and geometrical complexity."

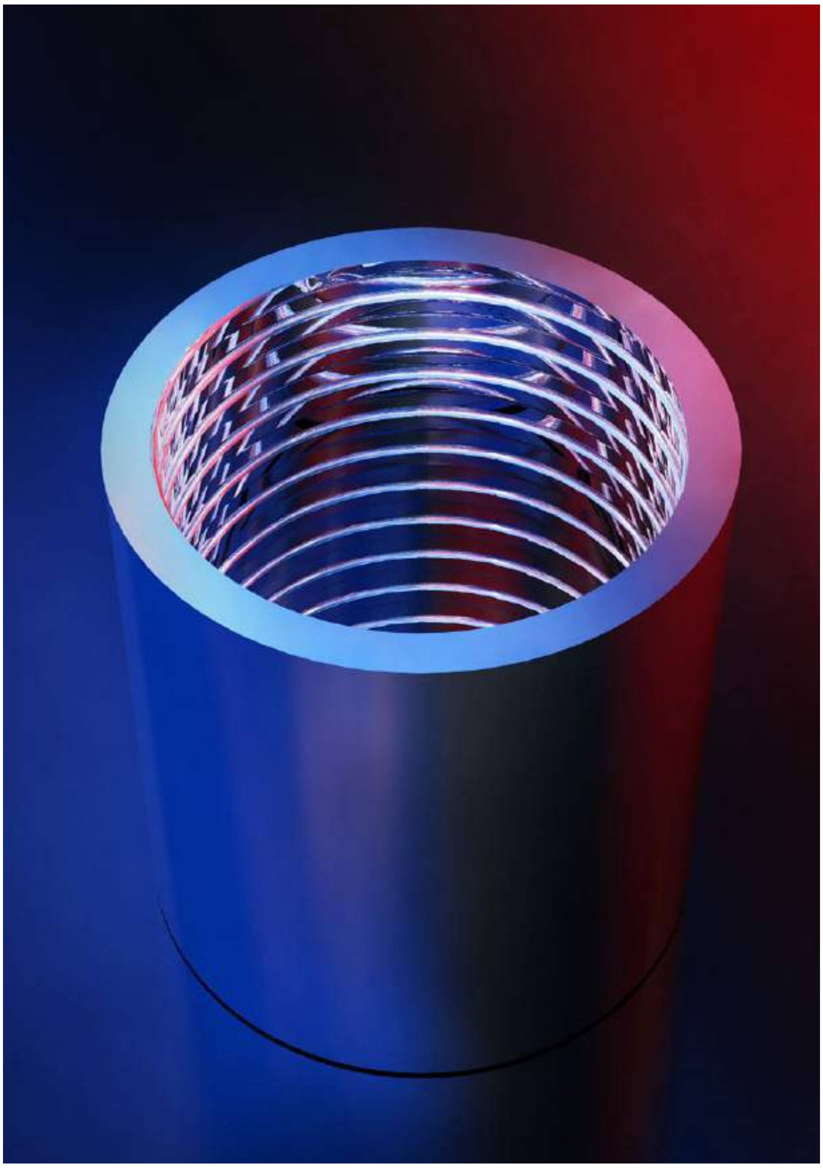

Fig. 8 Sleeve made of Vibenite 280 for production of cheese snacks

rock drilling. VBN Components has already launched a collaboration with Swedish company Epiroc to test the benefits of Vibenite 480.

Awards

The new material innovations from VBN Components have raised quite a lot of attention. In 2013, the company was awarded Sweden's most prestigious innovation prize, the SKAPA, established in honour of Alfred Nobel. More recently, it won a regional innovation award, and Germany's business association AGS-SPD also granted VBN its innovation award. The latter was presented in Berlin by Evelyne Gebhardt, one of fourteen Vice Presidents of the European Parliament.

Recent achievements and future projects

VBN's Customer Relations Manager, Isabelle Bodén, stated, "Ground-breaking innovations often come from small companies. Companies that exist due to invention and are driven by the will to do something better and more efficiently. VBN Components without a doubt belongs to these companies, managed by enthusiasts who believe they can succeed and who do not stop until they do. We have been able to reap the rewards of more than a decade of hard work. Among other things, a license agreement has been signed and a patent battle won,"

In late 2018, at the same time as the company was celebrating its ten-year anniversary, a multi-million euro license agreement was signed with a global engineering group. This multi-national company was one of VBN's first clients and had reportedly followed the progress of the company, recognising that this was a one-of-a-kind opportunity. The agreement includes an exclusive license within a specific niche of high-strength component production, which is currently subject to a confidentiality agreement.

Today, this customer receives finished products, as well as R&D support, from VBN in order to tailor this new type of manufacturing to its operations. Larger production volumes will later be produced at the customer's own premises worldwide, using VBN-installed manufacturing cells running VBN's AM-HSS process.

At the time of the agreement, Nilsson commented, "This is an incredibly important verification that our 3D printed materials Vibenite are at top level. After considerable technical testing and analysis, the agreement has been signed and we are very much looking forward to collaborating with this global partner."

"The agreement is a milestone in VBN's success story," he continued. "It is a multi-million euro deal that will grow steadily with expanding business and deliveries. The engineering group is one of the actors that started collaborating with VBN at an early stage. The license agreement is showing that our initial idea of making better materials with 3D printing, than what's possible traditionally, is really working. The customer gets a better material, much larger product flexibility, shorter lead times and considerably lowered machining costs," he concluded.

In 2013, an international steel producer contested VBN's first patent regarding high purity in high-carbon content high alloy steel materials. It took five years before the dispute was finally settled, when in December 2018, at the European Patent Office in Munich, Germany, the Boards of Appeal ruled in favour of VBN Components and dismissed the request to revoke the patent. "We were, of course, very pleased to have it confirmed at the highest level that our material technology is groundbreaking and with full IP protection," reported Beste.

"We were, of course, very pleased to have it confirmed at the highest level that our material technology is groundbreaking and with full IP protection..."

New collaboration

Recently, VBN began a collaboration with a leading company within the food industry. Several development projects have been launched, and a sleeve made from Vibenite 280 for the production of cheese snacks is first in line. Reportedly, the wear of VBN's Vibenite 280 sleeve is negligible, while the same sleeve in a traditional material is rapidly affected by wear with decreased production as a consequence. Other projects are under development and are being implemented during 2019.

Future projects

VBN Components is the only company additively manufacturing high alloy materials with high carbon content, resulting in uniquely hard and wear-resistant materials. The extremely high purity of Vibenite alloys – a result of the patented technology – gives very high fatigue resistance. Following this path, VBN will continue developing both new alloys and novel ways to process these wear-resistant materials by AM. The possibilities are vast, from 'Vibenite Combo', in which Vibenite is built upon other existing components, to 'Vibenite Grado', which is able to give different properties in different parts of the component. What is certain is that VBN Components plans on staying innovative and keeping on improving competitiveness of industrial components by giving them remarkable properties.

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Developing an effective metal powder specification for Binder Jet Additive Manufacturing

Powder specifications vary significantly across the various metal Additive Manufacturing technologies. As Andrew Klein, Director of R&D at The ExOne Company, and Jamie Clayton, Operations Director at Freeman Technology explain, powders for Binder Jetting in particular have very specific process-related requirements. In the following article, the two offer their insight into the rapid assesment and qualification process for a new 316L stainless steel powder.

Binder Jetting is an established metal Additive Manufacturing technology with notable advantages relative to other AM processes. Build times tend to be relatively fast and large-scale structures are readily manufactured. Binding powder layers during processing, rather than thermally fusing them, avoids the build up of residual stress in the finished component. As demand for this cost-effective technology grows, it becomes increasingly important to broaden the range of qualified metal powder feedstocks available.

ExOne, based in Pittsburgh, Pennsylvania, USA, is a global leader in Binder Jetting technology, providing machines, AM products and related services. The company routinely faces the challenge of assessing new metal powders from customers to determine how the technology will perform for a given application and is actively engaged in qualifying new materials. This article looks at how ExOne has learned to differentiate powders that will perform well from those that will not, and the pivotal role of powder flow measurements in defining specifications.

An introduction to Binder Jetting

In the Binder Jetting process, a recoater and roller spread fine layers of metal powder across the build plate. The printhead then releases droplets of polymeric binder into the powder bed to selectively bind defined areas, and the build plate is subsequently lowered in readiness for spreading another layer of powder. Binding successive layers of powder progressively builds a green part or body which is removed from the build box for further processing. Metal powder not bound into the finished component, typically around 95% of the powder feed, is recycled.

Fig. 1 Binder Jetting is a flexible, cost-efficient process for manufacturing complex components to high resolution

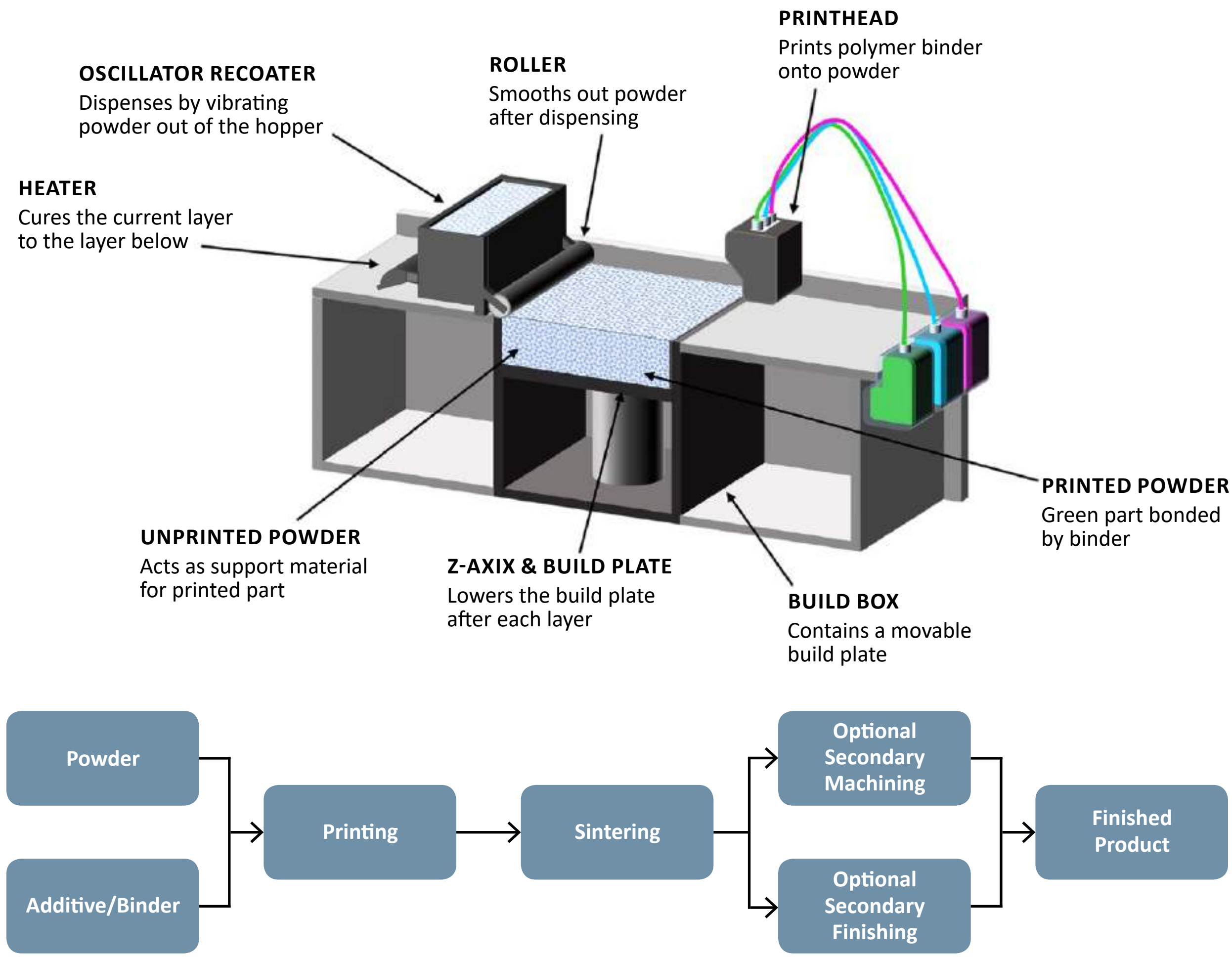


Fig. 2 Schematic of the Binder Jetting process and the key components of a system

The green body produced in the build process is subject to partial or full sintering, burn out of the binder and fusing of the metal particles, to give a finished component with the required properties. Infiltration is also an option. This involves filling the interstitial pores of a cured metal matrix with a low melting alloy such as bronze to achieve densification without shrinkage. With infiltration, shrinkage may be limited to around 1%, while with sintering it is usually in the order of 15%, though sintering has the advantage of producing a densified (between 96–99%), single alloy component and is usually the preference for industrial applications.

When it comes to choosing a manufacturing method for a specific application, Binder Jetting is most commonly compared with either Powder Bed Fusion (PBF) or Metal Injection Moulding (MIM), since it shares certain characteristics of both techniques.

Binder Jetting is differentiated from PBF by the fact that heat is not employed during the build process. This avoids the development of residual stresses in the part and the associated need for secondary post-processing to relieve them. It also eliminates any requirement to support the structure during construction, via anchoring to the build plate, to avoid thermally induced warping. In Binder Jetting, the part is supported solely by loose powder in the build box. Furthermore, Binder Jetting is typically a less material- and time-intensive process, offering superior spreading speeds and often proving the most cost-effective AM option overall.

When it comes to comparisons with MIM, Binder Jetting is simpler and more flexible as there is no requirement for a mould. A single Binder Jetting machine can simultaneously produce different parts, small and large, including complex geometries, and lead times tend to be shorter. These benefits are particularly attractive for short/low-volume production runs. If the requirement is for a high-volume run of a small component, for instance, then the economics may well be in favour of MIM, since the investment cost of a mould, potentially in the region of $50,000, is low per unit. On the other hand, for lower volume runs, in the order of a few hundred thousand, Binder Jetting is likely to be more economically advantageous, with the exact switchover volume depending on the specific part/application.

In summary, Binder Jetting combines certain attractions of both MIM and PBF, producing parts with mechanical properties (strength, elongation, hardness, density) that compare favourably with those made by any metal manufacturing technique. This makes it a compelling, cost-efficient choice for a range of applications across the aerospace, energy/oil and gas, automotive, pump and tap industries. The ability to easily produce legacy and custom parts is especially valuable. Specifying powders that will perform well in the Binder Jetting machine is critical to meeting these diverse applications.

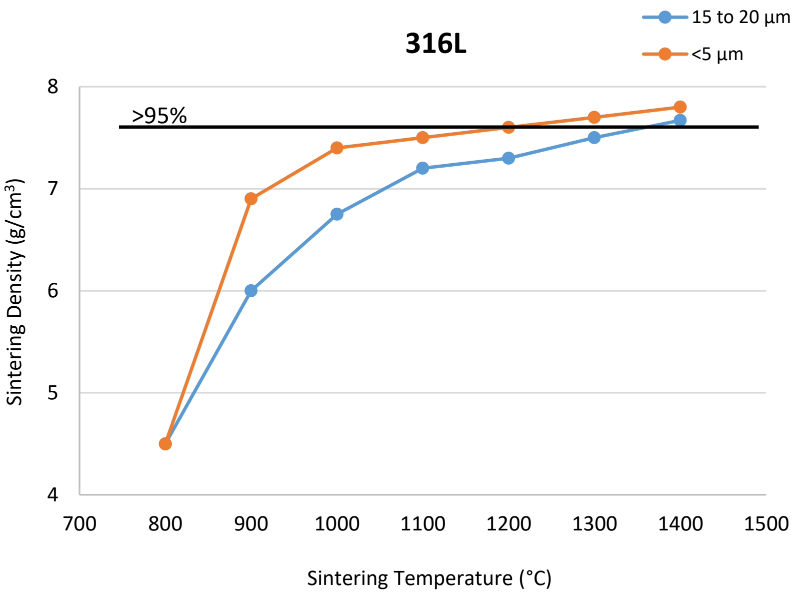


Fig. 3 Finer powders are highly desirable for Binder Jetting, sintering at lower temperatures and over a narrower temperature range

Specifying powders for Binder Jetting

Particle size and size distribution (Dv10, Dv50 and Dv90) are primary parameters for metal powders for Binder Jetting, with finer particles offering superior sintering characteristics. Fig. 3 shows how reducing the Dv50 of the powder from 15–20 µm down to < 5 µm facilitates sintering at a lower temperature, over a narrower temperature range. This has the advantage of reducing the likelihood of slumping and distortion during the sintering process, making it easier to produce finished components with precise dimensional integrity. Fine powders are, in essence, integral to high-resolution production.

However, finer powders tend to be less free flowing than coarser analogues. Analysing the flow of powders is especially important because ExOne's systems are capable of handling both spherical gas atomised powders and angular water atomised powders. Binder compatibility is also routinely assessed by measuring how long it takes for a known volume of solution to soak into a sample of powder; curing of the resulting sample enables further assessment of this aspect of performance.

Experience at ExOne shows that these characteristics alone are unable to reliably determine whether a powder will perform efficiently. When the company relied solely on these characterisation techniques/tests, it was necessary to trial the powder in a Binder Jetting machine to determine whether it would work effectively; a costly, time-consuming approach. Around three years ago, the decision was taken to invest in technology to quantify powder flowability, with the aim of establishing a test regime to robustly differentiate poorly performing powders without resorting to a production trial. The company chose to invest in an FT4 Powder Rheometer® produced by Freeman Technology, Tewkesbury, UK, an instrument that offers dynamic, shear and bulk property measurement.

Establishing flowability specifications for Binder Jetting powders

ExOne handles a significant number of different metal powders, from customers looking to determine whether Binder Jetting is feasible for a specific application, for its parts-on-demand service, and in connection with the development and supply of qualified materials for customer use. Following the purchase of the new powder tester, the company began to measure a comprehensive set of bulk powder properties for each material encountered, using standard test protocols [1]. Correlating variables from this growing database with manufacturing performance made it possible to develop specifications defining powders with desirable characteristics and to establish optimal processing parameters for powders with specific properties. The company now rapidly assesses the suitability of new powders by applying acceptability criteria that include values for the following flowability metrics:

- Stability Index (SI)
- Flow Rate Index (FRI)
- Cohesion
- Wall Friction Angle
- Permeability
- Compressibility

SI and FRI are dynamic powder flow properties. Dynamic properties such as Basic Flowability Energy (BFE) and Specific Energy (SE) are generated from measurements of the axial and rotational force (torque) acting on the helical blade of the tester as it is rotated

	Minimum	Ideal case	Maximum	Customer powder
Stability index	0.65	1.00	1.20	X
Flow rate index	0.96	1.00	2.50	X
Cohesion (kPa)	0.11	Low	1.76	X
Wall friction angle (°)	10.40	Low	32.10	X

Table 1 Test results for a customer's powder are compared with established ranges for key flowability properties

along a prescribed path, through a conditioned powder sample. BFE is measured with a downward traverse of the blade which subjects the powder to forced flow conditions, pushing it down against the confining base of the sample vessel. SE, in contrast, is measured with an upward traverse that applies a gentle lifting action, making values more representative of unconfined flow behaviour in a low stress state. SI and FRI both derive from BFE measurements. SI is a measure of how BFE changes with repeat testing of the same sample while FRI quantifies change in BFE as a function of flow rate (impeller speed), indicating whether the powder flows more (or less) easily at higher flow rates.

Cohesion and Wall Friction Angle (WFA) are both shear properties. Shear Cell testing involves measurement of the force required to shear one consolidated powder plane relative to another and is particularly useful for determining the ease with which a consolidated powder will transition from the static to dynamic state. WFA quantifies the strength of interactions between the powder and a certain material of construction and is measured by shearing the powder against a representative coupon, rather than another powder plane. WFA is used directly in hopper design methodologies (along with other shear parameters) but is more broadly indicative of the compatibility of a specific "powder/material of construction" combination and quantifies the likelihood that material will adhere to processing equipment.

Compressibility and permeability are both bulk powder properties. Compressibility is determined by measuring bulk density as a function of applied pressure while permeability, which is indicative of the resistance the powder presents to gas flow, is quantified from measurements of pressure drop across the bed at a certain air flow rate.

Measuring all these properties, along with particle size and morphology, makes it possible to predict how a powder will behave during production, as illustrated by the following example studies.

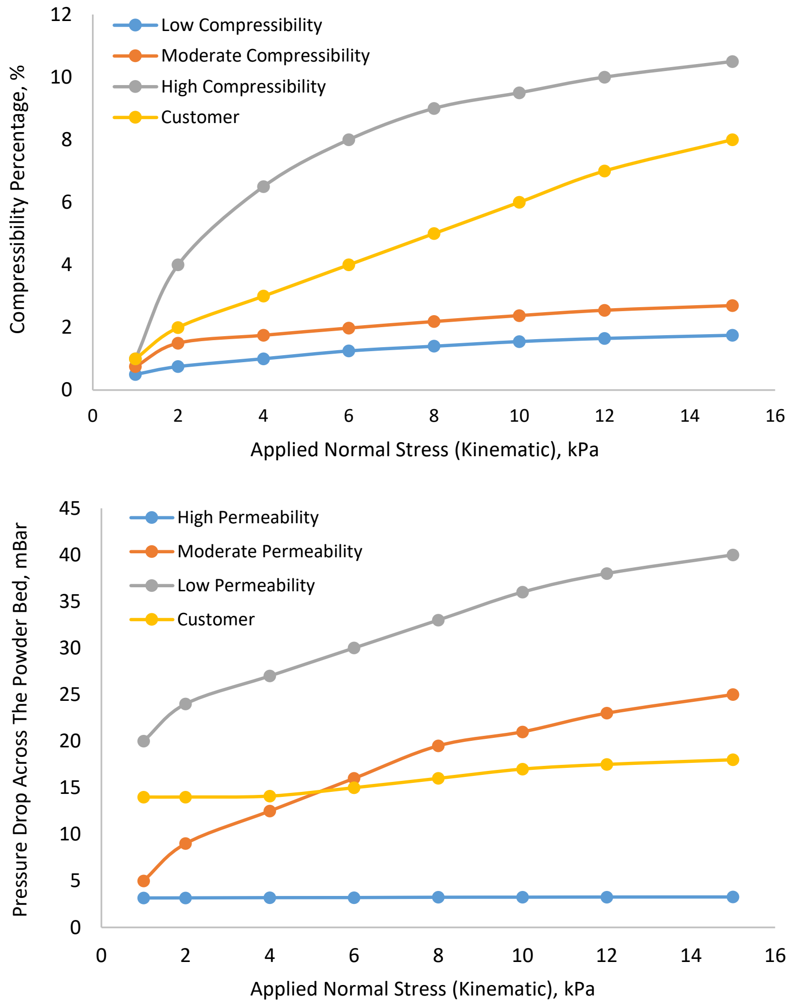


Fig. 4 Compressibility (top) and permeability (bottom) data complete the assessment

Case study: Assessing customer powders

Table 1 and Fig. 4 show established acceptance criteria for the six flowability properties that ExOne uses to answer the customer question: 'Can I process this powder?' An important point to note is that, for some properties, the ranges of acceptability are relatively broad. While these boundaries define the limits of processability, the optimal processing parameters vary considerably depending on where the properties of the powder lie within these ranges. Established correlations not only indicate whether the powder is suitable for manufacturing but also define the most suitable processing parameters.

The ranges identified remain subject to change should a new powder exhibit behaviour lying outside the established correlations. However, this happens relatively rarely. It is now possible to determine whether a new powder is suitable for processing in just a few hours; a significant improvement on the days, weeks or even months that were historically invested in feasibility studies, prior to purchase of the powder tester.

Case study: Assessing the suitability of new powder supply

As a result of offering a parts-on-demand service, ExOne is a significant user of metal powders, the cost of which directly impacts component price and profitability. Establishing less expensive metal supplies is therefore a valuable activity, provided that the powders fully meet production requirements. The data shown in Table 2 is for two supplies of 316L stainless steel powder.

These two water atomised powders exhibit very similar particle size distribution data, with Dv10, Dv50 and Dv90 all essentially equivalent, within acceptable tolerances. The morphology of the two samples was also found to be comparable (as analysed by scanning electron microscopy – data not shown). With respect to flowability, FRI, cohesion and wall friction angle all lie within the boundaries of acceptability. However, SI does not. SI is numerically defined as the ratio of BFE measured after seven repeat tests to BFE measured in test one. The results therefore indicate that BFE is increasing with repeat testing, or more fundamentally that the powder is physically unstable.

The implications of this difference were investigated by running the powder through the AM system.

	316L	316L - Alternate supplier
D_{10} (µm)	6.4	6.6
D_{50} (µm)	16.1	15.8
D_{90} (µm)	29.1	30.0

	Minimum	Ideal case	Maximum	Customer powder	316L - Alternate supplier
Stability index	0.65	1.00	1.20	1.03	1.52
Flow rate index	0.96	1.00	2.50	1.35	1.27
Cohesion (kPa)	0.11	Low	1.76	0.62	0.62
Wall friction angle (°)	10.40	Low	32.10	27.80	24.02

Table 2 Particle size data for the powders are closely similar and three out of four of the flowability parameters meet the acceptability criteria. However, the alternate supply has a high SI and goes on to exhibit poor recycling performance

Initially it performed well, but part quality gradually degraded over time. After four to five cycles, as the powder was progressively recycled, it became impossible to run the system successfully with the alternative supply, though the original material retained performance under the same conditions. The machine was cleaned out and the entire testing process was repeated, but the same effect was again observed. Closer investigation of the alternative supply revealed that it had more flaky particles than the original, that ultimately became prone to interlocking. The measurement of SI clearly identified this physical instability and the associated limitations and unsuitability of the cheaper material.

> *"After four to five cycles, as the powder was progressively recycled, it became impossible to run the system successfully with the alternative supply, though the original material retained performance under the same conditions..."*

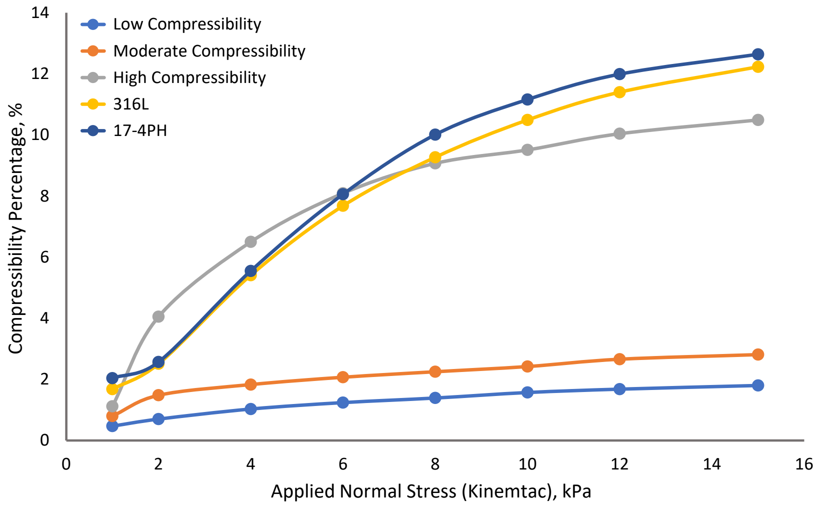
Case study: Developing a new qualified material

In this final study, the results shown are for a new material developed to extend the company's range of qualified materials for Binder Jetting. 17-4PH is a widely used stainless steel, particularly in MIM, prized for its hardness and strength, relative to 316L, with applications

	316L	17-4PH
D10 (µm)	3.7	3.9
D50 (µm)	9.8	10.1
D90 (µm)	21.4	21.7

	Minimum	Ideal case	Maximum	316L	17-4PH
Stability index	0.65	1.00	1.20	1.03	1.03
Flow rate index	0.96	1.00	2.50	1.75	1.49
Cohesion (kPa)	0.11	Low	1.76	1.15	1.01
Wall friction angle (°)	10.40	Low	32.10	25.00	25.70

Table 3 Particle size distribution data and flowability metrics indicate that the two stainless steel powders have closely comparable properties



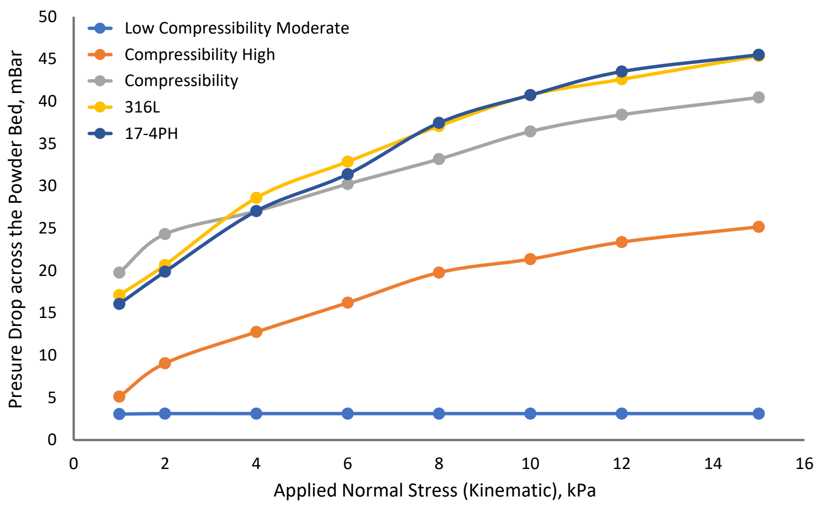


Fig. 5 The compressibility of the 17-4PH powder (top) is relatively high and permeability is relatively low, but, in both cases, values are closely similar to those for 316L powder

in the dental and medical industries and for the manufacture of firearms. Table 3 and Fig. 5 show how the properties of a 17-4PH powder compare with those of an established 316L powder for Binder Jetting.

In this case, the two powders are extremely similar, in terms of particle size metrics and all flowability characteristics. The 17-4PH powder exhibits relatively high compressibility and low permeability, but, in both cases, the measured values are closely similar to those for the established 316L powder. These results predict that the new material will perform in a very similar way to the existing 316L stainless steel powder, a prediction confirmed in production trials.

In conclusion

Binder Jetting is uniquely attractive as a metal manufacturing process, combining compelling features of both PBF and MIM to offer flexibility and cost-efficiency. These advantages are driving uptake of the technology, intensifying the need to be able to robustly identify metal powder feedstocks that will perform successfully in Binder Jetting systems. Experience at ExOne indicates that bulk powder property measurement is essential to differentiate powders that will perform well from those that will not and to identify optimal operating parameters for each specific powder.

Using an FT4 Powder Rheometer, the company has established acceptance criteria for dynamic, shear and bulk powder properties that securely identify high-performance powders for Binder Jetting in just a few hours, without any requirement for a production trial. Powder property data have proved an essential complement to particle size and shape data for this assessment, with the adoption of an effective powder testing strategy saving the company time and money in feedstock sourcing and the day-to-day servicing of customer requirements.

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Fig. 6 Binder Jetting is a flexible, cost-efficient process for manufacturing complex components with high resolution.

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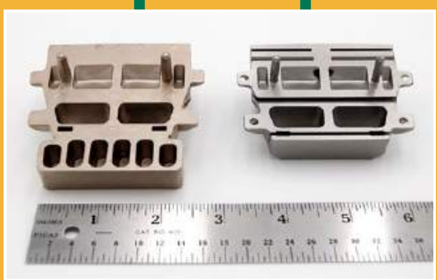

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Rapid qualification of new alloys for Additive Manufacturing through a holistic process chain

The limited number of alloys currently commercially available for metal Additive Manufacturing is regarded as a key factor hindering the growth of the industry. In this article, Rosswag GmbH's Daniel Beckers reports on a high-speed qualification process that the company has developed for new alloys, and that spans the complete AM process chain – from alloy atomisation to L-PBF process parameters, heat-treatment and mechanical testing.

With Additive Manufacturing on the rise when it comes to its market share in the manufacturing industries, and with the development of more sophisticated tools for the design of parts specifically for AM, customers and producers alike are shifting their focus increasingly toward the materials that are commercially available for the technology. This brings to the fore one of the most crucial barriers for the widespread adoption of AM; namely, the low number of alloys usable as standard materials for AM parts. A comparison between the number of commercially available alloys available for conventional manufacturing and Additive Manufacturing is shown in Fig. 1.

Compared to conventional manufacturing processes, where up to 2,500 steel alloy compositions are available for their respective fields of usability, only about two dozen different alloys are available for metal AM. This material gap slows down development speed, due to the time and costs involved in developing and qualifying new materials, and as a result the procurement of the necessary powders can take months for customised alloy compositions. To bridge this gap, a new high-speed material qualification route has been developed by Rosswag GmbH which is centred on the process needs to optimise material qualification with a focus on time and availability, from powder production to the first solid technical data.

Rosswag GmbH is a family-owned company, founded in 1911, with over a hundred years of experience in open-die forging with over four hundred different raw material alloys, from steels, nickel-base alloys and aluminium to titanium materials, all

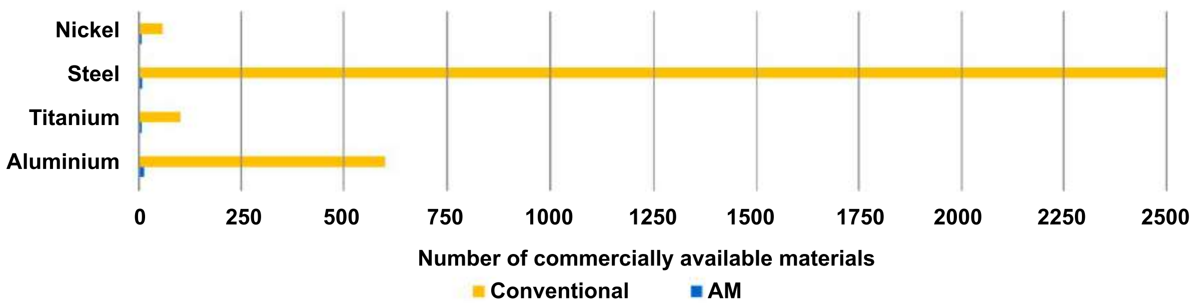


Fig. 1 A comparison between the number of materials available for conventional manufacturing routes compared to Additive Manufacturing

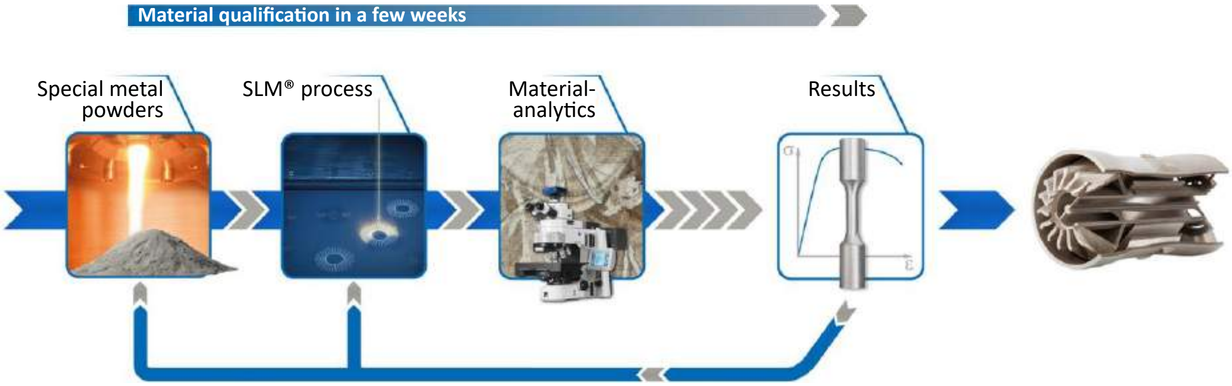


Fig. 2 Material qualification process chain with iterations aiming at the L-PBF process parameters and material composition

available from stock. The company employs a staff of two hundred and is regarded as one of the world's leading suppliers of open-die forged products up to 4.5 tons, which are manufactured in-house in a holistic process chain. Its in-depth knowledge of the manufacturing and testing processes is reflected in the high quality of its end products, which are used in the aerospace industry or in energy engineering. Rosswag also holds a number of industry certifications, such as ISO 9001 and ISO 9100 for aerospace.

To further increase its potential for innovation, Rosswag founded its Engineering division in 2014 after seeing the potential of Laser Powder Bed Fusion (L-PBF) technology and possible synergies between the forging division and the new capabilities offered by Additive Manufacturing. The incorporation of the Additive Manufacturing process enables the production of functionally optimised metal components in addition to forged products. In 2017, the Additive Manufacturing production operation was supplemented with in-house metal powder production facilities for material development.

To complete the already comprehensive production chain, in 2018 a new material analytics laboratory was installed. This enables Rosswag to analyse and quantify material properties such as alloy composition, microstructure and porosity. Furthermore, a complete examination of produced powders is possible to assess particle size distribution and relative humidity, as well as the flow characteristics of the powder. These properties are crucial to ensuring powder usability for Additive Manufacturing. By combining all of its experience and equipment, Rosswag was able to develop the following material qualification route, and became the first AM powder producer to be certified by TÜV SÜD Industry Service GmbH.

Material qualification

Rosswag's material qualification process consists of a number of stages which together make up a flexible and fast workflow that is able to develop different material compositions and target the optimisation of process parameters in the L-PBF process. The process chain is shown in Fig. 2.

An important step in the qualification process is the production of the metal powder. Since the procurement of typical amounts of around a few hundred kilograms is time consuming and costly, especially in relation to custom-made powders, the focus here is on small amounts (≤ 20 kg) of self-produced metal powders. For the production of powder for qualification, a Blue-Power AU3000 atomiser is used (see

Fig. 3 Blue Power AU3000, with high-speed image of the CCA gas atomisation process [1]

Fig. 3 left), with an Al_2O_3 crucible and a volume of 3 litres. This can equate to up to 12 kg of feedstock material.

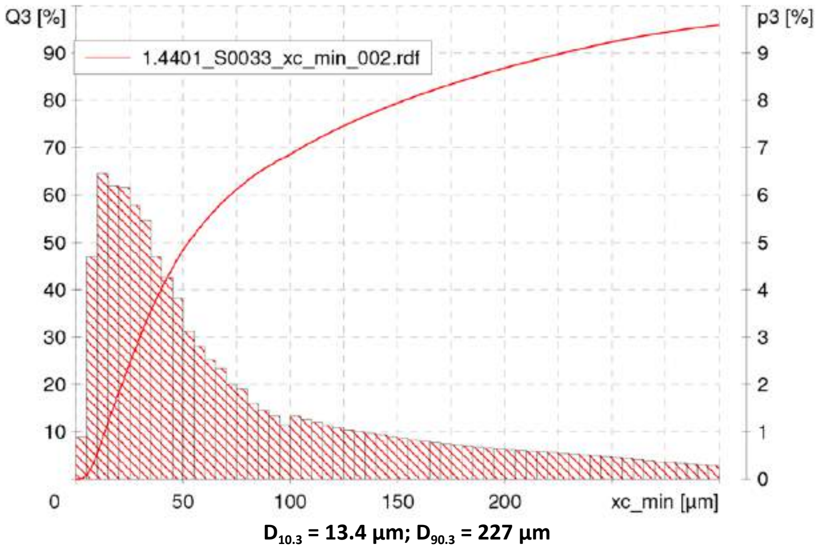
The system uses an inert gas (in this case, argon) to atomise a melt stream and create the powder (Fig. 3, right). To minimise powder oxidation, the melting and the atomisation take place under an argon atmosphere created by purging the melt and atomisation chamber before the process start. The atomiser is especially designed for particles in the size range between 10–100 µm using a close-coupled nozzle. Here, the melt only travels a few millimetres before coming into contact with a supersonic gas flow field. It is therefore capable of covering the typical AM particle size ranges. The necessary powder can be produced within a matter of days.

After powder production, the material composition is analysed via x-ray diffraction (Bruker S8 Tiger) to ensure that it did not change during the melting process. In the case of a problem, a change in composition by making further additions of alloy elements to the melting crucible before atomisation is possible without significant effort. Afterwards, the powder must be sieved and air classified into the target size range to ensure flowability in the powder layer application (Fig. 4).

During preparation of the powder, the flowability is constantly controlled by a Hall-Flowmeter and a powder coating system developed by Rosswag Engineering (Fig. 5), simulating the coating process used in an SLM Solutions SLM®280 HL Additive Manufacturing system [2].

The coating device creates a defined powder layer on a metal plate. This layer is then analysed via image processing. Typically, around 60% of the atomised material can be used in the AM process. At the end of the powder production process, powder characterisation including particle size and shape measurement, and a humidity check, is performed.

Directly connected to powder preparation is parameter development, with a primary focus on



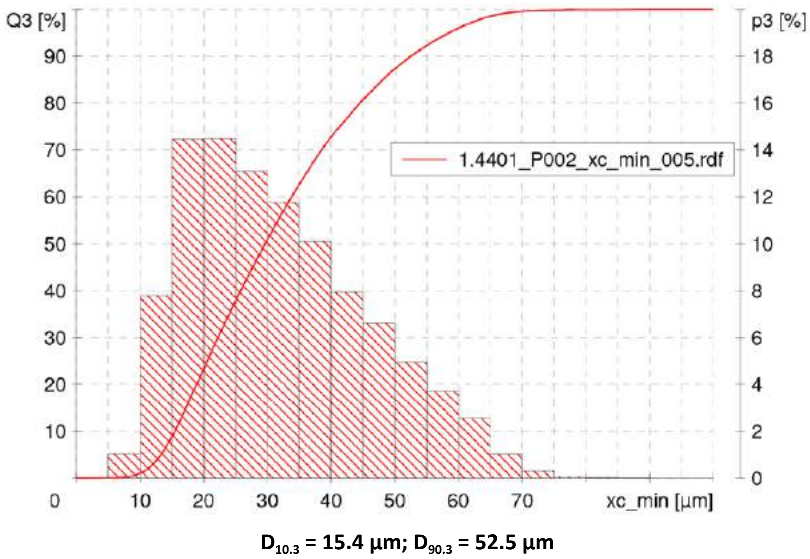


Fig. 4 Typical as-atomised particle size distribution (left) of a 316L stainless steel and the sieved powder for the L-PBF process

Fig. 5 Hall-Flowmeter and system for the simulation of the powder coating process for flowability control [2]

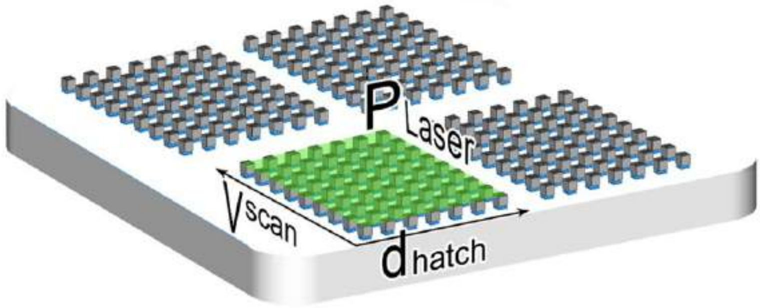


Fig. 6 Build plate for parameter development with the main parameters of laser power, scan velocity and hatch distance, referring to the volume energy density

producing a highly dense material with low porosity. For the porosity analysis, a build job with cube samples is processed, as shown in Fig. 6.

Here, every cube is printed with a different set of process parameters. To increase the amount of data generated, the cubes can be arranged in matrices to vary an additional parameter. Typically, the scan velocity and the hatching distance, as well as the laser power, are varied based on the volume energy density as given in the following equation.

$$E_d = \frac{P_{laser}}{v_{scan}\Delta_{hatch}h_{layer}} \quad \left[\frac{J}{m^3}\right]$$

The produced samples are then subjected to grinding and polishing. In the second step, a parameter set based on the first results from a porosity analysis is chosen for the Additive Manufacturing of additional sample geometries. In most cases, these specimens are used for mechanical testing, such as impact or tensile strength testing. The chemical composition of the additively manufactured material is also evaluated to further evolve the alloy composition, if necessary.

All of these steps can be performed within a few weeks, giving customers the opportunity to receive the first solid data about their materials in a short time frame. This helps to evaluate the next steps in their development, by either changing certain parameters or the material, or even giving the possibility to stop the project before either time or costs are beyond reason.

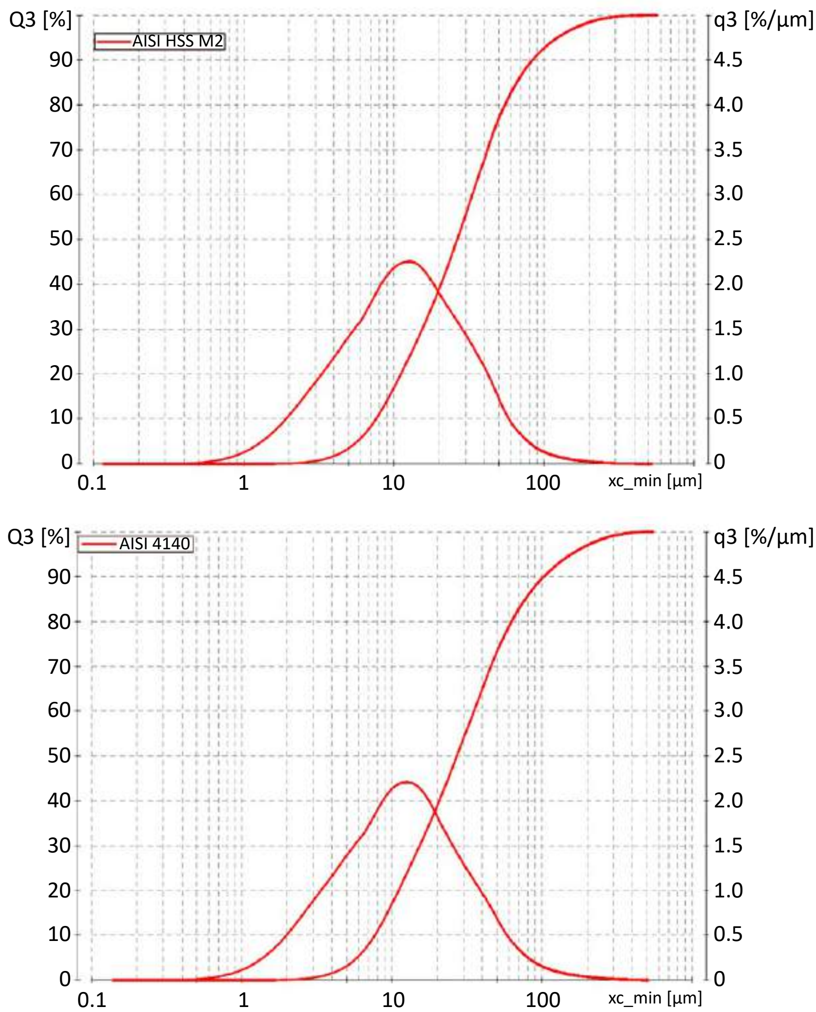


Fig. 7 Achieved particle size distributions as-atomised for the AISI4041 and AISI M2 steels [3]

Case study: AISI 4140 & AISI HSS M2

The concept and functionality of Rosswag's qualification route was evaluated with the qualification of two steel alloys, an AISI 4140 and an AISI HSS M2 tool steel, both of which were achieved within a few weeks, including the production of the necessary powders. AISI HSS M2 is one of the most used cutting steels, because of its extremely high wear resistance. With a carbon content of 0.9 wt.%, weldability is relatively poor; this poses a problem for the L-PBF process, since it is based on micro-welding.

The second material is AISI 4140. This has a high strength and toughness and many different heat treat-

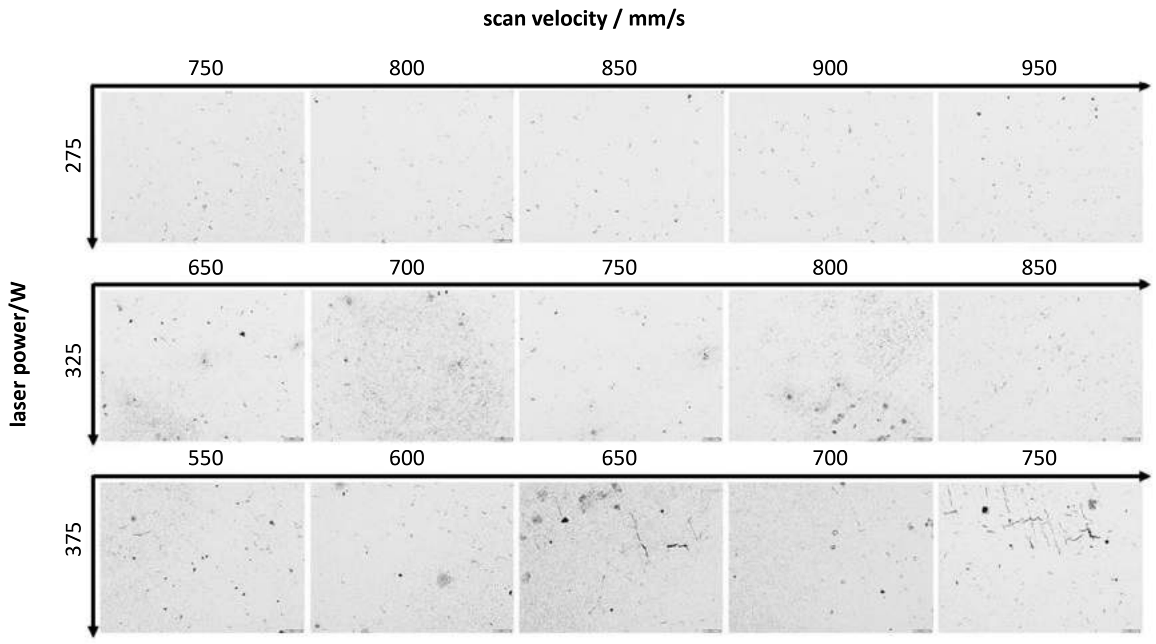


Fig. 8 Porosity analysis results for different AM parameters for AISI 4140 with a constant hatch distance of 100 µm [3]

ment procedures for this material are well researched in order to optimise mechanical properties based on an application's requirements. Because of a carbon content at 0.45 wt.%, a limited weldability was predicted.

After the atomisation of both alloys, the produced powders were measured in the as-atomised condition to evaluate the atomisation parameters for further optimisation. The resulting particle size distributions are given in Fig. 7.

Both powders show a typical distribution for steel alloys atomised in the plant. After conditioning the powder for flowability and usability in the AM process, the samples for parameter analysis were produced as defined above. Sample production took place on an SLM 280 HL. Laser power, hatch distance and scan velocity were varied. For both materials, 30 µm layer thickness was used. After grinding, polishing and etching the samples, the microstructure was analysed with a Scanning Electron Microscope (SEM) and a light microscope. Results for the AISI 4140 porosity analysis are shown in Fig. 8.

The image shows results for different laser powers and scan velocities and gives an impression of the influence of the different parameters on the development of pores with changing volume energy. A full overview over the achieved densities is given in Fig. 9.

The diagram shows the average material density plotted versus the energy density. The different shaped markers indicate different hatch distances and the colouring refers to the laser power. The results show that neither a high nor a low energy density performs best in the case of average material density. Choosing a certain set of parameters is also always choosing between a dense material and build rate, since both criteria are often in conflict with one another. The final set of parameters here was

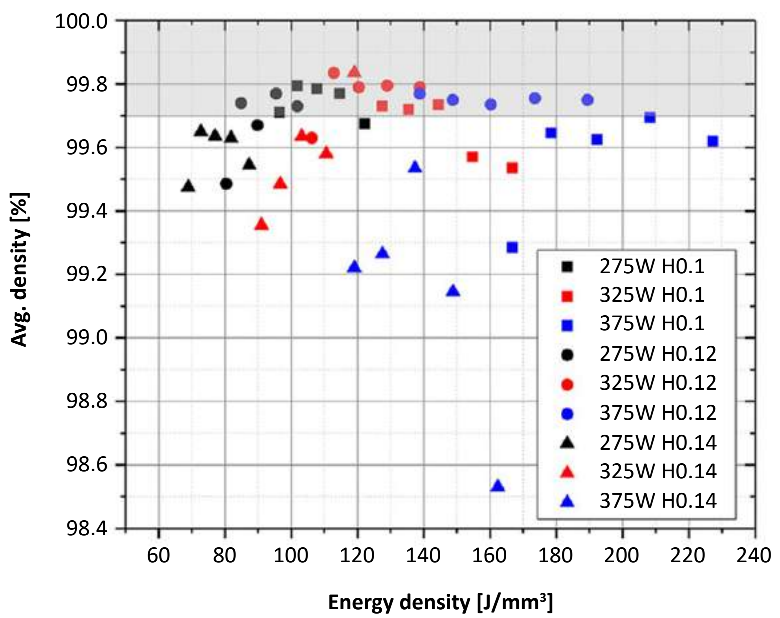


Fig. 9 Averaged sample densities of different process parameter sets for AISI 4140 [4]

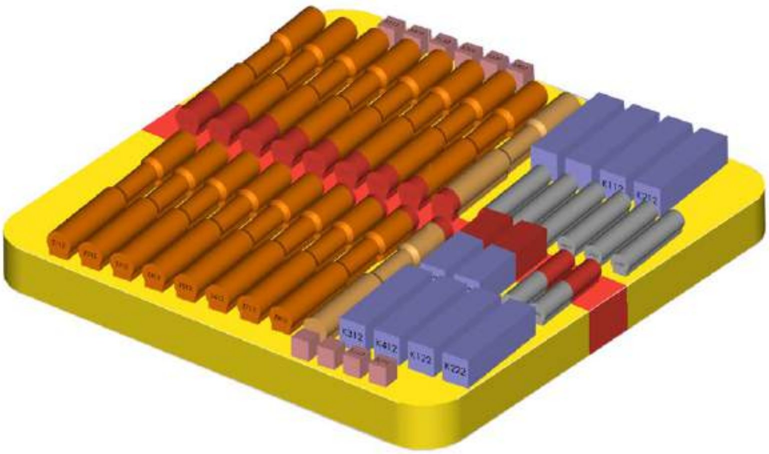


Fig. 10 Build plate with different sample geometries for testing

chosen with a hatch distance of 120 μm, 275 W laser power and a scan velocity of 900 mm/s.

With the given parameters, a second build job with different sample geometries for impact and tensile strength measurements was carried out according to Fig. 10. The plate shows that, even with a very small build job, in terms of height, a large number of samples can already be created. After the build, some of the AISI 4140 samples were hardened for 20 min at 850°C and quenched in oil. Afterwards, a tempering process took place at 450°C for two hours followed by cooling at room temperature under ambient conditions.

The samples were mechanically machined to achieve a sample geometry in accordance with DIN 50125. Some parts were heat treated afterwards. This consisted of soft annealing and hardening followed by tempering. The tensile strength testing was conducted in accordance with existing ISO standards. The sample was tested at room temperature and at 400°C.

Further tests were carried out, such as the Charpy impact test. Here, standardised samples with a v-shaped groove are broken by a drop hammer. The energy the hammer transfers to the sample is a measure of the toughness. Hardness was measured with Rockwell and a diamond cone with an angle of 120°. Table 1 shows the results of mechanical testing for the AISI 4140.

The data show that the mechanical characteristics at 400°C are below the values measured at room temperature. This is because of the easier movement of dislocations in the material. The difference between the heat-treated samples and the as-printed samples are small compared to the temperature influence. In general, the as-built samples have a 16% lower tensile strength than the tempered ones.

In Table 2, a comparison between the additively produced samples and conventionally produced samples is shown, to further evaluate the performance of the L-PBF process.

Condition	Young's-modulus [GPa]	$R_{p0.2/1.0}$ [MPa]	R_m [MPa]	A [%]	hardness [HRC]
As-built Room Temperature	208 ± 15	1175 ± 5/ 1240 ± 10	1280 ± 10	7.2 ± 2.8	39
As-built 400°C	188 ± 11	984 ± 26/ 1037 ± 2	1060 ± 18	7.5 ± 1.9	-
Hardened and tempered RT	194 ± 3	1290 ± 10/ 1310 ± 10	1325 ± 5	4.2 ± 3.6	40
Hardened and tempered 400°C	161 ± 8	900 ± 14/ 1040 ± 10	1055 ± 5	5.7 ± 1.8	-

Table 1 Results of the mechanical testing for the AISI 4140 for different material treatments [3]

	L-PBF		Forging*	Hot Rolling*	Casting*
	As-built	Hardened and tempered	Hardened and tempered	Hardened and tempered	Hardened and tempered
$R_{p0,2}$ [MPa]	1175 ± 5	1290 ± 10	1010	975	717
R_m [MPa]	1280 ± 10	1325 ± 5	1165	1136	791
A [%]	10.55 ± 1.9	7.4 ± 1.8	13.6	12.8	4
Hardness [HRC]	39	40	34	33	-

Table 2 Mechanical data for additively manufactured samples of AISI 4140 compared with conventionally manufactured materials [3] [5] [6]

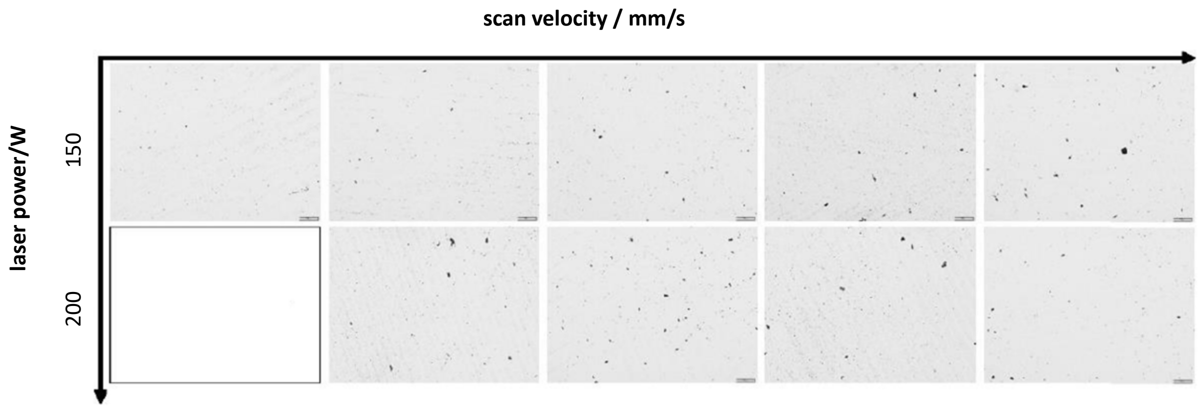


Fig. 11 Porosity analysis results for different AM parameters for AISI M2 [3]

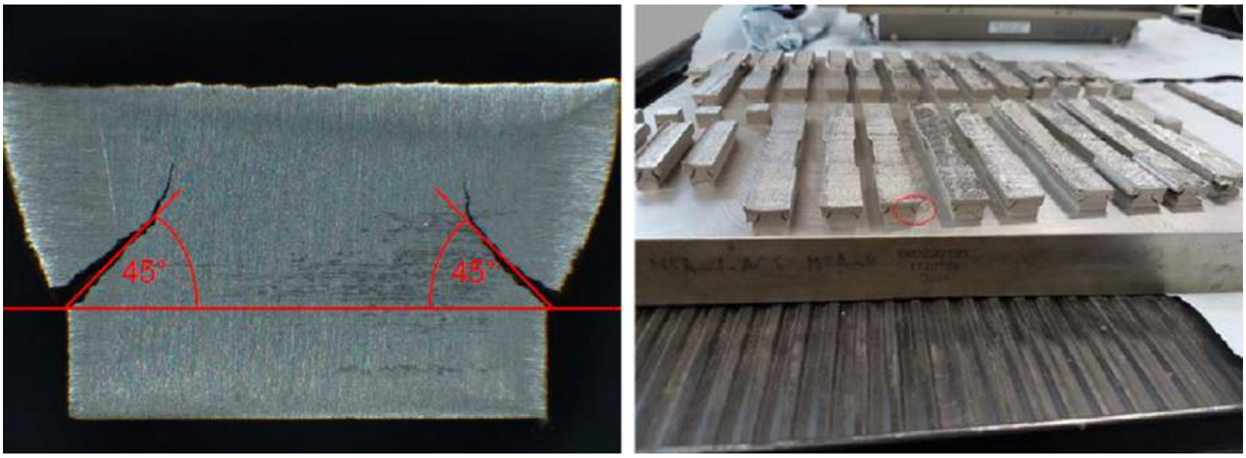


Fig. 12 Samples of the AISI M2 with cracks at the diameter transition area due to internal stress [3]

The comparison shows that the L-PBF process performs in the same range of magnitude as the conventional samples. Depending on the manufacturing route, it can even outperform conventional production processes for the given characteristic values.

Results for AISI M2

AISI M2 was prepared in the same manner as the 4140 steel, beginning with a parameter development evaluation by printing cube samples and analysing the achieved material density. Some results are given as an example in Fig. 11.

This figure shows that it is generally possible to achieve a good first material structure, in terms of overall material density. After using the results to validate a first set of process parameters, a sample build job was produced comparable to the build job shown in Fig. 10. Despite the fact that a sufficient material density can be achieved, the production of AISI M2 samples was aborted due to major defects during the recoating process as a result of part distortion and cracking (Fig. 12). The fractures result from a brittle carbide network and internal stresses due to the high cooling rates within the L-PBF process.

Although experiments to assess the mechanical properties of AISI M2 were not possible, this alloy should perform in the tempered state much better in terms of wear behaviour in contrast to the untreated part thanks to the precipitation of carbides. These should also lead to an increase in tensile strength, because of the blocked dislocation movement.

Conclusion

Within the scope of the works of R Koch 2018 [3] and J Damon 2019 [4], together with Rosswag Engineering, the material qualification process for AISI M2 and an AISI 4140 was performed. The process was covered from powder production up to the production and testing of characteristic mechanical values, including a preceding parameter study for the L-PBF process.

Both materials show a sufficient material density when an appropriate set of process parameters is selected. In the case of AISI 4140, a build job with additional samples was realised and the mechanical data achieved, due to impact and tensile strength testing, as well as hardness testing, was compared considering different heat treatments and different sample manufacturing routes (i.e. casting, hot rolling and forging). The data show that, for the given static mechanical results, the AM samples are compatible and, in some cases, even outperform the conventional samples (here produced by casting and hot rolling).

In contrast to these results, AISI M2 poses a good example regarding the importance and essence of time frame within the qualification process. Due to the short and fast iteration cycles in the proposed qualification process at Rosswag, the problems with the M2 could be identified in an early project state, and a fast decision about the further development was possible without losing more time or money than needed for initial tests.

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