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THE MAGAZINE FOR THE METAL ADDITIVE MANUFACTURING INDUSTRY

METAL AM

in this issue

DESIGNING FOR METAL AM

COMPANY VISIT: MATERIALS SOLUTIONS

VIENNA CONFERENCE REPORT

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METAL ADDITIVE MANUFACTURING

It's amazing what you can do with metal powders...

Welcome to the first issue of *Metal Additive Manufacturing*, the new magazine from Inovar Communications Ltd focusing on the world of Additive Manufacturing with metals.

As a publishing company dedicated solely to metal powder based manufacturing processes, our team has many years of combined experience working with the industries that create the wide variety of metal powder based components that are used in all areas of life.

Our first magazine, *Powder Injection Moulding International*, was launched to meet the needs of the rapidly growing Metal Injection Moulding (MIM) and Ceramic Injection Moulding (CIM) industries. This was followed with *Powder Metallurgy Review*, a magazine that covers developments in the wider PM industry, from pressed and sintered structural components to Hot Isostatic Pressing (HIP), hardmetals and more.

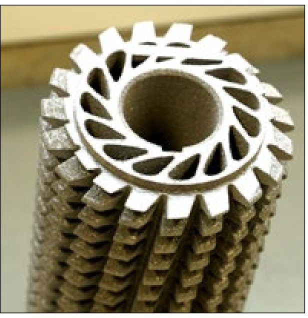
Metal Additive Manufacturing magazine will focus on both commercial and technical developments in the international metal AM industry. As with all our titles, *Metal Additive Manufacturing* is available as a free to access digital download as well as in print via a subscription.

Our commitment is to offer editorial content that is not only of value to those involved in the AM industry, but will also help potential users understand, and leverage, the benefits that this rapidly developing manufacturing technology offers.

Nick Williams
Managing Director

Cover image
This model wing demonstrates AM's ability to combine differently oriented lightweight structures within one part. The model has been produced in one step (Courtesy Concept Laser GmbH)

METAL ADDITIVE MANUFACTURING



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industry news

GE Aviation's first AM part cleared to fly in commercial jet engines

The T25 sensor provides pressure and temperature measurements for the engine's control system (Image GE Aviation)

GE Aviation has reported that the US Federal Aviation Administration has granted certification of its new T25 engine sensor for the GE90-94B engine. The upgraded T25 sensor, located in the inlet to the high pressure compressor, is being retrofitted into more than 400 of the GE90-94B engines in service. The T25 sensor, which incorporates an additive manufactured component for the housing, provides pressure and temperature measurements for the engine's control system.

The company added that its GE90 engine, which was the first jet engine to utilise composite fibre polymeric material on the front fan blades 20 years ago, achieved another milestone by becoming the first GE engine to incorporate an additive manufactured component in a commercial GE jet engine. The GE90 family of engines powers Boeing's 777 planes.

"Additive Manufacturing has allowed GE engineers to quickly change the geometry through rapid prototyping and producing production parts, saving months of traditional cycle time for the T25 sensor housing without impacting the sensor's capabilities," stated Bill Millhaem, General Manager of the GE90/GE9X engine program at GE Aviation.

Several next-generation engines currently in development will incorporate additive manufactured parts. On the company's LEAP engine for narrow-body aircraft and the GE9X for the Boeing 777X aircraft, GE Aviation will produce part of the fuel nozzles via Additive Manufacturing.

www.geaviation.com

Airbus Defence and Space develops aluminium bracket for new satellite

Airbus Defence and Space in the UK has produced its first space qualified aluminium 3D printed components following a two year research programme under the National Space Technology Programme. One of the components is a structural bracket for Eurostar E3000 telecommunications satellites manufactured from aluminium alloy. The bracket is for mounting the telemetry and telecommand (TMTC) antennas onto the satellite and has successfully completed flight qualification testing. It is reported as being ready to be flown on a forthcoming satellite.

The bracket is a single piece laser melted part weighing 35% less than the previous bracket which comprised four parts and 44 rivets. The Additive Manufactured bracket is also 40% stiffer than the previous manufactured component and does not result in waste generated by conventional machining.

Evolution of existing multi-part bracket to a single piece laser melted part (Image Airbus Defence and Space)

Amy Glover, Senior Spacecraft Structures Engineer responsible for the project, stated, "Producing the first flight qualified AM component is a major milestone and the result of two years of great teamwork funded by Innovate UK in partnership with our suppliers. Through developing and proving the design and manufacturing process, which significantly reduces the testing required, we can now look at what other opportunities there are for AM components that will be lighter and quicker to manufacture."

The AM bracket was manufactured for Airbus by 3T RPD Ltd, a production Additive Manufacturing company based in Newbury, UK.

Airbus Defence and Space added that it is continuing with its implementation plans for AM waveguides, heat pipes, propulsion components, secondary structures and tanks.

www.airbusdefenceandspace.com

Rolls-Royce to flight test Trent engine with its largest ever 3D-printed part

It has been reported that Rolls-Royce plans to flight-test later this year a Trent XWB-97 engine fitted with what it claims is the largest component ever built using Additive Layer Manufacturing (ALM). The titanium structure is a 150 cm diameter x 50 cm depth front bearing housing containing 48 aerofoils, manufactured using the ALM technique.

Rolls-Royce is reported to have already ground-tested several XWB-97s containing the large part, but no engine with such a large ALM component has ever powered an aircraft in flight. It was added that although no production XWB-97s will contain the ALM component, the project is a step towards proving the industrial viability of the process which it says could trim 30% from like-for-like manufacturing lead time.

"It is ideal for prototyping. Shortening the manufacturing time by almost a third gives us more time to design, which is always a benefit," stated Alan Newby, Chief Engineer for Future Programs and Technology. "We are also able to produce designs that we wouldn't otherwise be able to do."

Rolls-Royce plans to flight-test a Trent XWB-97 with a AM titanium front bearing housing

Rolls-Royce is reported to have been using ALM to repair components for at least five years. "We are using this knowledge now to build up to bigger components," added Newby.

www.rolls-royce.com

Concept Laser sees 2014 sales up 75%

Additive Manufacturing technology supplier Concept Laser, based in Lichtenfels, Germany, states that it received 110 new machine orders in 2014 versus 84 in 2013, a 31% increase. With sales growth in recent years averaging 40-50% annually, sales in 2014 were up 75% from the previous year, driven primarily by large-system sales in the 1000 W laser class. The number of employees had also increased as of the end of the 2014 to 103, 30% more than the previous year.

According to Frank Herzog, President and CEO, 2014 was the most successful year in the company's fifteen year history. "In our competitive environment, we not only kept pace with the rapid growth in the market, we even exceeded it. This was the result of our R&D efforts and continuous product expansion. Today, 160 employees are involved in the LaserCUSING process. At Concept Laser alone, 40 of our 103 staff members work in R&D."

Key focus areas include series adaptation of multi-laser technology for increased building speed, as well as pioneering work in the area of real-time monitoring for quality assurance, known as QMmeltpool 3D. For 2015, Concept Laser has announced an X line 2000R, which will feature two 1000-watt lasers and variable optics.

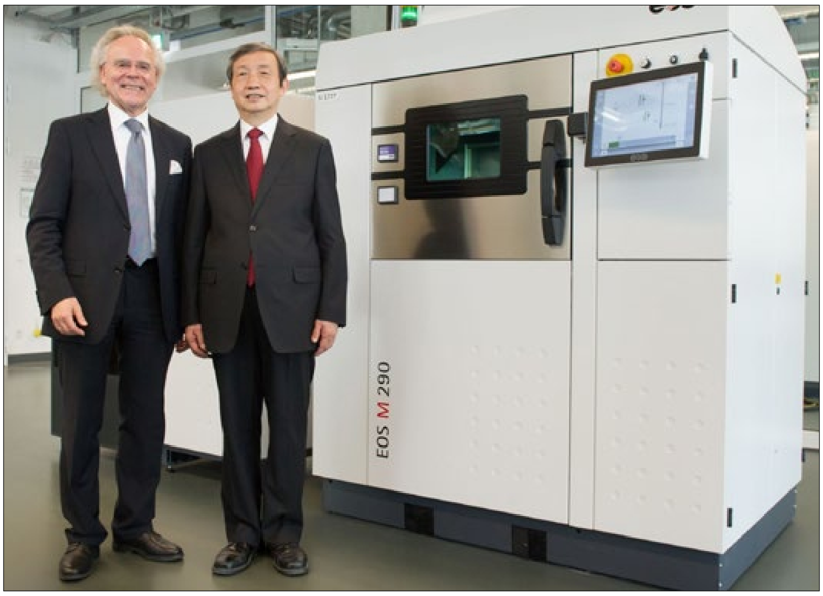
Concept Laser's X 1000R has driven record sales for the company

The company cited predictions of up to 400% growth for AM technologies within the next five years. Prognoses like these, it was stated, are forcing the main players in the market to step up their technological and capacity efforts. Concept Laser, as an owner-operated medium sized business, is relying on organic growth. "We invest nearly 10% of our sales revenue directly in research and development," stated Herzog. "The conservative and long-term mindset of small and medium-sized businesses offers, in my view, the ideal basis for fully realising our strengths in the market."

The company's infrastructure at its headquarters in Lichtenfels was also expanded in 2014 to meet demand, including a new 3,500 m^2 production hall, which is nearing completion and will increase machine output by a factor of 2.5. Separate inspection chambers for confidential customer projects and improved delivery times are important considerations for customers. A new, 600 m^2 state-of-the-art process development and material research centre was also launched in 2014. Last but not least, to meet the enormous demand from the aerospace industry in the US, Concept Laser Inc., with headquarters in Dallas, Texas, was founded in the summer of 2014.

www.concept-laser.de

Chinese Vice Premier visits EOS



Dr Hans J Langer (left) and Chinese Vice Premier Ma Kai

EOS has reported that on March 20 this year it welcomed Chinese Vice Premier Ma Kai to its Technology and Customer Center in Krailling, near Munich, Germany. During the visit EOS Founder and CEO Dr Hans J Langer gave an introduction to EOS as a company and to industrial 3D Printing applications in a number of industries.

"We are very honoured by Vice Premier Ma Kai's visit and look forward to further intensifying our business relationships with potential local customers and partners as well as strengthening the dialogue with the Chinese government," stated Dr Langer. "EOS has a clear commitment to China which is one of our key growth markets. Over the last five years, we were able to grow our installed base from ten systems back in 2010 to over 130 in 2015."

"Additive Manufacturing is a driver for change for the Chinese manufacturing world and as such supports China's evolution from a mostly factory-based economy to one built on high-end and high-tech manufacturing," added Dr Langer.

In 2013 EOS opened a new office and technology centre in Shanghai, China, which enables advanced support services to Chinese customers. Across China EOS also has service offices in Beijing, Chengdu and Shenzhen, it operates with a broad sales network and cooperates with ten local distribution partners.

www.eos.info

EOS and MTU form strategic partnership for quality control in metal AM

Germany's EOS and MTU Aero Engines have been working closely to develop quality assurance measures for metal engine components using Additive Manufacturing. The two companies have now signed a framework agreement for the joint strategic development of their technologies.

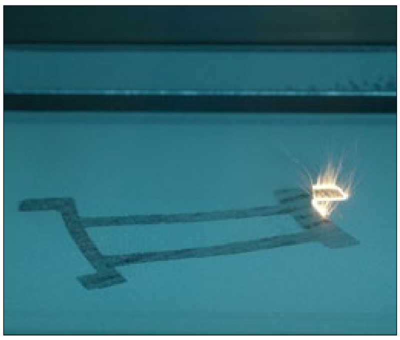
The first result of this joint work is the Optical Tomography (OT) developed by MTU. In addition to several sensors that monitor the general system status, the camera-based OT technology controls the exposure process and melting characteristics of the material at all times, to ensure optimum coating and exposure quality.

Dr Adrian Keppler, Head of Sales and Marketing at EOS, stated, "MTU and EOS have been working intensively for several years and this collaboration is now about to develop into an even closer, partner-based technological cooperation, centred on their quality assurance tool. The OT solution enables us to perform an even more holistic quality control of the metal Additive Manufacturing process, layer by layer and part by part. A very large proportion of the quality control process that previously took place downstream can now be performed during the manufacturing process, with a considerable saving in quality assurance costs. This also allows us to satisfy a central customer requirement in the area of serial production."

Thomas Dautl, Head of Production Technologies at MTU in Munich, added, "By employing the quality-assurance system developed by us for use in serial production, EOS is backing an industrially proven solution for its Direct Metal Laser-Sintering process. It has proven itself in practical testing and we now intend to make it available to other customers too."

MTU has gained experience over several years by deploying the tool on EOS systems, not only does this ensure comprehensive transparency but it also provides a quality analysis method for the entire manufacturing process and supports its full documentation.

www.mtu.de | www.eos.info



MTU produces components by Selective Laser Melting (SLM)

GE's new 'brilliant factory' provides flexible manufacturing structure

GE has announced an investment of over $200 million in a new production plant located in Pune, India. The new facility will produce a wide range of products, from jet engine parts to locomotive components, for four different GE businesses under one roof for the first time.

The plant covers 67 acres and will employ 1,500 workers who will share production lines, support infrastructure and equipment such as 3D printers and laser inspection technology. "The plant will allow us to quickly adjust production as demand comes in, using the same people and space," stated Banmali Agrawala, President and CEO of GE South Asia.

The facility incorporates a new flexible concept that GE calls the 'brilliant factory', in which factory equipment and computers talk to each other over the Industrial Internet in real time, share information and make decisions to preserve quality and prevent downtime. In such a factory, production lines are digitally connected to supply, service and distribution networks to maintain optimal production.

"The brilliant factory is more than 3D printing parts from digital files, which we already do," stated Christine Furstoss, Global Technology Director at GE Global Research. "We can build a factory that can make itself better."

India was chosen as the location to build GE's first iteration of such a plant because the company stated it wants to harmonise its operations there, gain size and scale quickly, and support its suppliers. "We have too many small suppliers and their ability to leverage size and scale becomes a problem," Agrawala stated. "The multi-modal plant is good for us and good for them. It will give us a chance to invest in the right tools, processes and training, keep our machines utilised and develop new products faster and cheaper. It will also give us a chance to experiment and try new things."

www.ge.com

The small parts CNC machining section of the plant (Courtesy Farhad Bomanjee/GE)

GKN Aerospace and Arcam announce technology development partnership

A new Joint Technology Development Partnership between Sweden's Arcam AB and GKN Aerospace, UK, will see close collaboration between the two companies to fully industrialise Additive Manufacturing technology for aerospace applications.

"We have been working with Arcam for some time exploring what we believe to be one of the most promising of the additive processes," stated Russ Dunn, Senior Vice President Engineering & Technology, GKN Aerospace. "Our aim has been to fully understand how EBM [Electron Beam Melting] can be applied to our future aero structures and aero engines portfolio."

The agreement forms part of the GKN group's major AM research and development initiative. Within the GKN Aerospace business four dedicated global AM development centres have been established in North America and Europe, each clearly focused on progressing specific additive processes and technologies.

"We believe the array of processes that fall under the 'additive' umbrella will revolutionise manufacturing across every industrial sector - particularly in aerospace where cost, weight and performance are critical. Drawing on GKN Powder Metallurgy's experience and our own extensive aerospace expertise we aim to develop a roadmap that will industrialise Additive Manufacturing for this sector," added Dunn.

GKN Aerospace also placed an order for two Arcam Q20 EBM systems to be installed at GKN Aerospace's Bristol, UK Additive Manufacturing centre. The Arcam Q20 provides a build envelope of 350×380 mm and is suited to manufacturing of a wide range of aerospace related components such as turbine blades and structural airframe components.

"Arcam's strategy is to establish our technology for production of orthopaedic implants and aerospace parts, two areas with high requirements on material properties and productivity," stated Magnus René, CEO, Arcam. "We are convinced that the close collaboration with GKN Aerospace will be key for further industrialisation of our EBM technology in the aerospace industry."

GKN Aerospace and ARCAM engineers plan to work together to create the next generation of EBM equipment able to manufacture complex titanium structures at the high volumes required to meet future demand.

www.arcam.com

www.gkn.com/aerospace

Materialise broadens Additive Manufacturing offering with metal 3D printing

Materialise NV (NASDAQ:MTLS), based in Leuven, Belgium, a leading provider of Additive Manufacturing software and 3D printing services, has announced that it will soon start offering aluminium to its industrial customers. Speaking at the RapidPro event in Veldhoven, The Netherlands, Materialise CEO Fried Vancraen announced AlSi10Mg as the first metal option to join a portfolio of more than twenty 3D printing polymers currently offered to industrial customers.

With a facility of more than 120 3D printers and wide variety of technologies, Materialise has grown into one of the world's largest and most comprehensive providers of Additive Manufacturing services. With aluminium printing, the company adds a powerful new tool to its services for industrial applications.

"We believe that offering aluminium alongside a wide range of polymers allows us to be of better service to our customers," stated Jurgen Laudus, Director Additive Manufacturing Solutions at Materialise. "Aluminium is a perfect addition to the plastic materials we already offer and it opens doors for new applications."

AlSi10Mg is an aluminium alloy that combines good strength and thermal properties with low weight and flexible post-processing possibilities. For those reasons, it is an often used material in automotive, aerospace and automation. Applications include housings, ductwork, engine parts, production tools and moulds, both for prototyping and manufacturing purposes.

www.materialise.be

Sandvik to increase its AM research

Sweden's Sandvik AB is increasing its research spending on Additive Manufacturing technology, according to a report published by Bloomberg. In an interview with Mikael Schuisky, Operations Manager for Additive Manufacturing at Sandvik, the company is recruiting further staff for its 3D printing research and development centre in Sandviken, Sweden.

The R&D centre will examine how the technology can be used in the production of everything from mining drill rigs to fuel tubes for nuclear power plants, states Schuisky. Advantages may include faster production, increased flexibility and being able to create components in shapes impossible to accomplish through standard methods.

"We're making a focused strategic push to research this for the benefit of the entire group," stated Schuisky.

www.sandvik.com

Growth in orders at SLM Solutions exceeds expectations

SLM Solutions Group AG, leading provider of metal Additive Manufacturing technology based in Lübeck, Germany, has stated that 2014 exceeded all expectations for the intake of new orders. As of December 2014 a total of 53 machines ordered reflected 112% growth over the previous year's level of 25 machines. Additionally, North America alone saw a 170% increase in orders over 2013.

Uwe Bögershausen, CFO, stated, "As expected, we received most of our orders in the third and fourth quarters. This is not only connected with our customers' budget planning, but also with the fact that EuroMold is held in November. We were able to conclude additional business with our customers there, allowing us to once again accelerate our growth rate before the end of 2014."

At EuroMold 2014, which took place in Frankfurt between November 24 and 28, SLM Solutions received its largest individual order in its corporate history to date, among other orders. The Additive Manufacturing company FIT Fruth Innovative Technologies GmbH ordered five SLM 500HL systems, SLM Solutions' flagship machine. FIT Fruth uses SLM Solutions' machines for the serial production of transmission components for the automotive sector. "The fact that a contract manufacturer such as FIT Fruth awards us such a large order is genuine proof of their confidence in our technology," stated Bögershausen, adding that "EuroMold played a decisive role in helping us to already exceed our full-year targets by mid-December."

CEO Dr. Markus Rechlin stated, "Firstly, we are observing that our industrial customers are increasingly placing orders for several machines in order to deploy them in the direct manufacturing of complex components. We received a total of seven so-called multi-machine orders – compared with not a single one last year. Secondly, we are seeing repeat purchases in North America, as well as orders from new customers in growth regions such as Japan. I am particularly pleased that our flagship SLM 500HL is being ordered increasingly frequently. Thanks to its multi-laser technology, this is the most productive laser melting system on the market – and clearly, the news is spreading."

Up to December 17, 2014, a total of eight SLM 125HL systems had been ordered in the course of the year, as well as 35 SLM 280HL machines, and 10 units of the largest machine; the SLM 500HL.

www.slm-solutions.com

Lawrence Livermore and GE to develop open source algorithms for metal AM

General Electric (GE) and Lawrence Livermore National Laboratory (LLNL) have received $540,000 funding from America Makes to develop open-source algorithms that will improve the Additive Manufacturing of metal parts. The project intends to develop and demonstrate software algorithms that will allow Selective Laser Melting (SLM) to produce metal parts that are high quality and durable. Currently, states LLNL, there is no common approach to SLM that comprehensively reduces problems associated with this method such as surface roughness, residual stress, porosity and micro-cracking.

"With the SLM processes in place now, you don't always end up with a part that is structurally sound," stated Ibo Matthews, a researcher with LLNL's Accelerated Certification of Additively Manufactured Metals (ACAMM) Strategic Initiative team who is leading the Lab's effort on the joint project. "It's critical to have mechanically robust parts, especially for applications in industries such as aerospace and energy, where part failure could lead to major problems."

In order to manufacture a part using the SLM process, the user must enter data into the printer using

From left: Laboratory researchers Ibo Matthews, a principal investigator leading the Lab's effort on the joint open source software project; Wayne King, director of LLNL's Accelerated Certification of Additively Manufactured Metals Initiative; and engineering associate Gabe Guss.

a stereolithography (STL) file, which is a digitised 3D representation of the desired build. "Ideally, you would send the STL file to an arbitrary 3D printer and it will print out parts that are consistent in terms of dimensions and material properties," Matthews added. "Currently, that doesn't happen."

LLNL states that this is partly because errors appear during the initial translation of the STL file, requiring the user to fill in missing information as well as specify the type of powder material used. Many traditional printer designs treat every layer of powder the same without giving consideration to the thermal properties of the powder. In an ideal system, different layers would demand different laser scanning speeds and powers because the powder environment is changing as the layer-by-layer buildup proceeds.

"Commercial SLM machines do not permit access to specific process parameter information and tool paths," stated Bill Carter, a researcher with GE's Additive Manufacturing Lab, which is under GE's Global Research. "This limits the ability of researchers to perform controlled validation experiments that support modelling work and process development. The cooperation of GE and LLNL will result in a demonstration of the new protocol on several research machines, paving the way for more robust process control and optimisation strategies."

"If you were able to process a 3D part by telling the machine what are the right laser parameters for optimizing the heating and melting for each layer, then the overall manufacturing process can be made more robust and efficient," Matthews added.

LLNL and GE are developing software algorithms that will be compatible with all 3D printers that produce metal parts. This software will be able to control the scan laser's parameters - such as beam size, scan rate and power - on the materials, its powder characteristics and the detailed shape of the part being printed.

www.ge.com | www.llnl.gov

Chinese Navy installs AM systems on warships

China's People's Liberation Army (PLA) navy is reported to have installed Additive Manufacturing systems on a number of its ships to replace critical small components. According to PLA Daily, the system was recently put to use for the on-board repair of a transmission gear on a navy destroyer following a breakage that occurred when the vessel was anchoring.

Whilst naval vessels carry many small replacement parts with them on voyages, the ability to manufacture a wide range of components from a variety of materials on-board provides clear advantages.

"We have benefited from the use of 3D printing technology," Ren Yalun, an officer in the ship's mechanical and electrical section, told PLA Daily. "The 3D printer is like a miniature processing and manufacturing workshop that is able to quickly mend or produce parts, even nonstandard components."

The PLA's Academy of Armoured Forces Engineering is also reported to have developed a specialised AM system that can make most metal parts of an armoured vehicle or tank. The newspaper cited Xu Binshi, a senior PLA expert on equipment repair, as saying "It can print a part at a speed of up to 100 grams per second, but precision components such as gun barrels are still beyond its capability."

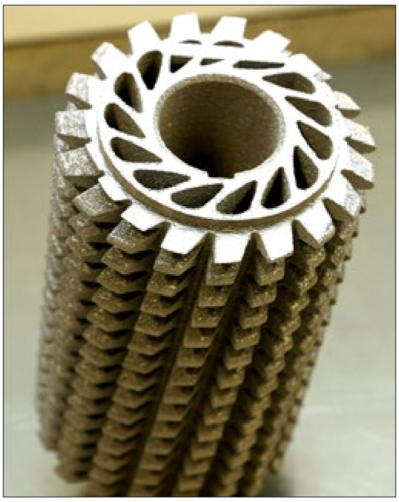
Sweden's VBN Components establishes plant for production of wear resistant components by Additive Manufacturing

VBN Components, located in Uppsala, Sweden, has established a new production plant in Uppsala for the manufacture of wear resistant steel components by Additive Manufacturing. The company will use its Vibenite60 range of high-alloyed PM High Speed Steel materials to manufacture tools, wear parts and components with complicated geometries that would normally demand significant machining.

The company stated that in autumn 2014 it issued new shares and received a large investment which has led to the rapid establishment of the modern plant. The new facility makes it possible for manufacturing industries to improve their profitability through improved material properties and utilisation as well as offering shorter lead times.

"During a customer visit we discussed the 3D-printing of a component where the customer had bought big metal bars for the manufacturing of a tool and needed to remove 80% of the material by machining. We could show that VBN can manufacture the same component with as low as 0.5% scrap metal," stated Martin Nilsson, CEO, VBN Components. "Of course, these substantial improvements are very positive, but we find the biggest gain to be that our material will last much longer than traditional components."

VBN added that Volvo is one customer that is currently testing its gear hobs, a production tool for gear wheel manufacturing. The new additively manufactured gear hobs do not only result in shorter lead times and less material waste, the tool



Hollow gear hobs offer high abrasion resistance and greatly reduced weight

weight has also been reduced by 40%, down to 9 kg.

"VBN is first to market with this type of material directly adapted to 3D-printing. What is unique is to combine an extreme wear resistance with advanced product shapes through 3D-printing," added Nilsson.

www.vbncomponents.com

Zecotek claims new process for the production of metal powders for AM

Zecotek Photonics Inc., a developer of photonics technologies for industrial, healthcare and scientific markets based in Canada, has announced that its wholly owned subsidiary Zecotek Display Systems Pte. Ltd. and Armenia based strategic partners the Institute of Chemical Physics and LT-Pyrkal, have successfully developed a unique manufacturing technology for metal powders to be used with 3D printers.

The new manufacturing approach uses metal hydrides synthesis and it is claimed to have significant advantages over traditional techniques. High productivity, superior quality of synthesized hydride, significantly lower energy consumption, ecological purity and safety of the process are among the stated benefits. "Our new and unique manufacturing technology for metal powders is a significant achievement in the advancement of 3D printing," stated Dr A F Zerrouk, Chairman, President, and CEO of Zecotek Photonics Inc.

"The quest for cheap and available powders of refractory metals has been long and hard and the 3D industry will value our solution. Laser sintering based 3D printing is undoubtedly the technology of the future. We expect the advantages of our breakthrough technology to greatly contribute to the rapid development of additive technologies for 3D rapid manufacturing. The development of a new generation of hydrogen-containing materials, including those based on refractory metals, nano-modified alloys and certain inter-metallides groups, is key for additive 3D printing technologies. Zecotek and its strategic partners are leading the way in this very vast and rapidly changing market."

The metal powder developed by Zecotek and partners is claimed to be compatible with Zecotek's 3D printer and other laser sintering based systems.

Zecotek has been working with the Institute of Chemical Physics of the National Academy of Sciences to extend the list of high-performance powder metal alloys for use in its compact, high-speed 3D printer. The Institute along with Zecotek and LT-Pyrkal are collaborating to fine tune the advanced technology necessary for the fabrication of metal powders from metal hydride compounds.

In July 2014 Zecotek contracted LT-PYRKAL to assemble and test its first compact, high-speed 3D printer which will use high-performance metal alloys and offer technical and commercial advantages over other 3D printing technology.

www.zecotek.com

NanoSteel expands material capabilities for Additive Manufacturing

The NanoSteel Company has announced the expansion of its Additive Manufacturing material capabilities to support the metal 3D printing of complex high hardness parts and the ability to customise properties layer-by-layer through gradient material design.

Following the development of its AM wear materials NanoSteel printed a bearing and impeller using the powder bed fusion process. These parts were measured to be fully dense and crack-free, with hardness levels >1000 HV. By delivering these properties in functional parts, NanoSteel stated that it took a significant step in the development of metal powders that enable affordable, robust industrial components to be produced on-demand through the 3D printing process.

Building on this the company used a combination of high hardness and ductile alloys to create a part featuring a gradient design. NanoSteel worked with the Connecticut Center for Advanced Technology to generate part samples using freeform direct laser deposition. This single Additive Manufacturing process achieved a seamless transition between the hard and ductile properties without subsequent heat treatment.

These gradient material designs offer the equivalent of "digital case hardening™", delivering impact resistance and overall robustness in addition to high hardness and wear resistance in a single part. By providing this capability, NanoSteel states that it offers OEMs considerable design flexibility in meeting part-performance requirements while taking advantage of the operational efficiencies of AM, including on-demand availability, less inventory and lower transportation costs.

NanoSteel impeller produced by laser powder bed fusion

"Proprietary metal alloys that support the cost-effective 3D printing of high-quality parts will help accelerate the transition from subtractive to additive manufacturing across applications such as wear parts, bearings, and cutting tools," stated Harald Lemke, NanoSteel's General Manager of Engineered Powders. The company's targeted markets for its AM powder portfolio are tool & die, energy, automotive and agriculture.

www.nanosteelco.com

Laser Additive Manufacturing Workshop addresses metal powder challenges

The proper selection, handling and tailoring of metal powders for Additive Manufacturing was a key theme at the Laser Institute of America's (LIA) seventh Laser Additive Manufacturing Workshop in Orlando, Florida, March 4-5 2015.

The conference, moving to LIA's home base from Houston, featured speakers from BMW, Siemens, GE Global Research and America Makes, as well as powder manufacturers LPW, Ametek, Advanced Powders and Coatings, Carpenter, Wall Colmonoy and North American Hoganas. Delegates, about half of whom were first-timers at a Laser Additive Manufacturing Workshop, heard real-world success stories of laser material deposition, as well as cutting-edge research into cladding and part production applications in aviation, automotive engineering, power generation and medicine.

AM optimised powders

Echoing a common theme at LAM 2015, namely the need for a new generation of metal powders optimised for additive processes, Satyajeet Sharma of Oerlikon Metco stressed that several alloys and composites used in laser cladding and Selective Laser Melting (SLM) are often identical to those used in thermal spray applications. Problems can arise, Sharma stated, when those powders, developed for other processes, are used in laser-based AM. "We have a higher cooling rate, which can create different stress conditions that will generate cracks and can cause elemental loss," Sharma explained.

Experiments with various powder compositions demonstrated that optimising Inconel 625 with iron and nitrogen showed pore-free cladding, whereas silicon and manganese compositions resulted in porosity. Sharma stated that it is unclear whether the modified elements or the process caused the porosity, but it was clear that porosity evident in the powders, "was taken forward into the clad." Other observations highlighted by Sharma were that increasing the ferrite content for Martensitic 431 steel helped prevent cracks after a customer switched from CO_2 to fibre lasers in an application.

It was also suggested that modification of either alloy powders or heat treatment may be required for SLM applications, as indicated by the fact that standard In625 did not meet AMS 5666 requirements in tensile bar tests and that standard C300 maraging steel showed about 15% less hardness after ageing.

New steel materials

Meanwhile, Harald Lemke of The NanoSteel Company Inc., discussed the development of new steel materials utilising the rapid cooling rates of laser AM. With a portfolio of 500 to 600 hard or ductile alloys, Lemke stated that NanoSteel, "can vary the dendritic and interdendritic space and tailor harder or softer materials and interlink them so you can design properties. We want to drive ferrous materials... and make it really affordable for nuts-and-bolts industries," Lemke added, referring to oil and gas, agriculture, mining and power generation.

In detailing alloy experiments using powder bed fusion, free-form directed energy deposition and binder jetting, Lemke stated, "We started enthusiastically and we ended up with a reality check. We initially had a lot of micro-cracks and it took some parameter development [to get very high densities]. Parameter development and powder optimisation [sphericity, oxygen, etc.] are important."

One adjustment NanoSteel made was coating some ductile alloys with hard alloys. By adding different volumes of material every 20 to 40 layers during directed laser deposition, Lemke stated, crack-free coupons were generated. "We can go up to a hardness of 60 HRC on the outside and around 20 HRC on the inside. We call this digital case hardening; it's like case hardening, but without the restriction from the temperature profile."

In another test, NanoSteel compared bronze infiltrated with 420 stainless steel to bronze infiltrated with two of its own alloys in a binder jetting process. While residual porosity was not down to 1% to 2%, Lemke noted, hardness was roughly doubled.

Custom alloys from commercial powders

At Hayden Corp., Daniel Hayden, President, noted that in some instances his firm will create custom alloys from commercially available powders. One customer, Hayden stated, wanted "a very specific level of ferrite in the end product. They were particularly concerned

Participants in the exhibit area at LAM 2015 (Photo Laser Institute of America)

Participants in the exhibit area at LAM 2015 (Photo Laser Institute of America)

about corrosion, but also the wear properties of the alloy — and no off-the-shelf ferrous alloy that we were able to get was going to get there." In creating a custom powder, Hayden was careful to do so, "in a way that was flexible, so we could try a bunch of different things but also do so rather quickly." By blending, agglomerating, cladding or coating, "you really can dial this stuff in."

ASTM standard guide for directed energy deposition of metals

Richard Grylls of Optomec spotlighted the *ASTM Standard Guide for Directed Energy Deposition of Metals*. The roughly 55-page guide, in the works for two years and now in the approval stage, advises readers to "be concerned about the powder, make sure you know what quality you're supposed to be buying, make sure you have the right mesh size range," and more, he noted.

Other news from LAM 2015

Christoph Leyens, Fraunhofer IWS, illustrated the potential material and cost savings of layer-by-layer, near net shape manufacturing. As an example he cited a potential reduction of up to €5,000 per part when producing a strongly twisted Ti64 leading edge for an aviation fan blade with AM versus conventional machining.

BMW's Wolfgang Thiele demonstrated how the automaker uses additive processes to produce more than 100,000 parts a year for its consumer vehicles.

Jim Sears of GE Global Research noted that 100 desktop 3D printers have been given to 1,000 members of an in-house makers guild to help engineers design parts optimised for additive production.

Forays into higher speed multibeam Additive Manufacturing included Henner Schöneborn of SLM Solutions discussing the company's Quad Laser Technology using four 400 to 700 watt fibre lasers. Max Schniedenharn of Fraunhofer ILT detailed a Selective Laser Melting approach using a line of five diode lasers that can be switched on and off as part geometries dictate.

For Cindy Freeby, New Business Development Manager at Ametek Inc., moving the LAM 2015 event from Houston to Orlando brought benefits thanks to a wider range of people attending. Exhibiting at LAM for the second time, Ametek emphasised its new gas atomised powders.

LAM2016

LAM returns to Orlando on March 2-3, 2016, with Paul Denney of Lincoln Electric as General Chair.

Thanks to Geoff Giordano, Communications Director for the Laser Institute of America, for preparing this report. LIA is the advocate for industrial manufacturing applications and the leading resource for laser safety since 1968.
Email: ggiordano@lia.org
www.lia.org/lam

ExOne announces six new materials for use in its 3D printing systems

The ExOne Company has added six new materials suitable for use in its binder jetting print systems. Cobalt-Chrome, IN Alloy 718, Iron-Chrome-Aluminium, 17-4 Stainless Steel, 316 Stainless Steel and Tungsten Carbide are now qualified for use. "ExOne developed the latest printable materials for our binder jetting process as a result of our expanding customer development programs," stated Rick Lucas, ExOne's Chief Technology Officer. "The diversity of this group of printable materials demonstrates the breadth of industries that ExOne touches."

- **Cobalt-Chrome (Co-Cr)**
  Traditionally used in various fields where high wear-resistance is needed, including aerospace, bearings and blades, Cobalt-Chrome alloy has recently received more attention for medical applications due to excellent corrosion resistance, high melting points and strength at high temperatures.

- **IN Alloy 718**
  Commonly used for components in the aerospace, chemical and energy markets, with applications including gas turbine blades, filtration and separation, heat exchanger and moulding processes, the alloy is desirable due to its oxidation and corrosion-resistant qualities, able to retain its strength even when subjected to extreme environments.

- **17-4 and 316 Stainless Steel**
  17-4 and 316 Stainless Steel both have broad applications in the automotive, medical and general industry markets, used to produce a range of products, including surgical tools, metallic filters, pumps, impellers and structural automotive parts. Both grades are known for their excellent mechanical and corrosion resistance properties and cost-effectiveness.

- **Iron-Chrome-Aluminum (FeCrAl)**
  Offering superior properties as compared to the other alloys, Iron-Chrome-Aluminum alloys are widely used in electrical furnace, electrical oven, home appliance, electrical heater and infrared settings.

- **Tungsten Carbide (WC)**
  One of the hardest carbides with a melting point of 2770°C, Tungsten Carbide is mainly used in the production of high wear-resistant abrasives, carbide cutting tools (knives, drills and circular saws), and milling and turning tools used by the metalworking, woodworking, mining, petroleum and construction industries.

ExOne stated that it generally qualifies materials for production printing through customer partnerships at one of its research and development centres, or in its eight worldwide production service centres (PSC). The company has previously qualified 420 Stainless Steel infiltrated with Bronze, 316 Stainless Steel infiltrated with Bronze, Iron infiltrated with Bronze, IN Alloy 625, Bronze, Bonded Tungsten and glass. The Company has also qualified silica sand and ceramic sand for indirect printing.

These qualified materials are distinguishable from printable materials in that they are commercially available for sale in industrial densities or for finished products printed at an ExOne PSC. ExOne manufactures and sells direct and indirect printing systems as well as printable and qualified materials, binder, cleaner and other consumables for use in its machines.

www.exone.com

Engineers at Dublin's Trinity College look to reduce cost of Cold Spray forming of metal components

Engineers from Trinity College Dublin are leading a €500,000 project to further develop Cold Spray (CS) technology for the production of metal components. The four-year project is funded by the European Space Agency (ESA) and represents the largest single research award made to the university by the agency.

It was stated that there are numerous applications in space which would advance significantly given access to this technology. With the right level of automation and robotic stage design this novel technique could also produce 3D components with low manufacturing costs. The concepts being brought forth in this project will specifically target these technological bottlenecks.

Professor David Jarvis, Head of Strategic and Emerging Technologies Team at ESA, stated, "Once developed, the new form of Cold Spray manufacturing could unlock new capabilities in coated materials, as well as multi-material combinations currently not possible."

Cold Spray accelerates powders of the desired materials at supersonic speeds before firing them onto structures via a nozzle. It is currently possible to build coatings or simple geometrical components made out of a wide range of materials (metals, composites, polymers) around 1,000 times more quickly than any other AM technologies allow.

The process does not require heat, which is advantageous because it means there are no heat-affected zones, microstructural changes, or distortions to worry about on the end-products. CS is, however, expensive and inefficient, so part of the team's work will seek to drive costs down.

www.tcd.ie

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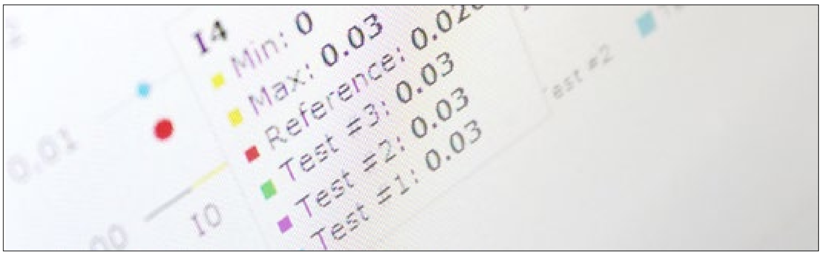
LPW Technology to launch new software for the management of AM powders

LPW Technology will launch an online software product that it claims enables higher efficiency and better quality control in Additive Manufacturing at Rapid 2015, May 18-21, California, USA.

LPW POWDERSOLVE™ is a secure, online, fully searchable powder characterisation management system that handles all the analytical data required to assess the performance of AM metal powders. By automating the process of data collection and analysis it delivers reliable and efficient tracking of the changing properties of AM powders, from the virgin state through repeated use and blending.

By efficiently ordering and presenting powder characterisation data, the software allows users to verify that powders consistently meet performance specifications, to accurately detect contamination or degradation and ensure sufficient powder is always available to meet production requirements. This information can be used to develop viable powder re-use strategies that reduce production costs, while at the same time safeguarding finished product quality. "With eight years of experience and a strong network of clients at the highest levels of industry, we understand that companies are looking for greater efficiency and understanding in powder specification as demands increase and powder re-use has become essential for the long term sustainability of the industry," stated John D Hunter, General Manager of LPW Technology Inc.



LPW POWDERSOLVE™ handles all the analytical data required to assess the performance of AM metal powders

"Supplementing the quality certification provided with all LPW virgin powders, with the most accurate and objective performance information available, our ultimate aim is to help end users take the intelligence and effectiveness of their company's powder lifecycle management to the next level," added Hunter.

ISO 13485 certification for medical supply

LPW Technology recently added ISO 13485 certification for medical supply to its existing quality control standards, AS 9100 and AS 9120 for aerospace, and ISO 9001. This standard certifies that LPW has established a quality management system that demonstrates its ability to meet the stringent requirements of customers in the biomedical technology and device market.

"Achieving ISO 13485 means it will be easier for our customers to go through their regulatory supplier approvals when bringing a medical or dental application to market which incorporates powders from LPW," stated Managing Director Dr Phil Carroll.

www.lpw.com

Bright Laser Technologies builds $16 million metal AM business

Huang Weidong, a researcher at China's Northwestern Polytechnical University in Xi'an, has seen his lab project of 3D printing metal products grow into a business that has achieved production values of 100 million yuan (US$16 million), the Chinese-language Economic Observer reports.

Huang began his research in the field of Additive Manufacturing involving metallic materials in 1995 and later headed a lab at the university in 1999. In 2007 Huang Weidong's lab sold its first 3D printer for metallic products. However the research and teaching workload of Huang and his colleagues hindered them from offering further services to the buyer.

Huang established Bright Laser Technologies (BLT) in July 2011. The company is reported to have seen its output value quadruple in 2014. It is currently working with 75 companies in the field of aviation and space including the Commercial Aircraft Corporation of China, which designed and built the country's largest commercial jet, the C919.

BLT holds 23 patents in metal Additive Manufacturing. It has the ability to manufacture products with dimensions ranging from 1 mm to 5 m and form more than 40 types of titanium alloys, superalloys, aluminium alloys, stainless steel and high-strength steel. The titanium alloy component that BLT produced for the C919 aircraft is the largest manufactured laser-formed piece in the world, the newspaper added.

BLT is expected to open a new production facility in Xi'an this year. BLT General Manager Xue Lei said that the company is also planning to increase its research and development staff in order to ensure that the company remains on the cutting edge. "3D printing technology is still in its early phase and the company is taking on the responsibility of promoting and expanding its market," Xue stated.

Turbomeca uses metal Additive Manufacturing for helicopter engine components

Turbomeca, one of the world's leading helicopter engine manufacturers, has begun using metal Additive Manufacturing for serial production of engine components at its facility in Bordes, France.

The company has announced that it is using Selective Laser Melting (SLM) to manufacture fuel injector nozzles for its Arrano engines and combustor swirlers for use in its Ardiden 3 engines. These engines are Turbomeca's latest models and are claimed to be amongst the most advanced turboshafts ever designed.

"After years of maturation and prototype testing, Turbomeca has entered serial production of parts using the latest additive manufacturing, or 3D printing process," the company stated in its press release. "The Bordes facility is one of the first of its kind to serial produce additive components for the aerospace propulsion industry in France."

The SLM Additive Manufacturing process used by Turbomeca builds the components in layers of between 20 and 100-micrometers thick from fine nickel-based superalloy powder.

AM has also helped simplify the manufacturing process. A traditional fuel-injector nozzle is made up from many different pieces, however the Arrano component is made from one single piece of material and features advanced injection and cooling functions.

Turbomeca is using Selective Laser Melting (SLM) to manufacture fuel injector nozzles and combustor swirlers

Turbomeca, a member of the Safran Aerospace, Defence and Security Group, currently has one SLM machine in service and qualified for mass production at its Bordes site, but plans for others to be integrated over the coming years.

www.turbomeca.com
www.safran-group.com

Over 3,000 Additive Manufactured medical orthopaedic truss implants from 4WEB

4WEB Medical, based in Texas, USA, announced at the North American Spine Society Annual Meeting held in San Francisco, November 2014, that surgeons have now implanted over 3,000 of the company's 3D-printed orthopaedic truss implants. The company's spine portfolio includes FDA-cleared Cervical and ALIF interbody devices, with plans to add TLIF, PLIF, OLIF, and lateral spine truss designs in the first and second quarter of 2015.

"Crossing the 3,000 implant milestone is a significant accomplishment for our company," stated Jessee Hunt, President of 4WEB Medical. "It is a testament to our surgeons' positive clinical experience with truss implant technology and the role it may play in achieving better outcomes for their patients."

The use of Additive Manufacturing utilises engineering principles such as structural mechanics and adjacent material reaction to produce innovative spine implants that may actively participate in stimulating the healing process. "The 4WEB Medical Spine Truss Systems are differentiated from other fusion implants currently on the market because the structural mechanics of the truss implants are designed to distribute loads across the entire endplate and throughout the device," stated Cameron Carmody, MD, Orthopaedic Spine Surgeon in Plano, Texas. "This is significant because these implants may reduce stress risers and subsidence-related complications and potentially stimulate a cellular response through a mechanical transduction of strain."

The truss implant designs have a distinctive open architecture, which allows for up to 75% of the implant to be filled with graft material to maximise bone incorporation. The 4WEB Medical ALIF device has a bi-convex surface that brings the implant and graft material closer to adjacent bone across the entire endplate rather than just around the outside edge. This, in addition to a unique implant surface texture, dramatically improves initial fixation and reduces the chance of migration.

The ALIF spine truss is available in 30 size options

www.4WEBMedical.com

Arcam order intake up 55% in 2014

Sweden's Arcam AB, a manufacturer of Additive Manufacturing equipment based on Electron Beam Melting (EBM) technology, reported further orders in December 2014 that resulted in a total order intake for the year of some 42 EBM systems, up 55% on 2013.

"The increase in order intake confirms the strong interest in our EBM systems for Additive Manufacturing and lays a solid foundation for continued growth in 2015 and onwards," stated Magnus René, CEO of Arcam.

The Arcam Group provides a range of Additive Manufacturing solutions for production of metal components. The group offers EBM systems through Arcam AB in Sweden, metal powders through AP&C in Canada and implant contract manufacturing through DiSanto in the USA.

www.arcam.com

Formnext 2015 secures key support and confirms new dates

The organiser of formnext 2015, the international exhibition for tool making and additive technologies/3D printing, has announced that in response to exhibitor requests the event has been moved forward by one week. The event is now scheduled to take place from November 17 - 20 2015. The venue remains unchanged and the exhibition will still take place in Hall 3 of the Frankfurt Messe, Germany.

Johann Thoma, Chairman of the Management Board for Mesago Messe Frankfurt GmbH, the formnext exhibition organiser, stated, "The fact that Thanksgiving will be celebrated during the week of the originally scheduled dates would have prevented many American participants from taking part. The new dates allow exhibitors and visitors from the US to attend formnext."

"Our core exhibitor groups for tool making and additive technologies/3D printing all benefit from the earlier dates. Formnext offers you the perfect opportunity to also welcome American customers during the exhibition now. We are delighted to have been able to accommodate this request from the industry," concluded Sascha Wenzler, Vice President for formnext at Mesago.

Following the November 2014 announcement that Euromold would be moving from its traditional Frankfurt home to Düsseldorf for 2015, this new event has succeeded in securing the support of a number of key players from the world of metal Additive Manufacturing, including EOS, Concept Laser and Renishaw. The organiser has also announced a strategic partnership with the TCT Show + Personalize in order to develop an annual conference as part of formnext.

Dr Adrian Keppler, Head of Sales and Marketing at EOS, stated in February, "Our goal was to make a well-educated decision for the future of our company and for our industry. We are currently operating in a fascinating and growing market environment and see great potential ahead for the entire industry. After a thorough analysis of all possible alternatives, we feel that 'formnext powered by TCT' has the biggest potential to become the leading, long-term global AM show of the future, offering the best platform we can currently think of to support further extensive market development of the entire AM industry. We look forward to meeting all relevant AM players at this show in Frankfurt."

Frank Herzog, President and CEO of Concept Laser GmbH, also stated last month, "The AM industry is extremely dynamic and continues to grow. We need a trade show to partner with which has the ability to keep pace with new developments in the industry. At this point, for us, the formnext powered by TCT exhibition has the highest potential to meet this goal."

www.mesago.com/formnext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Euromold forges strategic alliances with the Society of Manufacturing Engineers and Wohlers

Euromold 2015, a leading international trade fair for moulding, tooling and Additive Manufacturing organised by Germany's Demat GmbH, takes place from September 22-25, 2015 at its new home at Messe Düsseldorf.

Euromold's Diana Schnabel commented, "Euromold 2015 exceeds our expectations significantly, which makes us as organisers very happy. Apart from our longtime exhibitors, which remain loyal to us in great numbers, also in regards to the move to Düsseldorf, we find many new exhibitors as well, especially from the Additive Manufacturing & 3D printing industry with their booming and dynamic exhibitors from Asia and the United States."

The event recently announced strategic partnerships with Dr Terry Wohlers (Wohlers Associates, Inc.), a leading industry analyst, and North America's Society of Manufacturing Engineers (SME), one of the most widely known engineering associations worldwide. In additional to its extensive membership and publishing activities, SME organises the annual "Rapid" event, one of the world's largest events dedicated to Additive Manufacturing and 3D printing.

Schnabel stated, "SME will organise a similar event with many highly recognised speakers. Together with the new hall layout, which connects the different Euromold areas much better than in the past, very strong and future oriented impulses will be set."

Terry Wohlers stated, "I am more excited than ever about Euromold's role and influence in the development of the Additive Manufacturing industry. The organisers are taking a comprehensive and careful view of the AM ecosystem of today and the future."

Debbie Holton, Director of Events and Industry Strategy at SME stated, "SME is excited to partner with Demat and participate in Euromold. Collaboration between the US and Europe is vital to advancing Additive Manufacturing, as these markets are the largest in 3D technology. Advanced applications, machines and related technologies are constantly being discovered and launched."

"Through this concerted effort, and with other industry expertise, Euromold will continue to be the premier platform to bring people together globally, showcase the latest innovations and drive the technology forward."

SME will also work with startups and other leading companies to assist them in reaching the world market for Additive Manufacturing.

www.euromold.com

Dentsply Implants to use Renishaw metal Additive Manufacturing systems for custom medical devices

Renishaw plc and Dentsply Implants, one of the world's leading companies in implant dentistry, have announced an agreement which will see Dentsply Implants purchase Renishaw Additive Manufacturing technology for the manufacture of dental products. As part of the agreement, Renishaw stated it will cease development of its Laserbridge™ implant-supported frameworks.

Dentsply Implants is part of Dentsply International Inc, a leading manufacturer and distributor of dental and other healthcare products which has global operations with sales in more than 120 countries.

Mikael Sander, Group Vice President, Dentsply Implants, stated, "This agreement enables Dentsply Implants to fully exploit the exciting opportunity that 3D metal printing offers in the field of custom made medical devices. By using Renishaw's highly respected technology, we can enhance our ability to deliver innovative solutions in implant dentistry for improved patient care while advancing our already strong market position."

Bryan Austin, Director and General Manager of Renishaw's Dental Products Division, adds, "The chance to work with Dentsply Implants and see Renishaw Additive Manufacturing technology used by one of the world's leading dental implant companies represents a wonderful opportunity for the dental team at Renishaw."

The AM 250 from Renishaw

www.renishaw.com
www.dentsply.com

3D Systems awarded two aerospace and defence research contracts worth over $1 million

Additive Manufacturing equipment supplier 3D Systems, based in Rock Hill, USA, has been awarded two research contracts worth over $1 million from America Makes in a project funded by the Air Force Research Laboratory (AFRL).

Together with a number of US military suppliers including Honeywell, Northrop Grumman, and Lockheed Martin, 3D Systems aims to develop a precision closed loop and advanced manufacturing and monitoring platform, designed to deliver the accuracy, functionality and repeatability specifications demanded for flight worthy aerospace parts.

The first contract is led by 3D Systems in partnership with the University of Delaware's Center for Composite Manufacturing (UDCCM), Sandia National Laboratory (SNL) and Lockheed Martin Corporation (LMCO). The project is designed to integrate predictive technologies with 3D Systems' SLS 3D printers to dynamically monitor parts at the layer level during the manufacturing process, ensuring optimum accuracy and repeatability of manufactured aerospace parts.

The second contract, in collaboration with the Applied Research Laboratory of Pennsylvania State University in partnership with Honeywell International and Northrop Grumman Corporation, will focus on 3D Systems' Direct Metal 3D printing. As a result of this project, aerospace and defence manufacturers will gain full control of every aspect of the direct metal manufacturing process at the layer level, delivering fully dense, chemically pure, flight worthy metals parts.

"These important research projects will position leading industry manufacturers to 3D print high-performance precision parts at convincing scale with enhanced functionality," stated Neal Orringer, Vice President of Alliances & Partnerships, 3D Systems.

www.3dsystems.com

Aequs invests in Spartacus3D

India's Aequs, formerly QuEST Global Manufacturing, has announced it has invested in the Farinia Group's Spartacus3D, a French company specialising in metal Additive Manufacturing. From its facility in La Clayette, France, Spartacus3D manufactures optimised aerospace and automotive components from metal powder via Direct Metal Laser Sintering.

Both companies believe that the partnership will create synergy in aerospace manufacturing and accelerate further innovation in the aerospace supply chain. "We expect our partnership to advance the state-of-the-art in aerospace manufacturing and produce higher levels of customer customisation, on-demand responsiveness and product complexity at competitive costs," stated Frédéric Guinot, CEO of Farinia Group.

Aequs has manufacturing facilities located in India and USA. Customers include Airbus, UTAS, Eaton, Baker Hughes, Halliburton and Bosch.

www.spartacus3d.com
www.aequs.com

Linear Mold & Engineering continues expansion

Linear Mold & Engineering, North America's largest privately owned provider of metal Additive Manufacturing services, has announced further expansion with an order for four new machines from SLM Solutions GmbH.

The company, based in Livonia, Michigan, has already taken delivery of the first of its new SLM 280 HL systems. The SLM 280 HL single laser machine joins Linear's other two SLM (one single and one dual laser) DMLM machines currently onsite and brings its total number of AM machines currently in operation to eleven.

Three additional SLM 280 HL Twin Beam machines were scheduled to be installed early 2015, with a further six AM machines slated to be installed throughout 2015 to keep up with customer demand.

"The decision to expand, which was announced last year, was based on customer demand for 3D printed end-use production parts," stated John Tenbusch, President of Linear Mold & Engineering. "We also chose the SLM 280 HL from SLM Solutions based on the company's wide range of materials and speed to support production runs specific to this particular phase of Linear's growth."

Linear currently operates three existing SLM machines from SLM Solutions, as well as eight Direct Metal Laser Sintering (DMLS) machines from its long-time vendor EOS GmbH. "We are advancing our equipment plans for acquiring 3D metal printing machines from the two largest providers of this equipment in the world," Tenbusch added. "Our expansion plans announced in June of 2014 are extensive and the ongoing support we receive from both EOS and SLM Solutions give us the ability to provide our customers with the highest quality 3D metal printed components in the fastest time frame."

A complex AM component manufactured at Linear Mold & Engineering

www.linearmold.com

Hybrid Manufacturing Technologies wins international AM award

Hybrid Manufacturing Technologies Ltd, Leicestershire, UK, was announced as the winner of the inaugural International Additive Manufacturing Award (IAMA) during a reception at The MFG Meeting in Orlando, USA, March 4-7, 2015. Along with the award, Hybrid Manufacturing will receive a US $20,000 cash prize and a media package valued at US $80,000.

Hybrid Manufacturing developed a system that can be integrated into any CNC machine to allow for metal deposition (via laser cladding), finishing and inspection of parts on a single machine. The hybrid methodology integrates directed energy deposition into multi-axis CNC machine, using a tool changer to change between processes.

"Hybrid technology is exciting because it offers a new way to adopt Additive Manufacturing – as an upgrade to a CNC machine tool. Adding tool-changeable deposition heads to an existing CNC machine enables 3D printing of metal, without the need to buy a separate machine," stated Dr Jason Jones, Co-Founder and CEO of Hybrid Manufacturing Technologies. "This significantly reduces costs and provides an intuitive adoption path for CNC operators. The combination of additive with machining offers new capabilities, including in-process finishing, that cannot be delivered by either technology independently."

The IAMA is the result of a partnership between AMT-The Association for Manufacturing Technology and VDW-Verein Deutscher Werkzeugmaschinenfabriken (German Machine Tool Builders' Association).

"It was incredibly exciting to see so many dynamic innovations presented from around the world for this award. It speaks highly of the evolution of additive technologies and the realisation of radical productivity improvement for manufacturing," stated Douglas Woods, AMT President.

www.additive-award.com

www.hybridmanutech.com

Douglas K Woods, President, AMT (left) with IAMA winner Dr Jason Jones, Co-Founder and CEO of Hybrid Manufacturing Technologies Ltd (centre) and Dr Alexander Broos, Director Research and Technology, VDW (right)

→ **31 August – 3 September 2015 in Lüneburg / Germany**

Lüneburg is an ancient city from the Middle Ages close to Hamburg with picturesque houses, small streets and a lot of cosy cafés and pubs. Thus, it provides an optimal ambience for fruitful networking activities around the presentations.

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Further information and a Call for Papers:
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Helmholtz-Zentrum Geesthacht
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Metal Additive Manufacturing: Component design for successful commercial production

With Additive Manufacturing, the next generation of component fabrication technologies has arrived. No other technology, explains Tim Richter, of RSC Engineering GmbH, Germany, has the potential to change the design process and the appearance of new products so fundamentally. In this report for *Metal Additive Manufacturing* magazine, Richter shares his experiences in designing metal AM components for powder bed fusion based AM systems, explaining both the potential and the limitations of the process.

Additive Manufacturing promises to fundamentally transform the design and appearance of new components and applications. This article offers insight into the possibilities and the potential of Additive Manufacturing, as well as demonstrating how the performance of parts and systems can be increased through optimised design. This article will also explain how the benefits of the process have to be balanced with an awareness of a number of the restrictions that are an inherent part of AM technology.

The ability to produce metal components by Additive Manufacturing is not simply a shortcut from digital design (3D CAD) to real prototypes. Rather, the process offers the ability to create entirely new products that could not be manufactured using conventional methods. Additive Manufacturing allows a new degree of freedom in the designing of products, from lightweight structures to function integration, bionic and ergonomic designs.

The integration of these functions into a new part as a matter of course is what RSC Engineering calls 'Additive Manufacturing Optimised Designing'. Only through the combination of virtual product design, including CFD, FEM and other numerical analysing tools, and the application of AM optimised design principles, can the true potential of AM be fully exploited.

The technology for the Additive Manufacturing of metal components is now at the stage in its development where the safe, reproducible production of sophisticated technical components is possible. By continually developing and improving this technology, it has also become possible to produce complex components that simply would not be possible to manufacture with other methods.

Fig. 1 A gas emissions rake developed using AM optmised design (Courtesy RSC Engineering GmbH)

Fig. 2 The new fully integrated M2 cusing system from Concept Laser. With a reduced footprint, the M2 cusing gained a new filter concept, increasing its filter surface five-fold from 4 m^2 to 20 m^2. The new M2 cusing is also available in a multilaser version called M2 cusing multilaser, with either 2 x 200 watt or 2 x 400 watt lasers

The reality is, however, that an appreciation of this potential has not quite reached the consciousness of designers and engineers. The image of a porous chunk of metal that was rather expensive to manufacture but is only useful as a visual aid remains firmly in the heads of many designers. The big "wow", however, is usually not far away.

The Additive Manufacturing product development cycle

As a first step, it is important to understand that AM is an autonomous manufacturing process which also requires an individual, coordinated process for its application. Even though AM offers the opportunity to reproduce most parts that have been manufactured by conventional technologies such as milling or casting, only in the rarest of cases are the results better or cheaper than the original part. So going this new process only makes sense if expensive tools or programming costs can be avoided.

The real potential of AM can be utilised if the design process is optimised and the advantages of this new manufacturing technology are embraced. However, this also means that existing designs have to be fully reconsidered. The rewards for this are new, innovative solutions and products that will stand out from the competition.

The design phase

The advantages of AM as a prototyping tool are obvious. However, AM offers additional advantages if the final product is also planned to be produced by AM. The most important point here is that the prototype can already be, at the beginning of the design process, at a state "close to production." Production limitations can be taken into account right from the beginning of the design process, thus avoiding a long period of optimisation. Additionally, many features of a product in development can be analysed far more effectively and are more visible, at an early stage. This enables the identification of design drawbacks early on and helps keep a focus on the development of the product's advantages.

It should also be considered that critical features can be addressed separately when using AM. One can, for example, "print" only a small but crucial section of a final part for further optimisation. After the problem is solved, the solution can be introduced into the final product and will automatically be accurately manufactured if AM is applied for the manufacturing process.

Prototypes of a high quality are crucial for the development of a product. Even though virtual prototypes provide a great contribution to the development process, testing cannot be avoided in the majority of cases. It is also well understood that the haptic impression, and the perception of quality, can only be supplied by a prototype. Again the advantage is with a process that not only focuses on AM as a prototyping tool but uses the technology for the final manufacturing of the product.

Importantly, the development cost of a product can be decreased using AM. The fast path from the digital model to an Additively Manufactured prototype often shortens development time significantly. In our experience, the use of AM has resulted in situations where the manufacturing and testing of prototypes was faster and cheaper than combined CFD and FEM simulations of virtual prototypes.

Market launch of the product

Additive Manufacturing can today provide significant cost reductions for the market launch phase of a new product. As an example scenario, let us assume that the margin achieved with a 1000 piece lot of a conventional cast part is higher than with the AM produced version. A smaller lot of only 100 pieces might however be cheaper to produce by AM due to the negligible cost of setting up the manufacturing process. This favours market introduction strategies with small numbers of items, which decreases the overall risk of introducing a new product. An additional benefit occurs if design changes are necessary. Such changes can be implemented even during the manufacturing process of the production lot. This allows a high level of flexibility in part development, a fast feedback loop and the continuous updating of the product.

The same advantages occur if parts are ordered in small numbers, at changing time intervals or in different versions. Under such conditions AM is not only competitive but also creates a new market, the individual manufacturing of small production lots. The advantages of AM manufacturing are the elimination of expensive tooling costs, the decreasing of programming costs and the possibility of rapid design changes.

Mass production

As of today, the production of very large series of simple parts using AM is not always economically advantageous. Considering the development speed of the technology, this will inevitably change in the near future. A new generation of machines, such as the M2 cusing from Concept Laser (Fig. 2), with a smaller footprint and a higher productivity thanks to multi laser technologies, makes a big step in the right direction.

Even now, however, AM technology offers several advantages that can be exploited in mass production. The compact design of AM machines, and their modest demands on infrastructure, allows for a building up of manufacturing capacity wherever it is needed. This in turn decreases the need and cost for transportation and storage of goods, as well as reducing environmental impact. The high flexibility of the manufacturing process allows the reduction of the bandwidth of machinery necessary for the manufacturing and increases the manufacturer's flexibility. On-demand production now becomes realistic for mass production.

Fig. 3 This model of a wing demonstrates AM's ability to combine differently oriented lightweight structures within one part. The model has been produced in one step (Courtesy Concept Laser GmbH)

On the other side of the coin, dependency on suppliers decreases and delivery bottlenecks and capacity constraints can be circumvented. Thanks to the high quality standards of the Additive Manufacturing process per se, high component quality can be achieved regardless of the manufacturing location. In particular, the latest software quality tools allow the manufacturer to monitor the manufacturing process in real-time, which can eliminate the subsequent inspection of the components.

Flexible, globalised production

If manufacturing volumes of a production part drop, the previously outlined advantages of AM remain just as important. Even though AM may not be the first choice manufacturing technology for a specific part, it might be useful to redesign production parts according to AM optimised design principles to enable AM manufacturing, thereby freeing other resources rather than keeping a manufacturing line busy producing parts that may not find a market.

A further option to be considered with AM is location independent manufacturing. The contract for manufacturing spare parts can be given to a subcontractor without any major risk of quality losses thanks to the high level of quality and automation that AM offers. The economic advantage for the manufacturer arises when the downtime of industrial plants can be reduced, and storage cost can be avoided.

How to exploit the advantages of Additive Manufacturing

We are still at the beginning of the Additive Manufacturing age. Because this new technology is so different to what we are accustomed to, we have to rethink both the way we build things and the way we do business. We know from history that such changes take time. This means that, as of now, a priority is to identify promising projects for AM applications and to educate our customers as to the potential of the technology.

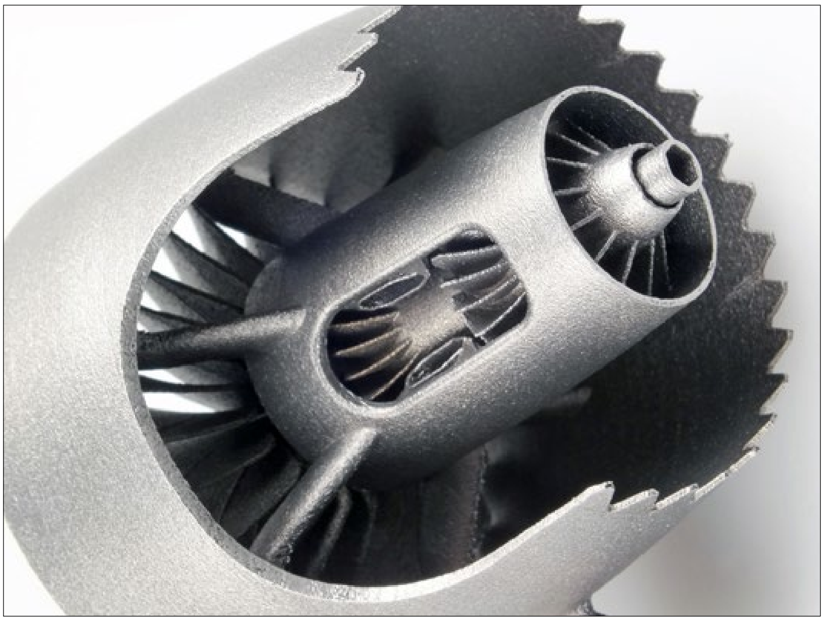

Fig. 4 This model engine production prototype was made in one step, including rotating shaft and 3D wing contours. The AM optimised design was manufactured via LaserCUSING® from stainless steel (1.4404).Minimal reworking thanks to the optimised design. (Courtesy RSC Engineering GmbH)

Identifying suitable projects

The most important criterion for success is the ability to identify the potential of a project as early as possible. Experience has shown that in most cases a simple rule applies; the smaller and more complex the component, the more efficiently AM technology can be applied, and the greater the rewards can be.

The word "project" was used on purpose. Often customers will only consider a single part to be changed or optimised. One of the main advantages of AM is the possibility to integrate several functions into a single component. In our experience the biggest margins can be achieved if it is possible to combine several functions from a number of different original components within one final part. Here, AM optimised design is working at its best. This also usually allows for a simplification of the surrounding parts, which opens the opportunity to produce them more cost effectively.

In order to identify suitable projects together with our customers, we developed our own set of criteria. As part of this process we consider not only the cost of manufacturing, but also the added value of the product and the cost-efficiency over the entire life cycle. However, a complete analysis of the whole life cycle of a product is not always possible or necessary. Many customers simply want to gain an understanding as to how their current component may change by using AM and try and understand how big the potential margins are. Here, direct comparability is the focus of our attention. In such a case we apply AM optimised design to conventionally manufactured parts. Because of the previously mentioned restrictions, this approach does not necessarily deliver the best possible result. It allows, however, our customers to understand the potential of the technology for their products on a demonstration level. In such a scenario, we offer additional consulting services with the aim to identify AM projects in our customer's portfolio with a high potential for efficiency increase and cost reduction.

Component development

The first decision in the design phase is if a chosen part will be changed, or if a completely new design has to be found. In both cases the aim is to achieve and improve the functionality of the part with as little material as possible in order to reduce the costs of AM. Additionally, the manufacturing process has to be considered, step-by-step, all the way to the final product in order to reduce the costs of any necessary follow-up processes after AM. The cost effectiveness of AM parts can, for example, be improved though the strategic positioning of functional surfaces during the AM design process. The provision of mounting points for subsequent machining operations is also an option that should be considered.

In order to identify the potential for material reduction, we consistently focus on the use of virtual prototypes. For the redesigning of an existing component, the use of an a standard commercially available FEM program is sufficient most of the time.

If the aim is to develop a totally new component, the use of high-performance topology optimisation software is the best route to an optimal design. The designs achieved by such tools typically have the appearance of natural forms such as branches or spider webs. The tricky part of this approach is to know at an early stage in the design process the specific loads and stresses of the new component. To understand the result of such a topology optimised bionic design it usually helps to take a look at natural models.

Topology optimisation software is an essential companion when applying the principles of AM optimised design. However, such software only supports the design process and cannot replace the design engineer. To achieve the best possible component concept, the engineer has to consider a wide range of issues. Beside mechanical stresses and forces, several other influences often have to be considered such as aerodynamic effects, vibrations, eigenfrequencies, cooling demands or measurement instrumentation.

Fig. 5 These models of a cannular combustor have been manufactured to demonstrate the possibility to include effusion holes and a swirler in the manufacturing process (Courtesy Concept Laser GmbH)

Fig. 6 This example of a universal joint further demonstrates how moveable parts can be manufactured as one piece using Additive Manufacturing (Courtesy Concept Laser GmbH)

Design optimisation for Additive Manufacturing

The Additive Manufacturing of metal components offers almost unlimited design freedom. The difficulty is to know how to use that freedom. For this purpose, the strengths of the manufacturing method have to be considered selectively, in compliance with the restrictions, to increase the value of the product further.

Here the keywords are function integration. For example, measuring holes or cooling channels can be integrated into the Additively Manufactured part. The possibility to even manufacture moveable joints in one piece has been demonstrated. However, the increasing complexity of such products also increases the requirements on the design tools used.

Currently available design programs were simply not created to enable the full exploitation of the freedom of AM optimised design. The problem is not so much the creation of certain complex geometries, but the replication of these a thousand times, which is usually necessary for lightweight structures or effusion holes. Even if a program works to create a difficult geometry, the fun usually ends if you try to export it into a standard data format.

To solve such problems two approaches are possible. The approach we choose is to partially design our own software tools. The alternative is to use some of the commercial software that is available. Unfortunately, such software can be rather specialised on specific requirement, usually quite expensive and not entirely free of bugs. An up-to-date overall solution for this problem is unavailable, and is unlikely to be seen soon.

Manufacturing direction

At the start of the optimisation process, it is critical to define the manufacturing direction within the build box. The choice of manufacturing direction has a great influence on manufacturability, surface quality and the accuracy of each component section. If you imagine the building of a small model house

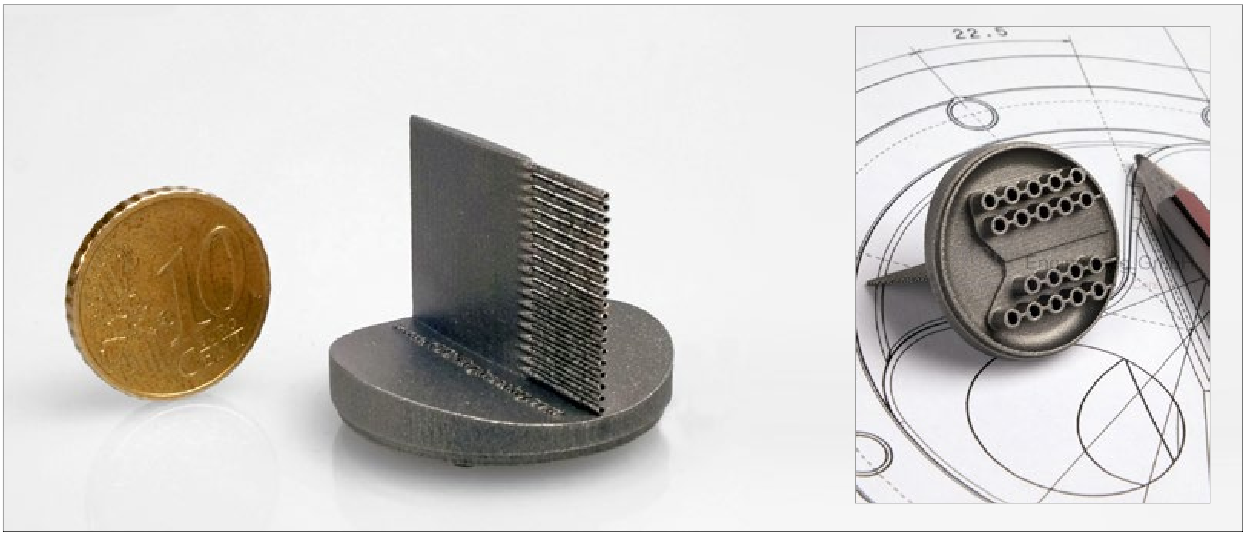

Fig. 7 This PITOT probe, with 19 measurement positions, was manufactured in one step, including all sampling channels (Courtesy RSC Engineering GmbH)

as an example, it's not a problem to build the vertical walls using an AM machine. The manufacturing of the ceilings (horizontal walls), however, is not possible without a supporting structure.

At a certain angle (rule of thumb, 45°) a limitation of AM technology has been reached. Designing greater angles will lead to manufacturing problems such as bad surface quality and cracks. In order to create the horizontal elements, supporting structures are necessary. The task of the supporting structures is to carry the very thin horizontal structure during the manufacturing process and to conduct the heat load from the AM process. After the manufacturing process, the support structures have to be removed.

"For the cost-effectiveness of Additive Manufacturing, fast and easy removal of the metal powder is an important consideration"

To do this without support structures, areas with an angle greater than 45° have to be avoided. To continue with the example of the building of a house, the house would have to be constructed with gothic arches and columns. Usually it is possible to simplify the manufacturing of a part through small design changes without compromising its functionality.

Fig. 8 shows a cross section of an emission gas rake that shows the angle limitation as an example. For the emission rake it was essential to follow the manufacturing angle limitation rule due to the fact that a supporting structure could not have been removed afterwards.

Avoiding stress

Another important consideration in the design of the AM components is the reduction of process-related stresses within the component. The Additive Manufacturing of metal components is comparable with a layer-by-layer welding process. Through the local introduction of heat into the component, stresses in the component may occur.

These stresses can be reduced by preheating the manufacturing space and the material. Concept Laser's patented light exposure strategy also helps to decrease stresses. However, the right design can also help. Flat, smooth walls should be avoided as curved surfaces and defined bumps decrease stress levels noticeably.

Another approach is to smooth transitions from one wall thickness to another. This not only decreases stresses, but also usually improves the stability of the structure. The same applies to the use of honeycomb structures instead of solid walls. With the same amount of material used, a stiffer solution is obtained and stress-induced manufacturing problems decrease.

Powder removal

During the AM process the whole manufacturing space in the machine is filled with metal powder. All the cavities in the manufactured part are therefore also filled with powder. For the cost-effectiveness of Additive Manufacturing, fast and easy removal of the metal powder is an important consideration.

The powder is collected, sieved and can subsequently be used again for the next manufacturing process. There is virtually no waste material, which for the processing of expensive materials such as titanium is a tremendous advantage over conventional manufacturing processes. In general, the cleaning process of the build chamber is easy and fast to implement. The cleaning of the manufactured part can be trickier.

Complex parts with hollow structures and many inner chambers need to be designed in such a way that allows the removal of the metal powder after the manufacturing process. Parts can be designed with complex channel geometries, for example, that enable the blowing out of metal powder using gas pressure. If such an approach is chosen, it needs to be considered that the metal powder will behave like a liquid.

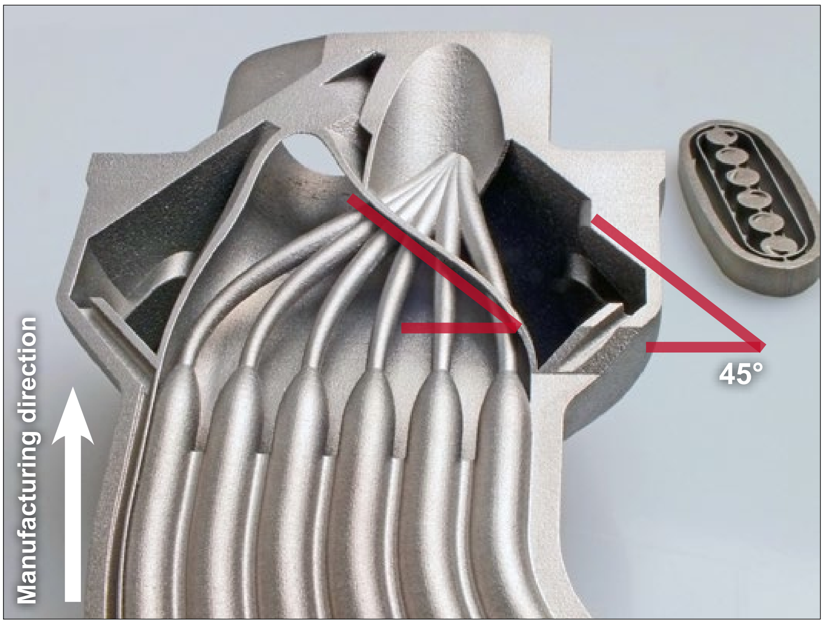

Fig. 8 This cross section of an emission gas rake that shows the angle limitation in the AM process. It was essential to follow the manufacturing angle limitation rule as supporting structures could not have been removed afterwards (Courtesy RSC Engineering GmbH)

Finishing processes

After the support structures and the unused powder are removed, the surface will usually be smoothed by sandblasting. If the surface quality of the AM process is not sufficient, it is also possible to rework the surface by conventional machining, such as milling or grinding. For certain fits, bearings, or seal surfaces, a cutting process makes sense. The advantage of AM technology to create surfaces and shapes freely can lead to new design challenges that need to be considered. For example, the forces applied by any fixing systems have to be considered in the design. This may be problematic, especially for topology optimised parts.

Conclusions

It is hoped that this article has managed to give a basic understanding of the possibilities and the potential of Additive Manufacturing and AM optimised design. The critical message that should be taken from this report is that, without a new approach to component design, only a small part of the potential of AM can be used.

The issues covered need to be considered in the design of a part and, for each individual project, an optimal design solution must be found in order to reap the benefits of the process. The possibilities of AM are, of course, developing incredibly fast and it is therefore difficult to draw hard boundaries on what is possible and what is not.

This is, however, a part of what makes AM technology so appealing for us. Because of the ever increasing manufacturing speeds, AM technology will become economical for ever more products. Through continuous development of the process technology, and the application of AM optimised design, a whole new range of innovative products will be in reach. This is the dream of every engineer.

About the author

Tim Richter is Managing Director and owner of RSC Engineering GmbH, based in Cologne, Germany. Richter is highly experienced in the design of metal Additive Manufactured components and during his work as a design engineer at the German Aerospace Centre (DLR), he developed components for aircraft engine combustors, high pressure, high temperature combustion test rigs and measurement probes for high speed applications.

RSC Engineering GmbH specialises in custom solutions for various fields of engineering, supporting customers from finding new ideas to the delivery and commissioning of components and complete systems. A core competence is Additive Manufacturing optimised engineering. By the novel combination of this know-how with proven solutions, RSC Engineering creates sustainable and economical solutions for customers.

RSC Engineering's partnership with Concept Laser GmbH, the inventor of the LaserCUSING® technology, allows the company to link its design experience with technology development. For customers, this means increased innovation, quality and reliability in the design and manufacturing of products.

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Materials Solutions: Expertise in metal Additive Manufacturing for the aerospace and motorsport industries

Materials Solutions Limited, located in Worcester, UK, is a world-class specialist in the Additive Manufacturing of functional parts using the Selective Laser Melting process. Dr David Whittaker reports for *Metal Additive Manufacturing* magazine on a visit to the company, where he spoke with founder and Managing Director, Carl Brancher.

Materials Solutions was founded in 2006 following a successful bid for grant funding from the UK's Micro and Nano Technology (MNT) scheme administered by the then regional development agency, Advantage West Midlands. The company started its Selective Laser Melting (SLM) operations in around 500 m^2 of laboratory space on the campus of the University of Birmingham. Initially, the company had evaluated the potential for commercialisation of a number of emerging manufacturing technologies before settling on SLM as the candidate to take forward. Brancher commented, "Unlike other options, the Additive Manufacturing of metals in general, and SLM in particular, excited significant potential end-user interest, which promised a strong market pull for its subsequent commercialisation."

In the SLM process, a metal powder is spread across a build area under an inert atmosphere and then a laser is directed by a 'slice' of a CAD model to selectively melt the powder, with the molten material then re-solidifying to form a contiguous slice of the physical part. The build plate moves down from the focal plane of the laser by the thickness of the next slice and powder is again spread across the build area and the next slice of the model is then created. This two-step process of powder spreading and lasing builds is repeated until completion, the fully formed part is now contained within a bed of powder, which can be re-used.

SLM differs from traditional processes in several key ways that are advantageous in certain circumstances. Brancher stated, "The ability to form parts without moulds

Fig. 1 The home of Materials Solutions in Worcester, UK

Fig. 2 Materials Solutions currently operates eight EOS machines, with a further three due to arrive this year

Fig. 3 View of the manufacturing area at Materials Solutions

or tools and from a single form of raw material means that lead-times for new designs are dramatically reduced and the cost of low volume parts is lower than in conventional processing."

"The process also has the ability to form complex parts previously fabricated using multiple operations. This leads to greatly improved reliability, particularly in fatigue-loaded applications and, again, lower costs than in conventional processing. Finally, the tightly controlled key process variables and broad process window lead to an extremely repeatable process, generating very stable material properties and part geometry."

In 2006 Materials Solutions installed the first operational EOS M270 SLM machine in the UK. The key difference between this machine and previous generation machines is the use of a fibre laser in place of a CO_2 laser. The fibre laser has, stated Brancher, far better beam quality and stability, as well as operating at a totally different wavelength. This change of laser transformed the process from sintering to full melting of the metal powder, resulting in far fewer material defects.

By 2010, the company had outgrown its initial site and relocated to its current premises in Worcester, a city sufficiently close to the original Birmingham home to facilitate the retention of key staff. In 2012 a further adjacent unit was added, doubling space to almost 2,000 m^2. The company today has a complement of around 20 employees.

Shifting Additive Manufacturing from prototypes to performance components

From the outset, Materials Solutions recognised the opportunity to push Additive Manufacturing from its original focus on the building of models or prototypes, where material performance is of little or no significance, into the building of high performance functional components where control over mechanical properties of materials is of paramount importance. In this context, the company has accrued significant knowledge and expertise in understanding the interactions between SLM processing conditions and achievable material microstructures and mechanical properties and performance.

Furthermore, Materials Solutions has chosen to target application sectors where the required control over material quality and performance is exacting. The company is focused in particular on developing the highly specialised capability of manufacturing high temperature parts in superalloys for gas turbines and similar high performance applications, in geometries that cannot readily be machined to shape.

Superalloys are nickel, iron-nickel or cobalt-base alloys that are generally used at temperatures above 540°C and deliver unique combinations of high temperature strength, ductility and creep resistance and corrosion resistance. Additive manufactured superalloys can achieve excellent mechanical properties because of the fine grained microstructure produced, although the microstructure is also orientated and this anisotropy needs to be controlled and understood. A further advantage of AM of superalloys relates to the demonstrated potential for processing 'difficult to weld' materials such as CM247LC.

It has been found that AM process conditions need to be tailored to optimise fully the response of each particular alloy type and it can be concluded that the greatest benefits will be achieved when new alloys are specifically designed to match the requirements of the AM process.

The targeting of this specific market has required the development of not only materials and geometry competencies, but also quality procedures that meet the requirements of flight parts. In particular, Materials Solutions can process the highest temperature capable alloys required for advanced and next-generation aero-engines.

In pursuing these business objectives, the company has always viewed one of its key tasks as being the assisting of its key customers in advancing AM component developments up both the Technology Readiness Level (TRL) and Manufacturing Readiness Level (MRL) scales. In relation to the MRL scale, this has required the company to involve itself closely in supply chain development and approval.

Brancher told *Metal Additive Manufacturing* magazine, "The vision of this process is bold and the advantages claimed are substantial, but, in many cases, the technology is not developed to its full potential. Often, the supply chain is not in place, the requirements of clients are not fully understood and the advantages are more aspirational than proven. However, at Materials Solutions, we are developing the applications know-how and a supply chain for the world's most advanced engineering companies."

"We operate a flat organisation so all of our engineers develop a deep understanding of the technology by operating it on a daily basis. They discuss the requirements directly with our customers' engineers and provide design-for-manufacture advice based on their practical knowledge learnt from years of experience."

Fig. 4 A 400 mm diameter combustion chamber

Brancher continued, "We specialise in high temperature alloys because it needs doing. Improved combustion processes reduce emissions and improve fuel consumption. This requires better fuel/air mixing, higher temperatures and better use of cooling air. So, novel designs in superalloys are our core skill."

In relation to supply chain development, wherever possible, the company tries to select suppliers that already have approval from the relevant end-user for sub-contracted services, for example component final polishing to enhance surface finish.

High capacity Additive Manufacturing production facilities

In relation to equipment for primary AM component building, Materials Solutions currently has eight EOS machines, seven EOS M270 machines and one EOS M280 machine. Three further machines are due to arrive during 2015 - an M290, and two M400s. The M400 machines are capable of 400 x 400 mm builds and the company has already been involved (during 2014) as a beta test site for a prototype M400.

All AM processing is carried out under liquid source argon cover and all EOS machines are under full service contracts with EOS. The changes in SLM machine capabilities over the years are perceived by Brancher as being:

- Higher power lasers aimed at processing in thicker layers for faster processing and the processing of aluminium, which, being a high thermal conductivity/reflective material, needs more power
- Production specific machines that are thereby necessarily less flexible with respect to swapping between materials
- The introduction of machines with larger build volumes
- The introduction of a greater number of smaller SLM machines, some of these being specifically aimed at the laboratory market and for dental and jewellery applications.

Fig. 5 Technical Director Trevor Illston and a 400 mm diameter part

Materials Solutions' current suite of machines is one of the largest commercially available metals AM facilities in the world and is probably the largest one focussed on gas turbine component production.

As well as the core Additive Manufacturing capability, Materials Solutions also has finishing process facilities in the form of abrasive blasting and wire EDM capability, its own heat treatment furnaces including a vacuum furnace, a machine shop and bench finishing.

For quality control, there is Rolls-Royce approved visual inspection, a metallographic laboratory equipped with optical and electron microscopes, a chemical analysis laboratory and calibrated pressure and flow benches for testing water and air flow and pressure.

Inspection capability includes a scanning programmable coordinate measuring machine and a GOM structured light 3D scanner, as well as traditional surface profilometry, shadowgraph and other tools.

Markets and materials

As mentioned previously, Materials Solutions' main market focus is on components used in aero-engines and land-based gas turbines for power generation. In addition, the company has targeted applications in a number of other high-performance application sectors, such as aerospace fluidic components, motorsports and components for non-conventional power generation. Around 50% of sales revenues are derived from exports, with customers in Japan, North America and throughout Europe.

Material Solutions' core competences are SLM materials capability and quality control. Materials processed by the company include Inconel 625 and Inconel 718, as well as other nickel based alloys such as Hastelloy X, C263, C1023 and CM247LC. Stainless steels such as 17-4 and 15-5 are also processed, along with maraging tool steel M300 and CoCrMo (Stellite). Recently, the company has added titanium capability and is building parts for aircraft and motorsports applications in Ti-6Al-4V. The CM247LC capability, in particular, is believed to be unique.

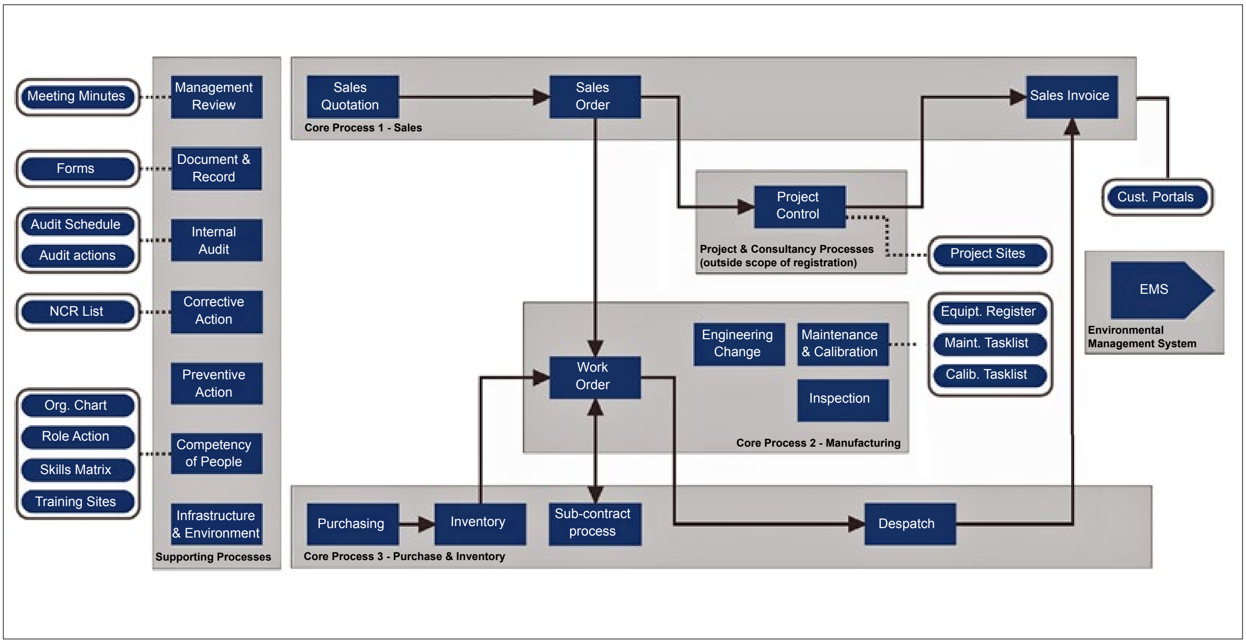

Fig. 6 The quality management top-level process map at Materials Solutions

IT, production and quality management systems

To aid the company in delivering advanced products into its chosen target markets, Materials Solutions has developed an extremely sophisticated production and quality control system. This system is paperless and uses data entry points throughout the factory with bar code scanners for tracking operations and the movement of work in progress.

The IT operations are cloud hosted and accessed over the Internet via Citrix, except for customer files that are secured in-house. This IT structure provides security and scalability and, with 2-factor authentication, enables secure off-site access. The focus on process control and validation has led the company to develop and patent procedures and equipment to validate laser scan speed and powder re-coater speed, which, though both being key process variables, are not checked conventionally.

Accreditations and customer approvals

The company's documented quality management system procedures and audited practices conform to key quality standards. Approval to ISO 9001:2008 has been in place since Jan 2008. Registration to the aerospace sector specific AS9100 Rev. C has been in place since May 2010 and was subsequently reissued to Rev. C Oct 2011. The company's suppliers are also expected to comply with the same standards.

In addition, Materials Solutions has customer approvals for metal powder-bed Additive Manufacturing from; Rolls-Royce plc, Rolls-Royce Deutschland, Rolls-Royce Canada (now part of Siemens), Rolls-Royce Nuclear Sector, Industria de Turbo Propulsores (ITP Group), Sumitomo Precision Products and several other motorsport and aerospace companies that prefer Materials Solutions not to publicise.

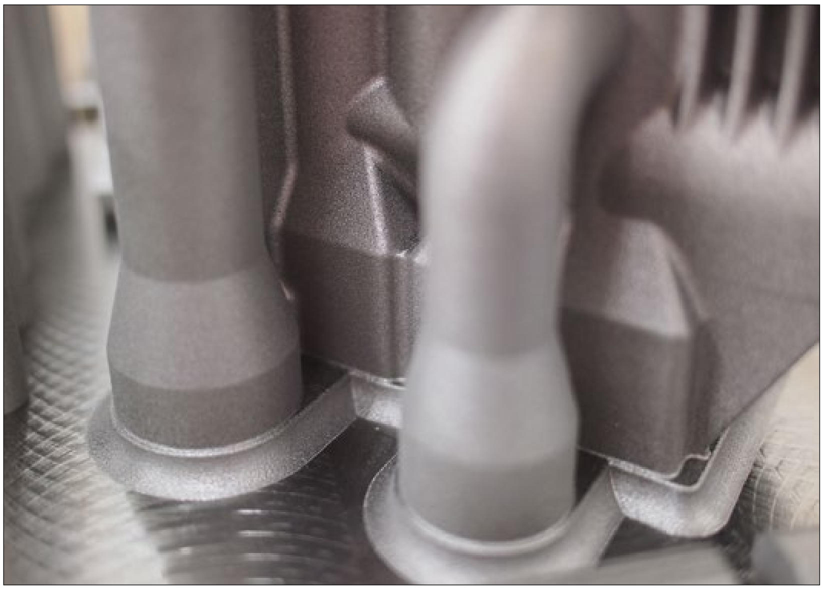

Fig. 7 Close up of a titanium hydraulic manifold

Intellectual property ownership

The issue of patent cover for procedures and equipment, developed by the company to validate the key process variables of laser scan speed and powder re-coater speed, has already been referred to. Materials Solutions now has a total of twelve issued patents, with a further eleven applications pending.

As a more general comment on the company's approach to developing and protecting intellectual property, Brancher stated, "Additive Manufacturing is a new and IP-rich environment, which presents challenges to end-users for adoption as a manufacturing technology. There is always the concern that unintentional infringement may lead to additional costs or delays. To counter this risk, Materials Solutions files many patent applications both to test the scope of existing patents and also to generate new patents. These patents not only protect Materials Solutions IP, but also generate IP assets that may be used in bargaining situations. However, one area where Materials Solutions does not file patents is for any element of the design of parts made or enabled by Additive Manufacturing. This space we leave to our customers, as their IP "win". We remain professionally blind to the designs we see and their function - what they are and what they do is of no interest to us. We make parts for many companies and, to us, they are simply geometries that need to be built to our customers' designs and specifications."

Thoughts on the future of metal Additive Manufacturing

In terms of the immediate outlook, Brancher sees 2015 as a growth year, not just for Materials Solutions, but also for the industry more generally. "There is an inflection point arriving soon and some big decisions are going to be made that will determine whether metals AM becomes main-stream, like EDM for instance, or remains a specialty process. In my opinion, the most exciting and fastest moving area will be in personal/polymer and my sense is that software tools and equipment development there (because it is so dynamic) will grow in sophistication and may provide some necessary elements to enable the revolution in metals manufacturing that has been outlined by the more evangelical wing of the metal AM community."

Fig. 8 Close up of a combustor can design by Materials Solutions to demonstrate capability

Design for Additive Manufacturing

In relation to the potential emergence of AM-friendly design concepts as an aid to adoption of the technology, Brancher commented that, "The AM process can build almost any design if enough support structures are added to it. So the question of additive-friendly design is really a question of cost and appropriateness of the manufacturing method. Under certain circumstances, a design is more appropriate for AM simply because making it any other way would take too long or cost too much. I do think that what AM has enabled is for designers to consider in depth the method of manufacture in ways that perhaps they have not done for conventional processes. By considering the manufacturing method, they are able to take advantage of it. Frequently we are shown designs that are difficult to make by any method as initially designed and toleranced. So there is a big 'win' associated with AM that is not specific to AM but is more one of considering the requirements of a design and what is functionally needed."

Barriers to growth

In relation to potential barriers to the growth of metal AM in the next five or so years, Brancher stated that, "Customers often do not know what they require of a design e.g. what mechanical properties, surface finish etc. are required, as opposed to those that have been specified historically. This is critical because AM does not naturally reproduce the same surface finishes as machining processes, nor does it achieve the same properties as cast of forged materials. A lot of additional expense is needed to build parts additively and then post-process them to resemble products from a historical method."

Brancher added that challenges for the metal powder supply chain to the AM sector relate to the achievement of consistency in chemical composition control and the reduction in achievable oxygen and nitrogen levels.

> *"Considerable skills are needed to use the current generation of AM tools - it is like having a piano in the room, no more than an ornament unless you have learnt to play"*

Additive Manufacturing in the technology life cycle

Concluding, Brancher told *Metal Additive Manufacturing*, "I had 25 years in the semiconductor industry and lived in Silicon Valley and then in Japan in the 1980s. AM currently is analogous to the early 1980s in the silicon processing time-line; simple machines and software tools and the technology walking around on legs. Considerable skills are needed to use the current generation of AM tools - it is like having a piano in the room, no more than an ornament unless you have learnt to play."

"For AM to turn into something resembling a revolution, more of the technology must become embedded into the machines and software tools, allowing designers to design for function and have almost instant design verification and manufacturing routes mapped. This may never happen because of the wide diversity of designs, making the software development too complex and the costs too high. However, I do expect more Artificial Intelligence to be embedded in almost all aspects of professional life from medicine through to manufacture."

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MAMC 2014: Vienna's Metal AM Conference reports on progress in a rapidly changing industry

More than 150 participants from 19 countries attended the Metal Additive Manufacturing Conference (MAMC), Vienna, November 20-21, 2014. The conference, organised by the Austrian Society for Metallurgy and Metals (ASMET) and voestalpine Edelstahl, reviewed the latest developments along the entire processing chain as well as novel applications. Prof. Bruno Buchmayr, Montanuniversität Leoben, and Prof. Juergen Stampfl, TU Wien, present an introduction to Additive Manufacturing and report on highlights from the MAMC 2014 conference.

Additive Manufacturing has received substantial interest in recent years, from a technological as well as from an economical point of view. AM technologies are capable of building complex three-dimensional objects by the stacking of thin individual layers. Since no tools are required in this additive approach, the degree of freedom regarding shape complexity is greatly enhanced compared to subtractive processes, such as turning or machining.

AM is largely used for the manufacture of short lead-time prototypes, but also for small-scale series production and tooling applications. In addition to applications in engineering, AM is becoming ever more popular in the medical sector, where patient-specific geometries are required, for example in orthopaedics, dentistry and hearing aids. Today suppliers offer a substantial number of different AM systems, ranging from domestic 3D printers costing less than $1,000 through to professional manufacturing systems costing more than $500,000. This large number of systems available on the market has led to significant market segmentation. In 2012, the ASTM International Committee on Additive Manufacturing Technologies proposed a scheme for categorising 3D printing systems. The main processes are described in Table 1.

Only a few of these methods are applicable to the processing of metals and by far the most significant methods in the context of this article are processes related to powder bed fusion. Several specialised applications rely on directed energy deposition, for example the repair of turbine

Fig. 1 Franz Rotter, President of ASMET and Head of the Special Steel Division of voestalpine, speaking at the MAMC 2014 in Vienna

Fig. 2 More than 150 participants from 19 countries attended the Metal Additive Manufacturing Conference

blades. Due to its importance in real-world applications, the Additive Manufacturing of metals has gained significant interest from high-profile industrial users, particularly in the energy and aerospace sectors.

The market for Additive Manufacturing

The overall market situation for AM technologies appears to be promising, as can be seen in Fig. 3 [1]. Services and products, defined as both AM systems and materials, have shown a significant growth since the 2008 financial crisis and worldwide revenues surpassed $3 billion in 2013. This growth has generated much interest in AM related activities. However, it should be noted that revenues from AM technologies are still small compared to the overall worldwide manufacturing market.

The worldwide installation base of professional 3D printers, defined as costing in excess of $5000, is dominated by North America (Fig. 4), followed by Europe and Asia. The largest number of applications relying on AM is still related to prototypes, small-scale series production and patient-specific parts for biomedical applications. Most of these applications make use of polymers as the base material. However, for engineering applications and more demanding applications in biomedicine, such as load bearing implants, metals are the materials of choice in the majority of cases.

The Additive Manufacturing of metals

There are three direct processes for metal Additive Manufacturing; Selective Laser Melting (SLM), Electron Beam Melting (EBM) and Laser Metal Deposition (LMD). For rapid prototyping, tooling and the manufacture of engineering structures, SLM is the dominant AM process. EBM is primarily used for TiAl6V4 and the intermetallic TiAl-alloy in the aerospace industry. Companies such as GE Avio Aero, it has been suggested, will concentrate in the future on large sized parts, with increased productivity thanks to higher laser power and parallelisation of operations, and increased reliability thanks to longer filament life, controlled leakages and better powder control and distribution. LMD is used primarily for the robot-assisted repair of 3D components such as the edges of turbine blades.

Each of the powder types used for these processes needs a specific optimal size (10 - 50 µm for SLM, 40 - 100 µm for EBM and 40 - 150 µm for LMD). Table 2 provides a direct comparison between SLM and LMD with reference to a number of criteria.

State-of-the-art SLM machines are typically equipped with a 400 W laser beam source and a build space

Process	
Material extrusion	A process in which material is selectively dispensed through a nozzle. FDM and 3D-bioplotting fall into this category.
Material jetting	A process in which droplets of build material, such as photopolymer or thermoplastic materials, are selectively deposited. Systems based on inkjet-heads fall into this category.
Binder jetting	A process in which a liquid bonding agent is selectively deposited to join powder materials.
Sheet lamination	A process in which sheets of material are bonded to form an object.
Vat photopolymerisation	A process in which liquid photopolymer in a vat is selectively cured by light-activated polymerisation. Many of the lithography-based AM approaches, for example two photon polymerisation, digital light processing, and stereolithography, can be grouped into this category.
Powder bed fusion	A process in which thermal energy, provided for instance by a laser or an electron beam, selectively fuses regions of a powder bed. Selective Laser Sintering (SLS) and Electron beam melting (EBM) fall into this category.
Directed energy deposition	A process in which focused thermal energy, for example laser or plasma arc, is used to fuse materials by melting as they are being deposited.

Table 1 The main Additive Manufacturing processes

of 250 x 250 x 300 mm³. To increase productivity, several approaches can be taken, including increasing the laser power to increase the scanning speed, use of larger layer thickness and larger beam diameter to increase the build speed. As reported in the presentation *Selective Laser Melting on the way to production: recent research topics at Fraunhofer ILT* [2], another method used to increase productivity is the parallelisation of the SLM process by using multiple laser beam sources and multiple laser scanning systems in one machine.

However, with the use of a beam diameter of approximately 100 µm, as commonly used in commercial SLM systems, the intensity at the point of processing is significantly increased due to the use of the increased laser power. This effect results in spattering and evaporation of material and therefore in an unstable and non-reproducible SLM process [2]. In order to avoid spattering and rough surfaces in the application of high laser power, a so-called skin-core strategy is used [3], where the outer skin is made with lower beam energy and the core with a higher energy.

Investigations by Fraunhofer ILT demonstrated that through the use of this concept, the build rate can be increased by a factor of 9 in the case of a maraging tool steel 1.2709. In addition, functionally adapted

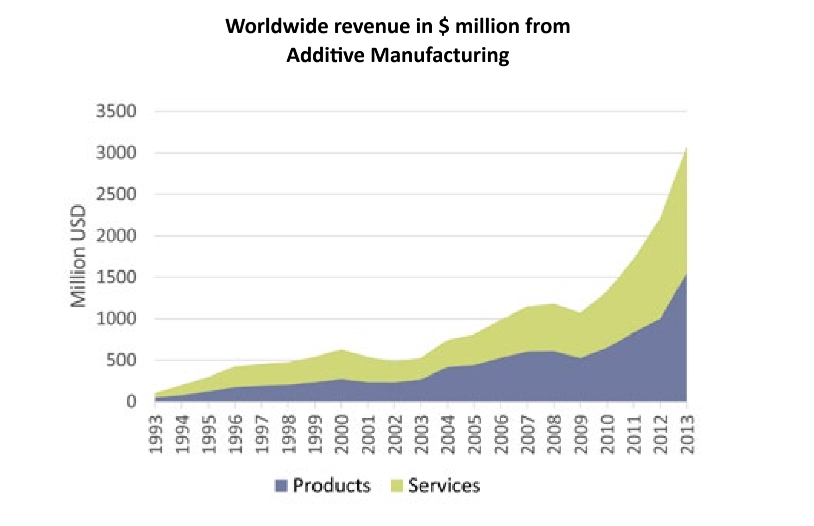

Fig. 3 Worldwide revenues in $ million, from sales of products (blue) and services (green) [1]

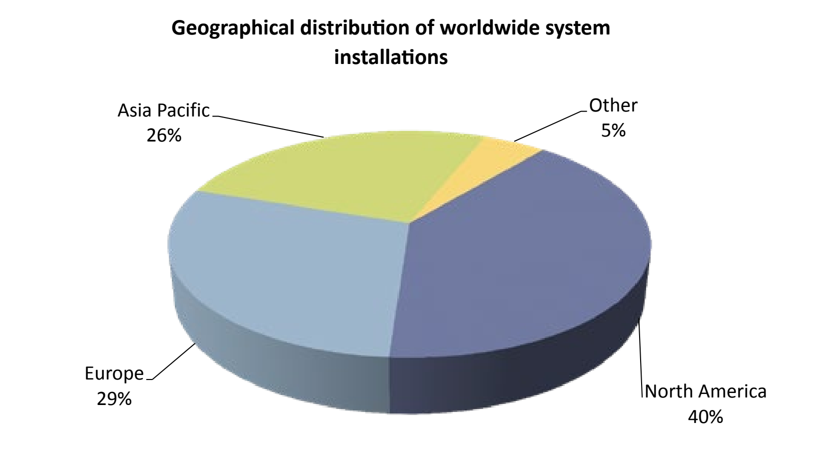

Fig. 4 Geographical distribution of worldwide system installations (industrial systems) [1]

Criteria	SLM	LMD
Density	100%	100%
Materials	About 10 -20	Larger number of materials
Component size	limited by chamber	Limited by handling system
Geometrical complexity	Almost unlimited Hollow structures	Limited, wall angle < 20°
Precision	< 0.1 mm	>0.3 mm
Roughness	30 -50 µm	60 -100 µm
Built on surface	Flat surface	Any 3-dimensional surface
Building rate	1 – 20 mm³/s	3 – 140 mm³/s
Applications	New parts	Repair and surface modification

Table 2 Comparison between SLM and LMD with regards to a number of important criteria

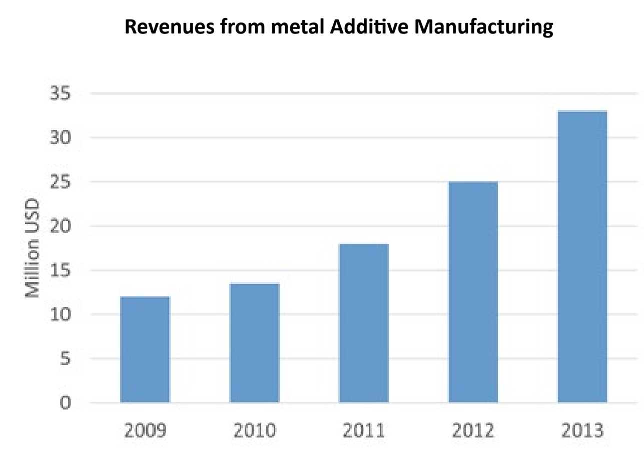

Fig. 5 Revenues from metals for AM [1]

component design using topology optimisation may also lead to smaller levels of part volume and therefore to cost reduction.

With regard to the increasing demand for quality assurance in order to detect welding defects, the Austrian research institute FOTEC Forschungs- und Technologietransfer GmbH reported in its paper *Melt pool monitoring and applications of Metal Additive Manufacturing* [4] that it has developed a photodiode-based monitoring system that is built into the working chamber of an EOS M280. Using fast signal processing by Matlab, imperfections can be reliably found and can be visualised in the form of a 3D model.

Materials utilisation in metal Additive Manufacturing

The areas which are of primary interest for the wider utilisation of Additive Manufacturing determine the market for commercially available metal powders. These include mainly bronze-based alloys, stainless steels and precipitation hardening (PH) steels, as well as high strength maraging steels. For medical applications, CoCrMo-alloys and pure titanium are the most prominent choices. For lightweight structures, AlSi-alloys (having a low melting point) and TiAl6V4 powders are in widespread use, mainly in the aerospace industry. Finally, nickel base superalloys with superior creep resistance at high temperatures, for example IN718, and corrosion resistant alloys such as alloy 625, are quite frequently used.

As presented in the paper *Powder for Additive Manufacturing* by Carpenter Powder Products [5], the quality requirements are challenging because chemistry, powder size distribution, cleanliness (metallic and non-metallic inclusions) and flowability all have a remarkable influence on the final product properties. An important question concerns the re-use of powder, because this may lead to some negative effects with regard to oxygen or other contamination pick-up during powder handling.

Currently, most of the metal alloy powders used have similar compositions to those used in cast or wrought form. Further chemistry modifications are performed to improve weldability and mechanical properties. Beside the optimisation of the main welding parameters of laser energy and scanning speed, preheating temperature, welding sequence or hatching style and stress relaxation by additional coupled heat sources are remedies for the avoidance of crack formation.

The metallurgical aspects of the SLM process, which are primarily related to the very short welding time, were considered in the presentation *Selective Laser Melting – a metallurgical and materials related view* [6]. The limited time available for diffusion combined with the high undercooling from melting lead to very fine microstructures and unstable or metastable phases. Temperature gradient and cooling rate determine the local microstructure as well as the residual stress state or distortion and the likelihood for cracking. For a new tool steel grade using a Bohler metal powder, optimal laser power and scanning speed were derived, to deliver zero porosity in the cross section, which is necessary for a good polishing quality in the manufacture of injection moulds for plastics, for example.

An exposure strategy, patented by Concept Laser and discussed in the paper *The advances of 3D systems* *direct metal printing for industrial parts manufacturing* [7], allows a significant reduction in residual stress. This is based on stochastically placed islands, which are worked through in succession. The typical topology appearance is like a chess board.

Lightweight designs for automotive, aerospace and space applications

As a general rule, the economic application of metal AM technology is based on the requirement for a small number of parts or tools, for the use of expensive materials and for small size parts having a very complex geometry. Fig. 6 shows the most important application sectors for the utilisation of metal AM.

The main benefit of AM for aerospace applications is a very high raw material to product conversion rate, equating to a low buy to fly ratio. Fuel consumption is primarily determined by the weight of the aircraft. Topology optimisation supports the design of load-adapted parts based on an FEM-analysis. Elements with low stresses are deleted until the optimisation criterion is fulfilled. This approach usually results in very complex parts with 3D freeform surfaces and hollow structures which can be preferentially fabricated by SLM without any geometrical restrictions. Meiners [2] demonstrated the high potential for weight reduction in the case of an aircraft seat with a weight reduction of approximately 15% being achieved. In addition, the method of topology optimisation can be combined with fine internal lattice structures to obtain a good stiffness to weight ratio, greater energy absorption capacity, etc.

Thanks to the unique properties of lattice structures and their low volume, the integration of functionally adapted lattice structures in functional parts is a promising approach for the realisation of the full technology potential of SLM. Parts made in this way are shown in Fig 7. It is worth noting that, for AM, manufacturing costs are independent of part complexity. Other interesting designs for the improvement of material efficiency using topology optimisation and bionic concepts were shown in the paper *Additive Designed Manufacturing* [8]. Fig. 8 demonstrates inner lattice structures in a cylinder head. In this case, the weight of the component could be reduced from 5.1 kg to 1.9 kg, equating to a 66 % weight reduction.

In the MTU Aero Engines presentation *The Additive Manufacturing Process Chain for Jet-Engine*

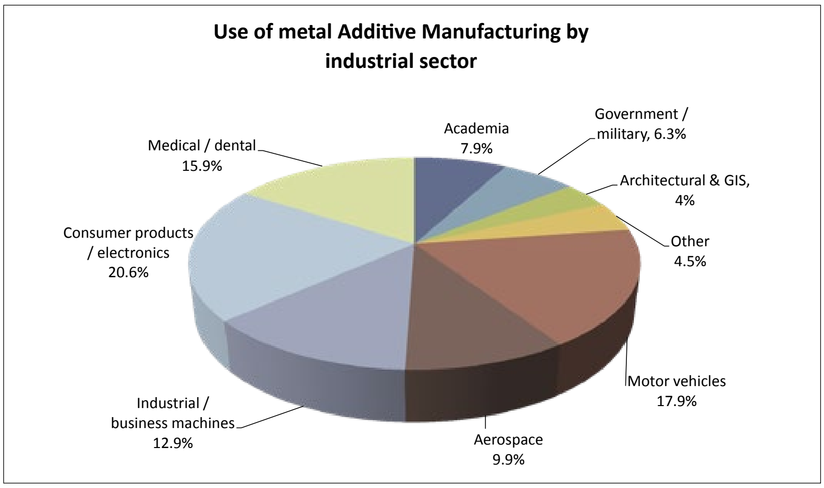

Fig. 6 Use of metal Additive Manufacturing in different industrial sectors [1]

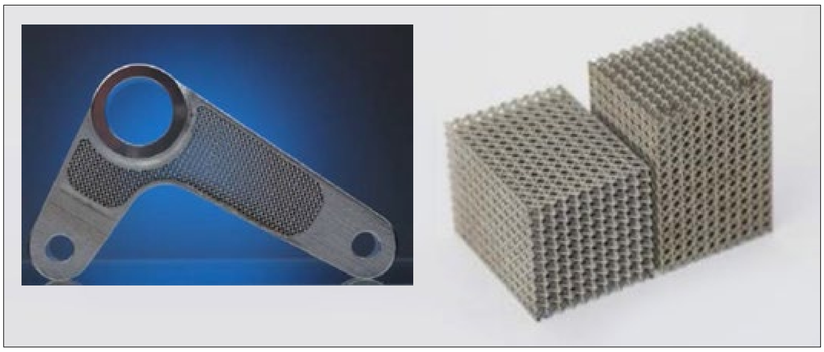

Fig. 7 Integration of lattice structures in functional parts [2]

Fig. 8 Lightweight design of a bionic cylinder head [8]

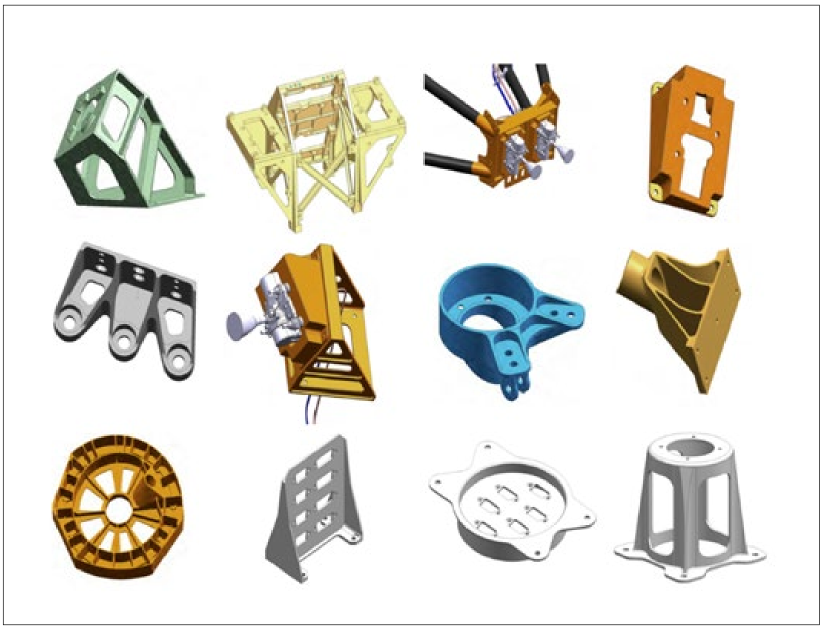

Fig. 9 Possible spacecraft parts for AM [10]

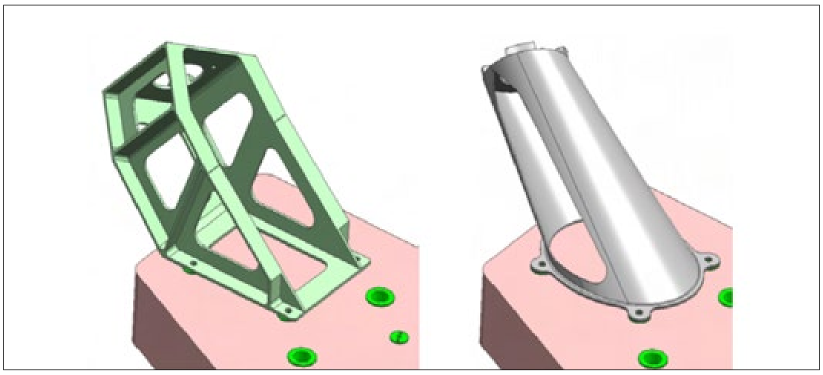

Fig. 10 Optimisation of a conventional support bracket design (left) for AM (right) [10]

Fig. 11 Tool for hot sheet metal forming [13]

Applications [9], Dusel reported on the significant increase in parts produced by metal AM, thanks to short lead times, cost reduction, and the enabling of new designs. The first serial AM production parts (boroscope bosses for the A320NEO engine) were introduced in 2013 with a scheduled production ramp-up in 2015/16. Six production machines (M280) and mainly nickel base alloys (IN 718, MAR-M509) are in use. In addition to the AM machines, the complete process chain needs to be set up, consisting of data preparation, stress relieving, parts removal, heat treatment, surface finish/machining and final inspection. It is essential to optimise the complete processing chain and to implement a quality assurance system to monitor every single stage.

QA aspects along the process chain are divided into those before (powder and machine condition, preparation procedure etc.), during (machine monitoring, TPM) and after (FPI, X-Ray, visual inspection, material testing) AM production. MTU summarised the internal challenges as follows:

- Further development of quality assurance
- Extend material database
- Extend AM part portfolio
- Establish design rules and layout for lightweight construction
- Make γ' strengthened materials accessible for AM production
- Integrated AM production facility

Expectations from the market were outlined as:

- Comparability between machines
- Productive machine time > 5500 h / year (OEE)
- Increases in quality and productivity
- Thinking in terms of serial production
- Further development of the complete process chain
- Exchange of knowledge regarding critical defects
- Common material and process parameter database

For spacecraft parts, AM is seen as a key technology to reduce the weight of standard structural components and to reduce the production costs of complex parts. Within two European Space Agency (ESA) projects, the applicability of AM technologies for the production of different systems and subsystems of telecommunications missions has been analysed. The benefits in terms of cost savings, potential assembly, integration time and mass savings at system level have been assessed. The most promising processes for Ti and Al alloys are SLM and EBM. Several

Fig. 12 A number of metal AM parts were displayed at MAMC 2014, including this AlSi10Mg distributor housing manufactured by Citim

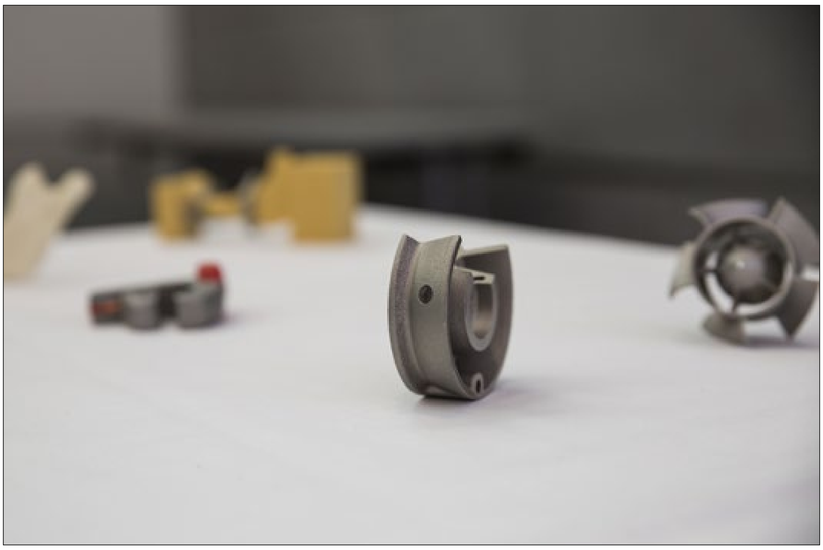

Fig. 13 Metal AM parts on display at MAMC 2014

structural parts were identified by OHB System AG in the paper *Additive Manufacturing for space application* [10], which could result in weight and production cost reductions if produced by AM. Fig. 9 shows some typical examples.

In order to take full advantage of the AM process all parts need to be redesigned and this leads, in most cases, to solutions with higher levels of complexity or smaller detail dimensions that render the parts no longer suited for conventional machining. The prerequisites for the introduction of AM technologies as a standard manufacturing process for spacecraft application are space-specific qualification and verification strategies, which are currently not in place. The most problematic issue in relation to standardisation is the large number of process parameters, the influences of which on the manufactured part are not always known or are unverified.

As an example component, OHB optimised an existing antenna support bracket, as seen in Fig. 10, which was originally designed to be milled from a bulk material block as can be seen in the image on the left. The optimised part on the right hand side is made by AM with a mass saving of 40%.

In comparison to conventional investment casting, Varetti in his paper *The EBM Technology at AvioAero – the dark side of the moon* [11] identified that a 50% cost reduction could be achieved with AM. He showed various Ti-based parts and even an LPT blade made from TiAl using the EBM process.

Tooling applications

As illustrated in the papers *Additive Manufacturing at University of Applied Science Upper Austria* [12] and *Metal Additive Manufacturing for tooling applications – Laser Beam Melting technology increases efficiency of dies and holes* [13], tools for metal forming and casting as well as polymer injection moulding can be improved using AM through the implementation of complex cooling systems close to the surface.

In sheet metal forming using press hardening (Fig. 11), as well as in aluminium die casting, this method can improve component quality and reduce process cycle time. Complementary to this, Vollmer in his paper *Evaluation and optimization of forming tool coatings processed by laser metal deposition* [14] showed the use of the LMD process to create thick film coatings on stamping tool surfaces.

Eifeler Lasertechnik illustrated the wide range of applicability of the LMD process in the paper *Laser metal deposition: A solution for wear protection, challenging repair and dimensional change* [15]. The three main areas of application are repair of tool components (repair of tool edges), provision of preventive wear protection and production of functional layers with increased thermal conductivity, surface hardness and adapted physical or chemical properties.

Conclusions

Metal Additive Manufacturing has gained greater significance in recent years. The most commonly used process for building metallic components is Selective Laser Melting (SLM). This process is economically used to manufacture small parts with complex geometries and in small quantities, without the need for tools. In combination with design approaches such as topology optimisation and lattice structures, outstanding solutions for lightweight constructions can be achieved.

These characteristic features make SLM the predominant fabrication process in application areas such as automotive, aircraft and space technology. In addition, tools with conformal cooling systems are established products for AM. Medical applications for AM are also of great interest, but have not been covered in this overview.

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References

[1] Wohlers T., Wohlers Report – 3D Printing and Additive Manufacturing State of the Industry, Wohlers Associates, 2014

[2] Meiners, W.: Selective Laser Melting on the way to production: recent research topics at Fraunhofer ILT, MAMC 2014, 20/21 November 2014, Vienna, Austria

[3] Schleifenbaum, H.et.al.: Werkzeuglose Produktionstechnologien für individualisierte Produkte, In: Brecher C.(eds.) Integrative Produktionstechnik für Hochlohnländer, Springer, 2011

[4] Gumpinger, J.et.al.: Melt pool monitoring and applications of metal additive manufacturing, MAMC 2014, 20/21 November 2014, Vienna, Austria

[5] Lherbier, L.W.: Powder for Additive Manufacturing, MAMC 2014, 20./21. Nov.2014, Vienna

[6] Buchmayr, B.: Selective Laser Melting – a metallurgical and materials related view, MAMC 2014, 20/21 November 2014, Vienna, Austria

[7] Averyanova, M.: The advances of 3D systems direct metal printing for industrial parts manufacturing, MAMC 2014, 20/21 November 2014, Vienna, Austria

[8] Schäfer, D.: Additive Designed Manufacturing, MAMC 2014, 20/21 November 2014, Vienna, Austria

[9] Dusel, K.-H.: The Additive Manufacturing Process Chain for Jet-Engine Applications, MAMC 2014, 20/21 November 2014, Vienna, Austria

[10] Schlitt, R.: Additive Manufacturing for space application, MAMC 2014, 20/21 November 2014, Vienna, Austria

[11] Varetti, M.: The EBM Technology at AvioAero – the dark side of the moon, MAMC 2014, 20/21 November 2014, Vienna, Austria

[12] Huskic, A.: Additive Manufacturing at University of Applied Science Upper Austria, MAMC 2014, 20/21 November 2014, Vienna, Austria

[13] Müller, B. et.al.: Metal Additive Manufacturing for tooling applications – Laser Beam Melting technology increases efficiency of dies and holes, MAMC 2014, 20/21 November 2014, Vienna, Austria

[14] Vollmer, R. et.al.: Evaluation and optimization of forming tool coatings processed by laser metal deposition, MAMC 2014, 20/21 November 2014, Vienna, Austria

[15] Pötzl, R.: Laser metal deposition: A solution for wear protection, challenging repair and dimensional change, MAMC 2014, 20/21 November 2014, Vienna, Austria

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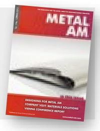

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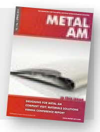

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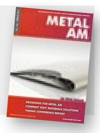

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