Additive Manufacturing:
Why we can afford to be bullish

New opportunities for additive manufacturing (AM) are emerging in multiple applications. There are many reasons to be optimistic on this young technology.

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Foreword

Additive Manufacturing: Why we can afford to be bullish

As is typically the case for the rise of any new development process, the industrialization of a revolutionary technology such as additive manufacturing (AM) requires a periodical evaluation of the current situation. With this background, the recent third Munich Technology Conference (MTC3), was held in October 2019 under the theme "Time for a Reality Check." The event has grown to become one of the most important conferences for the blossoming AM sector and this year attracted over 1,500 attendees from 32 countries.

The impact that AM is having on production is already noticeable within the industry. The opportunities that the young technology offers for individualized products down to "lot size 1" are undisputed and have been impressively documented. However, we have yet to make the great strides towards the broader application of AM that were anticipated several years ago. Numerous examples have shown that improvements in productivity and reproducibility still have to be accelerated and that a standardization of processes, materials and printers is required. These should therefore be the main areas of focus for the AM industry's efforts going forward.

Furthermore, universities need to consistently include more areas within the field of digital production into their curriculums. It is only once we have achieved a true mindset shift on how we engineer parts that the full potential of AM technology can fully thrive. A shift is also required when it comes to the economic evaluation of production methods. Only the total cost of ownership of a product can demonstrate the advantages offered by AM. The true benefits of AM that need to be highlighted include increased efficiency, reduced complexity and optimized logistics. This will require considerable research and marketing efforts.

We at Oerlikon are convinced that working together for the industrialization of AM will benefit every single player within the industry. That's why we're delighted by the strong partner network of the 3rd Munich Technology Conference. It consists of Technical University of Munich (TUM), GE Additive, Linde AG, McKinsey & Company, Siemens, and TÜV SÜD. This partner network and the Bavarian Cluster for Additive Manufacturing (which we are starting together with TUM, GE Additive and Linde), shows how strong the willingness is to rapidly integrate AM into industrial processes.

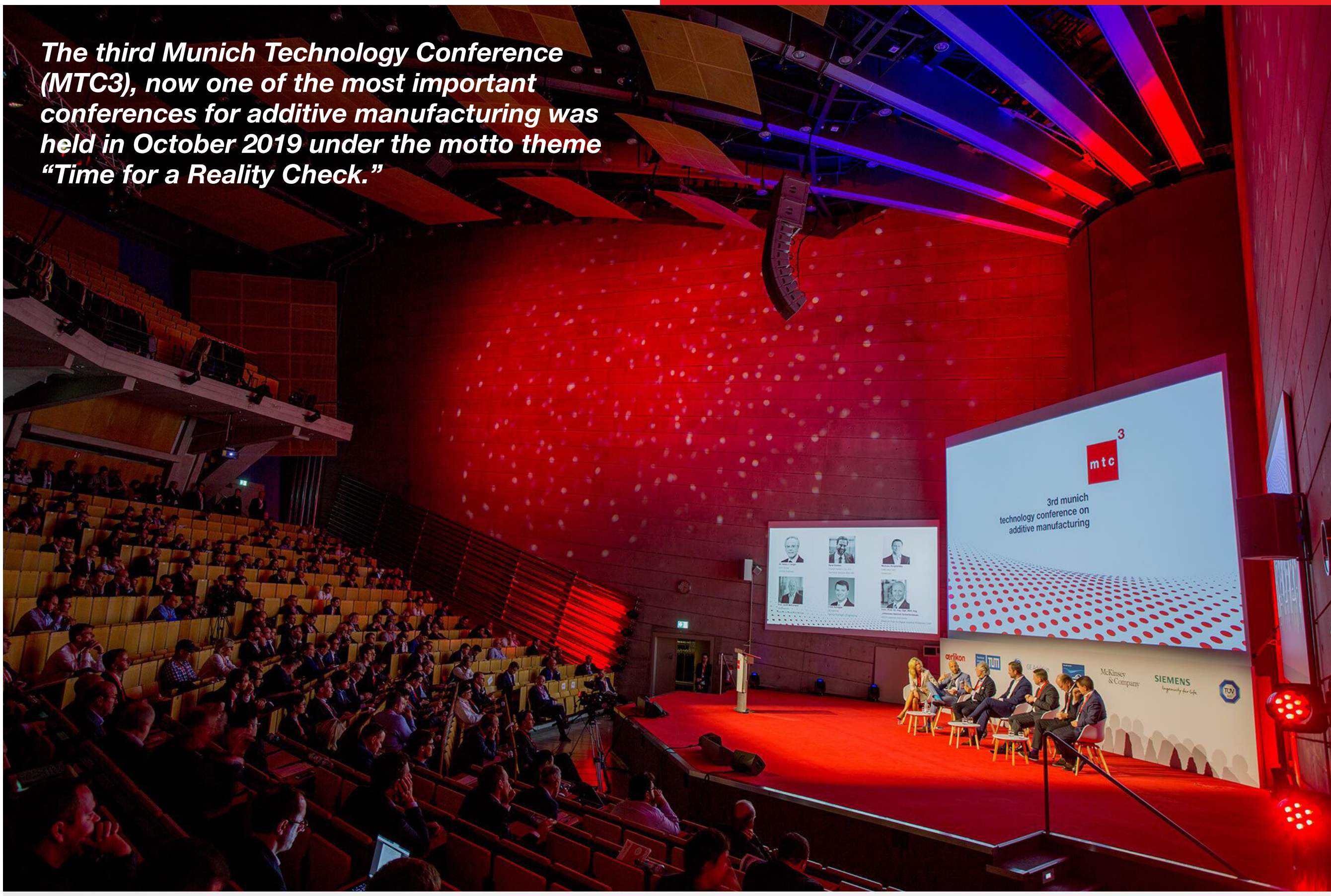
The purpose of this white paper is therefore to offer readers from across industries an evaluation of the current situation when it comes to AM adoption. It is aimed at everyone who is interested in this transformational technology, including those who are already working with AM or researching its potential. But we also want to reach out to all those who are still skeptical and want to find out more before investing.

The examples presented here feature products and business models based on AM, as well as the development of new technologies and materials. Last but not least, they relate to the progress being made in defining and setting uniform technical and legal standards. Since these insights are mainly based on presentations and discussions from MTC3, the structure and themes in this white paper are accordingly similar to those in the conference itself.

All examples presented in this white paper reaffirm that AM is on the home stretch towards industrialization and that a digital factory without AM will be virtually unimaginable in the future. As you will read throughout this document, the evidence for this is becoming increasingly prevalent and reassuring as we as an industry continue on this exciting journey.

On that final note, I would like to wish you interesting and informative reading on what is a truly revolutionary engineering field. ■

Prof. Dr. Michael Suess, Chairman of the Board of Directors, Oerlikon



The third Munich Technology Conference (MTC3), now one of the most important conferences for additive manufacturing was held in October 2019 under the motto theme "Time for a Reality Check."

#mtc3 #industrializeAM

Adding up @MTC3

3rd munich
technology conference
8–10 October 2019
TU Munich/Germany

mtc 3

> The **MTC3** event has been a revelation – for informed and real engagement on Additive Manufacturing – it is a must-attend event.
>
> **Rachel Park**
> 3D printing influencer, writer & editor

1500+ ATTENDEES

DZA	AUS	AUT	BEL	CAN	CHN
CZE	DNK	ECU	FIN	FRA	GAB
GMB	GER	GHA	IRL	ITA	JPN
LVA	NLD	NZL	NOR	ROU	RUS
SGP	ESP	SWE	CHE	TUR	UKR
GBR	USA				

32 COUNTRIES

49 SPEAKERS

9 CONFERENCE TOPICS

- Startup Pitches
- Collaboration
- Driving Industries
- Digital Manufacturing
- Materials
- Hardware
- Post-Processing
- Norms & Standards
- Fresh Ideas

3 DAYS

8 OCT · 9 OCT · 10 OCT

Day 1: **Startup Evening**
Day 2: **Conference**
Day 3: **Workshops**

16 WORKSHOPS

TOP10 INDUSTRIES

1. AM Solution Providers
2. General Industry
3. Academia
4. Aerospace
5. Consultancy
6. Automotive
7. Norms & Standards
8. Medical
9. Defence
10. Energy

oerlikon · Technical University of Munich TUM · GE Additive · Linde · McKinsey & Company · SIEMENS Ingenuity for life · TÜV SÜD

Introduction

Additive manufacturing (AM), more commonly known as 3D printing, is transforming markets and has the potential to start a technological revolution through out-of-the-box thinking. AM as a technology is developing along several material fields. Thus far, the majority of initial commercial development has taken place in polymers, with strong long-term potential existing within the metal AM sphere.

Traditional manufacturing involves taking a block of metal and removing material by machining or shaping by casting. In contrast, 3D printing allows forms to grow organically. The rise of AM changes the whole game and is forcing a reassessment of manufacturing across industries. This technology offers more design freedom when manufacturing complex shapes that are optimized in terms of their functions. This is inspiring innovation in everything from aviation parts to Formula 1, to healthcare and energy.

According to a 2019 Wohler's report, the global market for AM is currently valued at US$13bn. This is forecasted to grow to US$35.6bn in 2024. Relatively speaking, AM is still a very small market compared to injection molding or casting. But it is a valid one that is only going to get bigger.

It is also important to remember that AM is much more than a singular technology; it is a huge and highly complex field. It's scope ranges from electron beam melting, to materials, design or post-processing. Because there are so many areas to consider, the AM industry has formed a type of community in itself where collaboration and cluster cooperation strategies are key.

At the Munich Technology Conference on AM (MTC3) in October 2019, one of the leading conferences on metal AM, the invited technology experts present at the conference were polled and asked: "How optimistic are you that a fully integrated and automated printer will be available by 2023?" 46% of respondents reported optimism, with "proactive collaboration to bring industrialization of printers forward" taking place, while 9% were confident that a combination of printer and ancillary equipment would be possible in this timeframe.

But despite the optimism, the industry accepts that AM's true progression from visionary technology to mainstream commercialization will require progress in scalability, cost and production efficiency. To integrate this powerful technology into production across sectors, manufacturers will need to rethink the design to manufacture process and consider where AM can bring more value than traditional manufacturing. There are also external market forces at play. Following the euphoria that existed around the technology 5-10 years ago, right now, the AM community is facing up to declining global markets, amid tough economic circumstances taking shape around the world. In effect it's time for a reality check.

But despite all the apparent challenges, there are real opportunities for AM and many reasons to be optimistic and bullish going forward. Most of the players who were active in AM 20 years ago are still there today. They are in this for the long haul and truly see it as a long-term investment that will blossom in time. Certain industries exist such as aerospace and defense where there has been no market downturn. From an AM perspective, these are areas that contain parts that are very difficult to produce, high performance and mission critical.

This white paper will show why it is justified to be fully confident on the transformational power of this young technology. It will prove with industry examples that there are a lot of recent developments and achievements in AM, including the key application areas of aerospace, automotive and spare parts, as well as the sustainability advantage that it holds. ■

Peter Mayr, Technische Universität München (TUM), Chair of Materials Engineering of Additive Manufacturing:

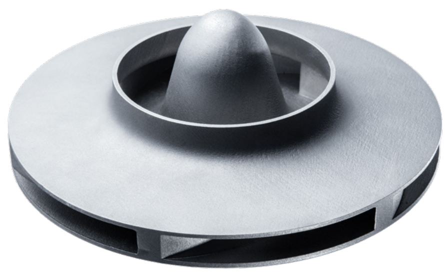
"TUM sees very high potential in additive manufacturing and wants to strengthen its role and even further increase our efforts. TUM can contribute with all its strengths: we have the brightest researchers across various disciplines, from medical to engineering. We have very clever and motivated students that can translate their ideas into start-ups. In the Munich area, we also have a very strong industry that drives us forward to support our ideas."

AM aerospace inconel nozzle

Aviation

There are several reasons why AM holds so much potential in the aerospace sector, mainly because of its lightweighting potential and the opportunity to print more complex parts. There are already a lot of polymer AM parts on planes as they take less time to validate than metal components.

The aerospace industry is reported to have a global market volume worth around €800 billion (source: IATA Forecast 06/2019). In other words, even if AM were only to address 0.5% of the volume, that would present a €4 billion market.



AM aerospace LENA impeller

AM has already made great progress in the aviation space. For example, Liebherr has gained authorization by the German Federal Aviation Office (Luftfahrtbundesamt, LBA) to produce components using AM. Liebherr-Aerospace has begun printing 3D components for Airbus, with the first industrialized part being a sensor bracket for nose landing gear on the A350 XWB. Airbus began testing metal AM parts several years ago, demonstrating flyable titanium parts back in 2015.

In general, the potential for AM is about high value applications. But it can also be about imparting multiple functions into a single part. For example, GE Additive has a fuel nozzle for engine applications which has reduced the number of parts required from 20 to 1. Imagine how much complexity can be saved through this type of innovation!

The biggest challenge for AM in aerospace, and perhaps rightly so, is the long regulatory approval process that the segment requires. The validation process for any metal component on an aeroplane can take 7-10 years. It means that as a whole we are only just beginning to see the applications get onto planes in the last 2-3 years, and even here they have so far only been non-critical components. But the progress made in plastics AM can be replicated in metals too.

For Chris Schuppe, General Manager Engineering at GE Additive, the dialog around AM in aviation has changed, which presents reasons for optimism. “The initial discussions we had were not easy. But what we are seeing now is demonstrations of quality over a long period of time. As the industry matures, both in civil and military aviation, we are starting to see the user base grow and expand, because they see other success stories out there,” he adds.

It will take some time for AM to truly take off in aviation but the industry is definitely already in a taxiing phase. ■

Dr. Roland Fischer, CEO, Oerlikon:

> **“On the one side, we need to manage to get volume, but on the other we need to develop all different fields, including powder and machines. Printer technology needs to get better, standardization has to happen, materials need to get much better, IT solutions are needed and to be an integral part. All of these elements have to develop.”**

GE Additive has a fuel nozzle for engine applications which has reduced the number of parts required from 20 to 1.

Automotive

The automotive industry is facing some headwinds, with disruptive pressures from new technologies such as electric cars and the debate around carbon emissions compliance. But it is another vast market where AM holds enormous untapped potential. McKinsey estimates that the current global market volume for the automotive sector is worth around €3.5 trillion. So even if AM were only to address 0.5% of the volume, that would be a €17.5bn market.

One of the biggest challenges facing the automotive sector is regulation around carbon emissions, which will only get stricter going forward. There are many ways in which AM can help here.

Like aviation, the key obvious benefit for AM in the automotive sector is in lightweighting. For example, we have seen BMW and Bugatti adopt AM components for this reason. In 2018, BMW began using metal AM to produce mounting brackets for its i8 Roadster. The aluminum alloy part is lighter than its injection molded counterpart, yet much stiffer, thus providing superior support to the roadster's soft convertible top. In January 2018, Bugatti announced the production of a titanium brake caliper using metal AM that is 40 percent lighter and stronger than its conventional aluminum counterpart.

A lot of automotive companies have announced plans to discontinue technology research based on traditional fossil fuel combustion engines, and look instead at fully electric and hybrid forms. Here is where the risk reduction advantage of AM can proliferate. For example, if parts can be developed that help to improve the cooling of car batteries, where you have high power densities, it could be a real benefit.

At MTC3, Siemens presented a printed polymer part that is specifically designed to get the air for cooling close to electric batteries in the car. This part improves the cooling of the battery by 22 percent, which is a critical performance parameter for a battery. While the part costs €10-15 to print, this is a very small investment considering the advantage that the part brings in energy savings.

Customization is another area where AM can make major inroads. Consumers are being given many more options to choose from. You see individualization of dashboards and even on exterior parts. While the industry has tried to simplify complexity and take out some hurdles, they will have to follow the consumer's wishes. For example, car models with identical paint jobs and equipment are rarely produced nowadays. This illustrates the incredible levels of customization at play right now.

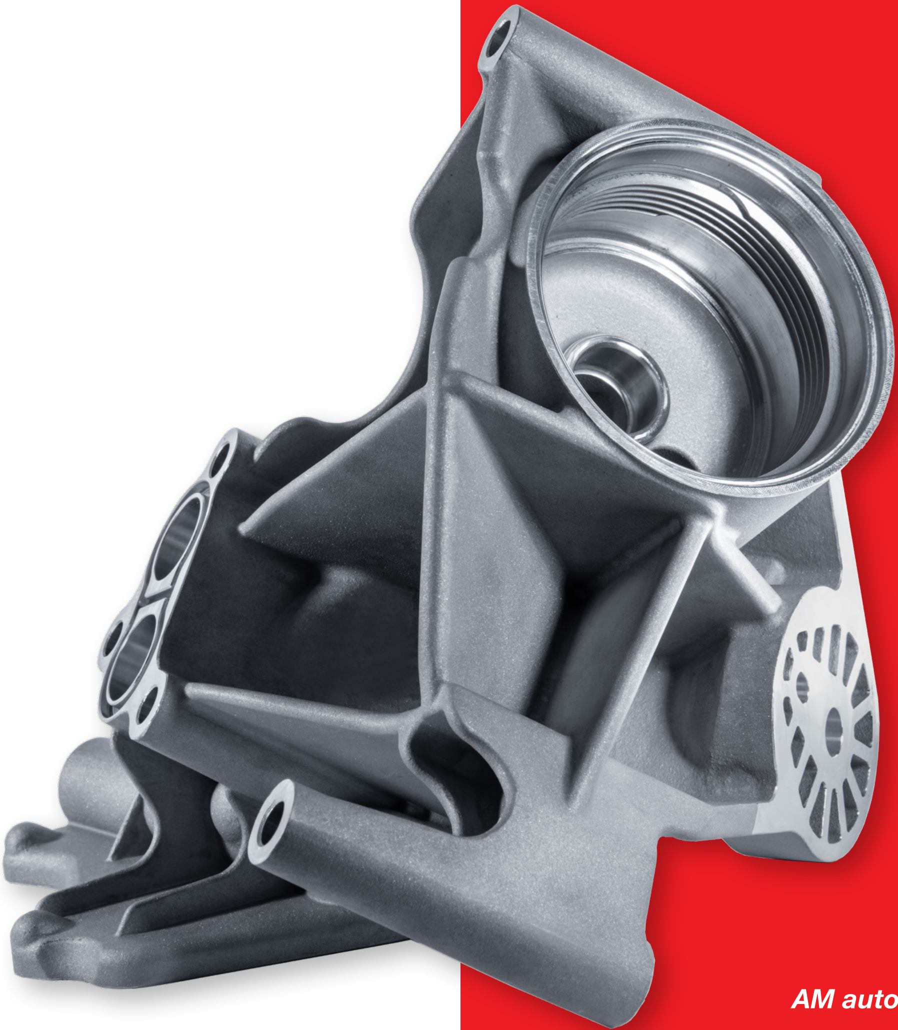
The automotive industry is currently addressing the mass customization challenge through increased logistics efforts. This means bigger warehouses with more different parts, more production in sequence and more just in time operations. But it does mean that the average cost per vehicle in terms of logistics has increased dramatically in recent years. The question is why are they not simplifying things by printing a few customized parts through AM? After all, if you can print the specific customized part that the consumer wishes, it could save a huge amount of hassle and storage space.

AM can truly drive innovation within the automotive space. ■

Andreas Behrendt, Partner, McKinsey & Company:

"The real starting point for me in terms of the uptake for AM is the mass customization of products. The automotive industry currently tries to solve mass customization with increased logistics efforts. The question is why they are not trying to solve this with AM."

AM automotive formula student cooling plate



AM automotive oil filter housing

AM automotive piston head

Healthcare

If you consider low volume, high margin industries where AM has true potential, the healthcare industry ticks all the boxes. Human beings are so unique and specific that the components used in medical procedures often need to be highly tailored and created to complex geometries. The cost savings come in the longer term, as these innovative products accelerate the healing process and therefore ultimately reduce the strain on both the healthcare system and the patient.

AM medical spine extension cage

Speaking more holistically, there are several ways in which AM is already showing potential within the healthcare sector. We have seen the orthopedics sector increasingly use AM methods in the production of implants. AM is making it possible to produce lattice structures that significantly accelerate the healing process after implantation. In the case of more complex medical interventions, surgeons can use patient-specific disposable surgical instruments, manufactured through AM methods based on 3D CAD data. There's also a promising role for the combination of AM and orthopedic technology to produce improved prosthetics and orthotics.

But AM also has potential in medical devices that offer dual benefits for both surgeon and patient. For example, we have seen the creation of an acetabular cup cutter for hip and knee replacement surgeries. This device features AM cup-shaped blades, which reduces time in surgery and addresses both patient safety and experience. The cutter's 3D-printed blades are more reliable and cost-effective, and have improved the surgical experience.

On the manufacturing front, we have seen progress in AM in medical technology too. Here you could enhance the value of centrifuge products while reducing manufacturing costs at the same time through the printing of parts.

When it comes to materials in healthcare AM, there is innovation in both plastics and metals, where titanium and cobalt chrome are strongly emerging within the field. Moving forward, there are likely some organic material strategies that could emerge if biocompatibility issues are resolved.

The potential market for AM in the medical space is in good health, with a wealth of future applications opening up. ■

The initial area of focus for AM was on the non-critical area of dental care. This industry has offered on demand global production for ceramic crowns for the last couple of decades. Within this space, for example, we have seen the first premium printable denture material system come to market.

The next phase for AM will go far further in terms of customizable and production grade metal implants. Work has already taken place in the field of acetabular hip implants, as well as spinal implants that help people recover from spinal fractures and slipped disks. Bone replacement through AM technology has also been possible, where titanium is used to recreate the bone before implanting for a fracture.

AM medical hip implant

Spare parts/ tooling

Tooling is one of the biggest horizontals in the world, servicing every industry from aerospace, to medical and power generation. If a tool fails, the value of not running the machine can go exponentially beyond the cost of the mere part itself.

However, despite this background and the growing complexity of globalized supply chains, there are actually less spare parts being kept in warehouses today than before. This poses a major problem where AM can be the solution. If you can reduce your downtime by having distributed manufacturing, where you can print your spare parts on demand where it is needed, using AM makes total sense. Users can simply send a file through to the facility where required and produce their spare part centrally and quickly at the point of use. It means that a warehouse full of assets is no longer required and that the real need for "just in time" operations can be addressed. Spare parts are currently being typically produced expensively at a warehouse somewhere in the world and when required being air flown. The logistics efforts and the warehousing efforts over time are huge. However, if an MRO hub like Singapore can produce the parts when required, it removes so much pressure off the supply chain in terms of logistics and cost. Printing farms could be set up all around the world that function as "printing on demand" businesses. Even if the AM component can serve as a short-term fix before the original part is delivered it would make complete sense to switch.

The potential for AM in tooling has not been lost of the big logistics providers. Deutsche Bahn (DB),the German rail operator, uses AM technology for more than 100 different components on its ICE trains. Applications include anything from headrests, fan propellers, various enclosures, and small components that make a big impact, such as spare parts for coffee machines and coat hooks for ICE trains. Global rail and transit manufacturer Wabtec became one the first customers for the H2 binder jet metal 3D printer from GE Additive. The US company plans to use the 3D printer to manufacture large, complex parts for the transportation industry.

For Oerlikon, early success within the tooling materials market has come within the plastic injection molding industry, a relatively low margin business where the impact around cutting operational downtime is exponential compared to the cost. Oerlikon also has a partnership in place with Lufthansa Technik

AM SLS Alstom filler hatch

(the maintenance, repair and overhaul division of the German airline), which operates a service for Lufthansa and other airlines to quickly offer and replace spare parts. The partnership has resulted in the set up of three identical 3D printers to produce a representative component in three separate locations: Oerlikon AM Charlotte (North Carolina, US), Oerlikon AM Barleben (Germany), and Lufthansa Technik in Hamburg (Germany). The idea behind this "triple test" is to dig down into the parameters that influence the performance of an AM-produced part and to establish methods and standards that deliver the certainty required when it comes to a part's performance. A particular focus, meanwhile, is highly stressed engine components, where Lufthansa Technik is aiming to use 3D printing in metals – and more specifically, nickel-based alloys. Advances will include the use of powder-bed fusion technology to replace lost material on a damaged part, such as an engine blade.

When it comes to tooling, AM will have a major part to play in the future. ■

Kartik Rao, Oerlikon, Head of AM Marketing and AM Materials Business line:

"I see a lot of potential in the tooling industry where you are creating tools for industrial plants and need very customized machinery. Tooling is one of the biggest horizontals in the world, as it services every industry from aerospace, to medical, to power generation. If a tool goes down they need to replace it very quickly as every hour there could be a thousand parts that they are not making. This is where AM can help."

Further industries

But potential applications for AM may only be limited by our imagination. There is well documented potential in power technology and construction, but even confectionery and beer production have seen some activity for AM, as the examples below illustrate.

Power technology: Power technology is an emerging application area for AM. Here the global market volume for power plant and grid technology is valued to be worth around €1 trillion (source: Siemens). Even if AM could gain just 0.5% of the volume, that would be a €5 billion market. Within this field, Siemens has already demonstrated their burner tip application in an E.ON power plant. The company is also working on developing lattices that better manage the heat going into their gas turbines. Several IGT companies have adopted real life parts in the combustion section in operations and shifted their production from traditional manufacturing like precision casting and machining towards AM.

The oil and gas industry is increasingly applying AM in up-stream and mid-stream applications, where it can either enhance the drilling process, improve gas/oil exploration or benefit gas transportation. At the recent K 2019 show in Düsseldorf, Oerlikon Barmag presented gear metering pump and extruder pump components created through AM, which permits the unrestricted creation of completely new designs for heating channels.

A more forward looking development, comes from Technical University of Munich (TUM) researchers, who are eyeing potential in sheet material laminated manufacturing based on materials such as copper for self-healing structures. This work could have potential applications in nuclear power plants. In this case the first wall of the material would be exposed to the high plasma that causes neutron radiation and potentially structure damage. But when designed in a certain form through AM, the structure could heal itself and require less long-term replacement.

Space exploration: Space exploration is another booming industry for AM, with lots of reusable and low cost launch vehicles already exploiting the technology to bring weight and subsequent costs down. Because the amount of parts required is so low, due to the rarity of launches, the value becomes immediately accessible for AM. Work in this area may also lead to applications back on Earth. For example, LENA Space has developed key propulsion hardware for space exploration, initially focusing on the development of a turbopump for a rocket. Their technology is also expected to have spin-off uses in energy, environment and transportation applications on Earth. LENA is also considering two potential proof-of-concept terrestrial applications: improved pumping performance on existing firefighting trucks and lightweight high-performance pumps for flood control.

AM powergen coated turbine blade

Consumer goods: Within the consumer sector, customization in glasses is an obvious application area for AM, as these are high-value items that are adapted to the individual. And what about customization in sports gear to the individual athlete or weekend warrior? Adidas recently presented its first polymer soles fabricated by means of 3D printing, with a custom sports shoe adapted perfectly to the foot of any athlete. In addition, Ridell, a manufacturer of helmets for American football players, is now working with this 3D process for padding.

Food & beverage: More out-of-the-box areas for AM include the food industry, where some players have dabbled in creating personalized confectionery products through 3D printing. But the technology's potential in food goes far beyond marketing. This industry is increasingly having to look into food safety, hygiene and efficiency, which is where AM technology can play a role. One of the most surprising recent adoptions of AM came when GE Additive announced that it is working with brewing equipment manufacturer Kaspar Schulz GmbH to identify AM applications in the beverage industry. The partners succeeded in replacing the racking arm component inside a Lauter Tun vessel which separates wort from solids, so that they could improve the filtration effect of the spent grain bed inside the vessel. A thinner blade with internal channels made through AM loosens the spent grains and distributes water throughout the bed evenly during rotation.

Finally, the customization potential of AM means that virtually anything is possible. For example, German rail operator Deutsche Bahn has been exploring the use of AM in the creation of more than 1,000 individual handrail signs. Each one contains text in German and braille.

There are so many future opportunities for AM. We just have to think outside of the conventional box to see where the tailored advantage lies. ■

Todd Skare, Chief Technology Officer, Linde:

"When solar started, it was far too expensive as well. But when enough subsidies go in and technology improves it got to parity when compared to conventional energy sources. I believe that AM is on the same path and I see productivity as something that's positive."

GE Additive is working with brewing equipment manufacturer Kaspar Schulz GmbH. The partners succeeded in replacing the racking arm component inside a Lauter Tun vessel which separates wort from solids.

Materials development

Materials are critical building blocks for successfully printing a product. With AM, the importance of metal powder is growing dramatically. The development of new alloys, in particular, increases the possibilities that AM has through design freedom. Partnerships will be key to making progress in scaling up production volumes and reducing costs, with material development following too. This is where Oerlikon comes in, a true innovator within this space. As a manufacturer of metal powders based on nickel, steel, cobalt and titanium, Oerlikon conducts research at its locations in the US and Europe, among other things with a prototyping center, but also through partnerships on new materials.

For example, Oerlikon recently entered into an AM research partnership with Linde, a leading industrial gases and engineering company, and the Technical University of Munich (TUM). The partners aim to develop a new high-strength, lightweight aluminum-based alloy that can serve the efficiency needs of the aerospace and automotive industries.

Gases specialist Linde is also high on the innovation trail in both pre- and post-production. The gas molecules developed by Linde play a crucial role along the entire AM value chain, influencing the quality of the powder and the end product and contributing to increased productivity.

"The Linde goal is to make the world more productive and that fits right into the whole value chain of AM, where gases are used from pre- to post-production," says Todd Skare, Chief Technology Officer, at the company. "There are many opportunities for productivity enhancement across the value chain. We look for different gases, whether inert or active gases, to help in all of these different phases of the process, in order to make AM really go forward," he adds.

An interesting area of development within AM that TUM is looking at is the field of graded structures, where the manufacturer begins with one material and ends with another. This approach means that you could have different properties (e.g. strength or flexibility) in different parts of the material component, which is something that cannot easily be achieved through conventional technologies. Engineering for the construction industry is just one area that could greatly benefit from this development.

Looking forward, there are so many avenues that need to be explored within the materials segment, but alloys will be key, for both lightweighting and performance. At MTC3, a poll asked which material should most urgently be AM ready in the next 2-3 years. In running order the responses were as follows:

- High temperature super alloys (25%)
- High strength aluminum (22%)
- New tool steels (16%)
- Copper alloys (10%)
- New titanium alloys (10%)

It will be this type of R&D that will take the AM materials segment forward. ■

AM metal powders

AM R&D quality testing

Digital manufacturing

Digitalization in AM not only involves creating the 3D printed parts. It is about having software, hardware and chemistry elements working together in tandem, so that functionality, new shapes & forms and groundbreaking designs can be generated.

With both hardware and software development so key to the future of AM, the work of suppliers such as Siemens is critical to the sector's evolution. The company supports more than half of the companies already operating within this space, including machine builders and OEMs who are looking to increase their production capabilities.

A major topic of discussion in engineering right now revolves around the role for artificial intelligence (AI) in product design. Here too there are obvious correlations between AM and AI. Siemens has already been employing a program based on AI and alternative design. For example, an AI created design was possible that was much smaller, had a far more efficient cooling structure and where manufacturing complexity could be reduced by 90 percent.

But this is just one example. Siemens generative design algorithms could define certain points where a screw needs to go in, for example. When you have a conventional design you could trigger generative design technology and then connect to the form that is required and let it optimize itself.

This type of generative design work is enabling engineers to define the problem space, the objectives and parameter constraints and then let the computer do the hard work in determining the ideal geometry for a part that achieves those dimensions. This is about adopting a multi-physics approach, that involves reduced weight, but also improved thermal properties, flow and structure.

This type of development does not mean that design engineers will become redundant in the future. It will simply make them more productive in what they are doing and offer more opportunity for creativity which can thus be geometrically optimized through AI.

Industry is digitalizing as a whole and AM will have a major role to play in this, as synergies emerge with high-tech fields such as AI. ■

Norms and standards

A young technology like AM needs a common framework for widespread industrialization to take place. General global standards are certainly required around powder quality and machine certifications, particularly in terms of security, safety and interoperability. This is why the AM sector is working hard to ensure that safety performance and security are optimized, while also keeping a careful eye that regulations do not become overly restrictive and hamper innovation.

With this background it is very encouraging that the different regulatory bodies around the world, have started to cooperate, including ASTM (American Society for Testing and Materials) and ISO (International Organization for Standardization). Several global standards are currently being drafted, with a workchair being put in place between the regulators.

In a way they are acknowledging that they need to prioritize an update on existing standards to envelope AM or come up with new ones entirely.

The latter is a major concern, particularly for security reasons. For example, if you want to transmit a digital file for a medical device to a manufacturer, how do you ensure that it is not being hacked and tampered with? If you have erroneous file degradation or even a hostile attack, the health of a patient could be compromised.

Progress is already being reported. For example, within the automotive sector there is now a TISAX (Trusted Information Security Assessment Exchange) standard on data protection. Once you get someone's digital file, you can ensure that you do not tamper with it and return it within the legal requirements.

TÜV SÜD is currently working with the Singaporean authorities on an Additive Manufacturing Readiness Scoring system. This framework is aimed at the qualification and the processes of powder machines to come up with a powdered score. The objective is to map that score against the requirements of the different industries.

TÜV SÜD and German rail operator Deutsche Bahn recently pooled their expertise to develop a certification scheme for the suppliers of spare parts and finished components produced by AM. The scheme ensures consistent and reproducible product quality throughout the process chain. Two companies – Siemens Mobility and MBFZ toolcraft – have already been certified according to this new guideline.

It is still early days for AM, which is why regulators are still far behind the technology itself when it comes to norms and standards. Progress in this field will be key to the technology's step towards broader mainstreaming. ■

Holger Lindner, Chief Executive Officer, TÜV SÜD:

"It is promising that regulators acknowledge that standardization around AM will not work in a pure top down approach. They will need to engage the producers, manufacturers, operators and companies like TÜV SÜD who are both present on the part of regulators but also on different verticals with the different partners to sound them out on pain points and see where fixes can be made."

The 3D-Printing Cluster is a network promoting start-ups and initiating collaborations in the AM field.

Prof. Dr. Michael Suess, Chairman of the Board of Directors, Oerlikon opens the MTC3 in Munich.

Sustainability

If there is one sole reason to be bullish on the outlook for AM technologies it is the growing demand for more sustainable solutions that help to cut carbon emissions and offset climate change.

While in the past, sustainability was a CSR report issue that was nice to have, today it is becoming a license to operate. For example, governments are effectively forcing the automotive industry to reduce its carbon footprint and the German automotive sector is now pushing for sustainability standards as a prerequisite to participate in tenders.

This policy dynamic is now working its way down the supply chain. For example, now battery manufacturers are having to consider where they can find raw materials, what is the performance cost and when the first lifecycle of a battery is over, how can it be recycled into another form?

But all aspects of the manufacturing sector are having to look further ahead. Imagine if a stricter version of the Paris Climate Change agreement were to come into force and set carbon emissions rates right down through the supply chain. The big OEMs would be forced to push compliance targets right down their supply chain, otherwise carbon neutral goals could never be met. If a manufacturer is not already considering how to address this issue, it could be at a major disadvantage for them 5 years further down the line. The fact that standard parts delivered through high energy consumption and long transportation supply chains adds to $C0_2$ emissions output, makes the business case for AM much stronger. Today, thousands of tons of semi-finished parts are transported around the world to be processed elsewhere each day. With AM, supply chains can be optimized and printing done on demand.

For Andreas Behrendt, Partner at McKinsey & Company there are two further key trends in sustainability that are presenting a major opportunity for AM:

1. **Lightweighting:** Whether it is an aircraft or car, everything needs to be lighter to cut energy consumption. Since AM makes it possible to create lighter parts with more intelligent structures that have the same robustness and stiffness, using it makes sense. The different angle here is that if you want to produce emission free, you will need to limit parts tourism as much as possible. Producing at the point of use is a real advantage here too.

2. **Electrification:** Whether it is about computers, phones, or cars, the amount of heat being generated by an electric motor, battery or CPU, needs to be cut or removed altogether. This is where AM designed parts can yield much more value and better features. The optimized designs can simply not be created through traditional CNC (Computer Numerical Control) milling.

The AM industry is currently considering what's needed to further demonstrate the drop in energy usage, the resources saved if you would have an integrated part as opposed to a single one and the savings in materials through adopting a structurally optimized format. Some standardization will be required in how the sustainability element is assessed, so that credibility will be maintained. But AM will thrive once that aspect of sustainability starts to be truly quantified.

Sustainability and carbon emission reduction is undoubtedly one of the biggest advantages for AM going forward. ■

AM general industry robot arm

AM SLS Alstom filler hatch

AM metal powders

How to take AM mainstream

It's clear from the examples in this white paper that there are many reasons to be bullish about the future for AM. Previously, the aerospace and healthcare segments were the most advanced when it came to initial AM interest, but even in those industries there were many companies who were yet to practically implement it. This has changed and all the major players have AM development in their pipeline. In the last 2 years, we have seen strong innovation in the automotive industry and other heavy industries too.

There are two basic pillars that the AM industry needs to consider to take AM into the mainstream. On the one hand, it is about managing to create both volume and a market. On the other, it needs to further develop the main areas of AM. So progress in both market and technology needs to be made.

The opportunities for AM are real but any company looking at this area needs to be realistic too and find the sweet spot. The consensus is that AM will function as a complementary processing technology rather than a replacement in many areas, where the basics will continue to be done through conventional means. AM is probably not a good technology for 80-90 percent of their applications, but there will be some applications within every sector where AM will help companies to save money and exponentially benefit their business. For example, if you are a major car producer, you could have a production run of 8 million cars a year. AM will only make sense here in the customized parts of the vehicle or in prototyping. But when it does fit, it can prove to be a very valuable addition indeed.

In terms of costs, printing an AM part is more expensive today than it would be when created through conventional means. But it is about assessing the benefits as a whole, rather than weighing things up dollar for dollar. For example, in the spare parts business, you need to look at the total cost of ownership, including warehousing and logistics, as well as the cost of a machine not running while you are awaiting a delivery. The real 90 percent of the advantage of AM kicks in when it is used to create structures and shapes that cannot be produced through any other method. If you have 2-3 critical components that can save your business millions of dollars and replace really expensive tooling or long waiting times, AM use could be very valuable. For another company it could be the customization advantage of AM, where small and highly complex production runs are required.

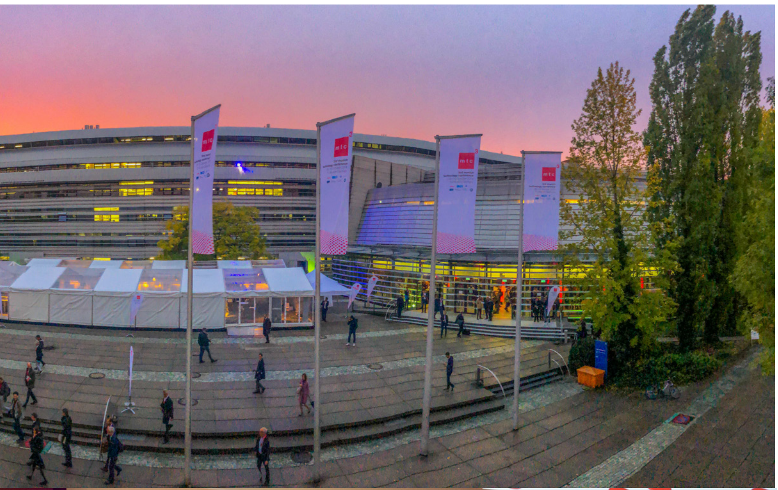
There are also regional opportunities for growth in new markets. Oerlikon, for example, has identified China as a core target market for expansion and recently opened a new facility in Shanghai in AM. This is both because of the industrial backbone of China but also because of China's domestic demand. After all, the country has a budding aerospace industry, huge demand for power generation and a major automotive industry.

One key point to remember that all partners stressed at MTC3 was how young this technology still is compared to other processing techniques. If you think about it, even laser welding technologies have only been around for 30-40 years. So it is unfair to make cost and development comparisons with AM, which is still less than 10 years old in certain target applications. For example, when you look at the application of industry robots and compare the evolution from CNC machines to AM, it also took 40-50 years to get this huge growth trajectory where costs came down and performance was higher and more accurate. McKinsey note the example of conventional robots for manufacturing, which only started to enjoy a truly super steep curve of adoption from 2010, once prices dropped dramatically and the sensors and accuracy of the robots themselves improved.

Todd Skare, Chief Technology Officer at Linde compares the advance in productivity and reduced cost in AM with other industries such as solar. "When solar started, it was far too expensive as well. But when enough subsidies go in and technology improves it got to parity when compared to conventional energy sources. I believe that AM is on the same path and I see productivity as something that's positive," he notes.

Chris Schuppe, General Manager Engineering, GE Additive, goes even further back in history in his assessment of the opportunity that AM presents. "Casting was invented in 1000BC in China and has been growing ever since. AM has only been invented 20-30 years ago. The hype is over and the reality is now in taking it into production. The question is how to continue that," he concludes.

In the year in which we celebrate the 50th anniversary of the moon landing, the small steps being made in AM today could have giant implications in the manufacturing of the future across the board. ■



Panelists at the Munich Technology Conference, October 9, 2019

About MTC

3rd Munich Technology Conference
October 8-10, 2019
Technical University of Munich, Germany

The Munich Technology Conference (MTC) is an annual meeting of experts and thought leaders from industry, academia, government and the scientific community that addresses today's burning technological challenges in one of Europe's most innovative cities. Initiated by the Swiss headquartered international technology Group, Oerlikon, and co-hosted by the Technical University of Munich (TUM) and the Bavarian Ministry of Economic Affairs, Energy and Technology (StMWi), the first MTC took place in 2017. The conference has grown to include some 40 speakers and attracted more than 1,500 advanced manufacturing professionals. Partners of the 2019 event are: Oerlikon, Technical University of Munich, GE Additive, Linde, McKinsey & Company, Siemens and TÜV SÜD.

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