Issue 7 | 2023/Q1

AM CHRONICLE

3D Printing Voice of the Region

Asia Pacific | India | Middle East | Africa

FEATURE ARTICLE

AMUG Brings together the global additive manufacturing stakeholders

Metal AM in Oil and Gas

Shell successfully installs the first 3D printed Leak Repair Clamp

AM Insights

Innovation in post processing of AM Implants

AM Standards and Certification

ASTM Standards for classification of AM Parts

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EDITORIAL

Emerging Markets will Drive Advanced Manufacturing!

India is emerging as a bright spot in the global economy currently with its population, pent-up growth, world power, democratic credentials, skilled workforce, among others. The International Monetary Fund believes the emerging markets and developing economies are expected to account for around 80 per cent of the global growth this year and the next.

Many of the new business ideas are emerging from India and the other emerging markets in the Middle East and APAC utilising advanced manufacturing technologies including Additive Manufacturing. We are firmly of the opinion that this will make India, MEA and APAC an exciting prospect for all the Additive Manufacturing stakeholders in the years to come.

At AM Chronicle this year we are mirroring this global sentiment by continuing our regional connect approach between India, MEA and APAC and also an outward global push this year with presence in Europe and North America. For a first AM Chronicle will be the Media Sponsor at AMUG and will also be represented at the DDMC conference organised by Fraunhofer. Backed by our expertise in organising Additive Manufacturing forums in India since 2015 we will be expanding our knowledge sharing and business forum to Middle East with the Additive Manufacturing Conclave Middle East in Abu Dhabi in September 2023.

Our feature article in this issue is focused on the Additive Manufacturing User Group conference to be held in Chicago in March. The issue also covers topics ranging from Application of Metal AM in Oil and Gas Industry, Role of AM Technology in Drone Technology, 3D Printing for Prosthetics, AM Basics and more.

We look forward to playing our role of unlocking the true potential of Additive Manufacturing in this region.

Aditya Chandavarkar
Co-Founder - AM Chronicle

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Metal Additive Manufacturing Symposium 2023

Bridging the Indian and Global Metal Additive Manufacturing Industry

25-26 May 2023
Taj Yeshwantpur, Bengaluru

The Metal Additive Manufacturing Symposium (MAMS) in its second edition is a user focussed technical conference mapping the latest developments and trends in the world of Metal Additive Manufacturing.

The conference will be supported by a table top exhibition and research poster presentations to enhance the interaction and networking.

Event Highlights

- High Quality Technical Presentations from Practitioners
- Networking with Leading Industry Experts
- Find Solutions for your Metal Additive Manufacturing Needs
- Curated Poster Presentations from Leading Research Institutes

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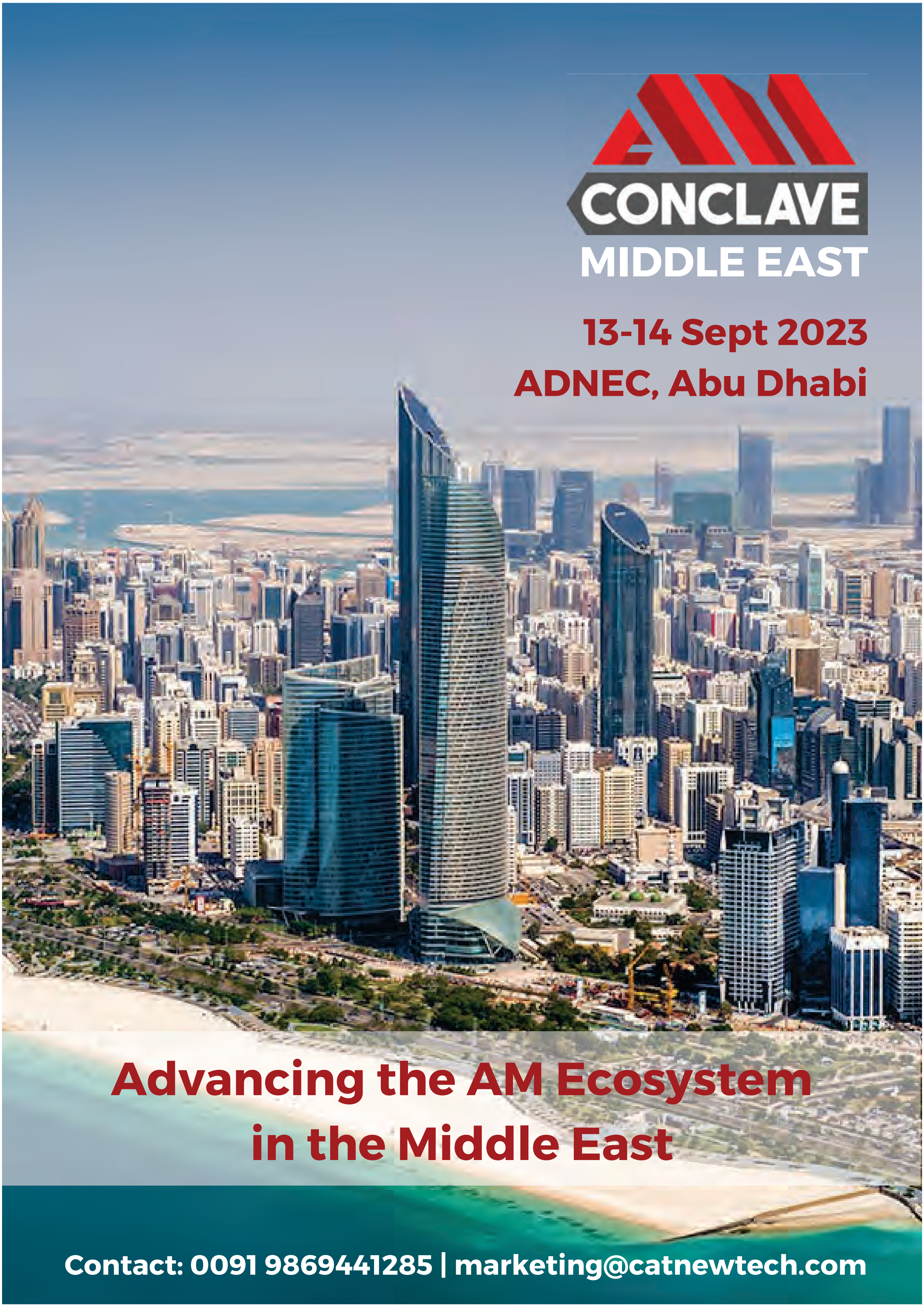
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AMUG Conference to bring together the Global Additive Manufacturing Stakeholders

Aditya Chandavarkar and Chinmay Saraf

Key events and happenings at AMUG 2023

The Additive Manufacturing domain has seen encouraging growth in various application industries. New companies have evolved, and a vast amount of investment from governments worldwide has added new opportunities. An essential aspect that has helped the Additive Manufacturing community grow is networking and knowledge sharing through various forums and events. The additive manufacturing user group (AMUG) 2023 conference is a gold standard in this aspect which allows the AM community to come together and share experiences.

The AMUG 2023 conference is scheduled for March 19-23, 2023, at Hilton Chicago, Illinois, USA. The event is divided into two key parts, the "AMUG Conference," scheduled on March 19-23, 2023, and "The AMUG expo," scheduled on March 19-20, 2023. The AMUG event is a must-attend as it is dedicated exclusively to additive manufacturing users. Stakeholders from the additive manufacturing community worldwide participate in AMUG as it offers excellent networking and knowledge-building opportunity.

One of the key USPs of AMUG 2023 is that it offers a unique opportunity for the international AM community to network through various events. AMUG also provides rich industry-relevant knowledge to the delegates through the conference. This year the AMUG Conference has well over 100 presentations and hands-on sessions, plus great keynotes, the Innovators

Showcase, and Training Sessions. 1865 attendants from over 21 countries attended the last AMUG conference, and this year, the AMUG organizing committee is confident that a higher number of delegates will attend the event.

"At least from my perspective, I would have thrown away every other conference I've ever attended. In lieu of making sure that I was at this one. This one to me is the standard of how to bring an industry together and have a conversation where no prejudice or no preconceived plan really can take foothold. " – Mike Gordan, The Capitol Group

Pre-conference activities are also arranged, that includes an ASTM certificate course on "Establishing an Additive Manufacturing Facility for Critical Part Production on Saturday, March 18 (9:00 AM – 5:00 PM) and Sunday, March 19 (9:00 AM – 3:00 PM). In addition to this there are Off-Site Tours planned to DMG MORI and Impossible Objects on March 19, 2023.

"My advice for people who are going to the AMUG Conference for the first time is…to stay hydrated. You'll be talking to so many people, be on your feet, you'll be engaged and listening and learning. And it's really important that you take care of your body so that you're getting the most out of it." – Kat Ermant, Peloton

The first keynote session will be delivered by Rob Ducey, LAIKA Studios, and Nicholas Jacobson, CU Anschutz Medical Campus, on March 21 from 8:00 AM – 9:00 AM. The topic of their presentation will is "Collaborations Between an Animator, an Architect, and a Surgeon: The Keys to Impactful Innovation in Medicine," which demonstrates the interdisciplinary application of additive manufacturing. The second keynote speaker session is organized on March 23 from 8:00 AM – 9:00 AM and will be delivered by Max Haot, Launcher. The topic of Max Haot is "High-Performance, Low-Cost Liquid Propulsion Enabled by AM," discussing the application of additive manufacturing in space.

My advice to future first-time attendees would be to NETWORK. If you see somebody that you recognize from LinkedIn, go say hi. If you use somebody from a company that interests you, go introduce yourself. The beauty of the AMUG Conference is that we're really all here to learn, to share our experiences, and to gain something from one another. And it should not be intimidating, we are all here for a common goal, and I hope that all future first-time attendees really make the effort to network and make new connections in the industry. – Laura Turnage, LOCTITE 3D Printing

During the AMUG 2023, scholarship awards are organized for the student community. The winner of the AMUG scholarship receives full-ride access, room and board, travel, and registration to ThE event. Students in manufacturing, engineering, design, art, medical, or a related field of more than 21 years are eligible for the scholarship.

Another staple of AMUG is the technical competition which has two themes – "Advanced Concepts" and "Advance Finishing." The award for the advanced concept is focused on using unique applications, processes, and utilization of additive manufacturing technology. The prize for advanced finishing is focussed on different finishing techniques, quality of finish and model development.

2022 Winner for Advanced Finishing – Bill Braune, Dinsmore, Inc.

So all in all, AMUG is the complete package when it comes to creating a vibrant and conducive environment for the Additive Manufacturing users to network, interact, learn and forge the industry forward !

ABOUT THE AUTHOR

Aditya Chandavarkar

Co-founder - AM Chronicle

Aditya Chandavarkar is a established entrepreneur with business interests in manufacturing, innovative technology, training and consulting. Among other activities he the Co-Founder of Indian 3D Printing Network and is a subject matter expert on 3D Printing/Additive Manufacturing with good grasp of Additive Manufacturing trends in the Region including India, APAC, Middleeast and Africa.

ABOUT THE AUTHOR

Chinmay Saraf

Technical Writer, AM Chronicle

Chinmay Saraf is a scientific writer living in Indore, India. His academic background is in mechanical engineering, and he has substantial experience in fused deposition-based additive manufacturing. Chinmay possesses an M.Tech. in computer-aided design and computer-aided manufacturing and is enthusiastic about 3D printing, product development, material science, and sustainability. He also has a deep interest in "Frugal Designs" to improve the present technical systems.

Shell successfully installs the first 3D printed Leak Repair Clamp

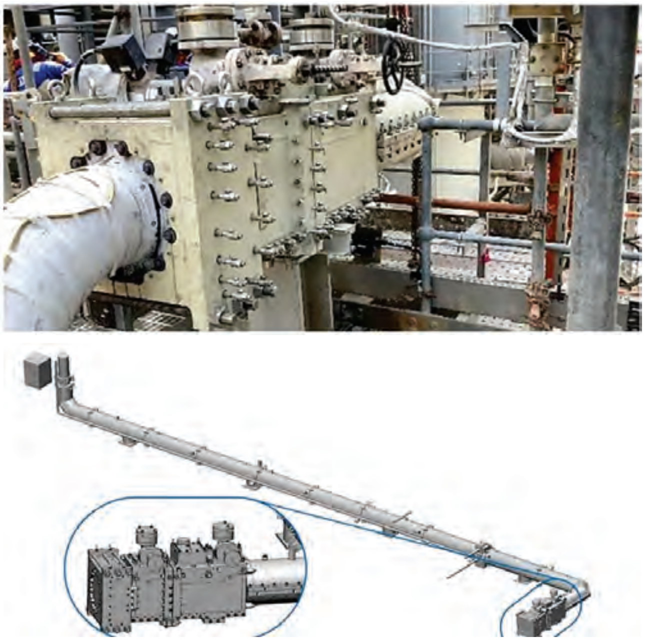
Angeline Goh

Successful installation of the first 3D printed leak repair clamp in service by Shell

3D printed clamp installed at a Shell site

Shell has successfully installed the first 3D printed leak repair clamp in service. Clamps, also known as mechanical leak repair enclosures, are engineered solutions that are used to encapsulate and restore integrity of operating pipelines against pipeline defects or wall thinning arising through erosion and corrosion mechanisms.

At present, a simple clamp can be manufactured within 3-5 days, but complex clamps may take 4 weeks or more, when factoring in delivery times from limited fabricators specialised in pressure enclosures. The ability to apply such temporary repairs is critical to enable facilities to remain on-stream. The availability of essential equipment can be maximised, thereby reducing production loss and environmental emissions. Defects can occur in diverse locations given the complexity of piping systems, often triggering the need for dedicated, customised solutions. The speed of response to restore the mechanical integrity and continuous safe operation of the asset is critical.



3D printing is an additive manufacturing technology in which the material is built up through a layer by layer deposition process. This technique is claimed to have an edge over other conventional manufacturing techniques such as casting or forging due to its ability to manufacture parts with intricate geometries. 3D printing offers the ability to produce the near net shape of the desired component, limiting the need for high material wastage during the machining process typical of current manufacturing practices.

Finally, 3D printing is transferable across product designs, as the manufacturing process only requires the use of computer-aided design of the product, and programming of the build (deposition) robot. In case of conventional techniques for large items, preparing bespoke tooling such as moulds and dies normally involves a greater lead time and costs.

Due to its merit, 3D printing technology was chosen for the fabrication of selected clamps for use in our operations. A proof of concept (POC) was executed collaboratively by Shell, TEAM, Inc. and Vallourec. Together, the team established a technical specification and inspection test plan for the first clamp with an industrial application to be produced completely with a Wire Arc Additive Manufactured (WAAM) technique. The goal was to verify the feasibility of using a WAAM technique to produce clamps for leak repair which will meet the required quality assurance for medium-pressure steam systems. The proof of concept helped gather insights into the steps needed to improve the quality and productivity for future applications.

Drawing of a 3D printed clamp

What did we learn?

- The 3D printed clamp successfully passed the burst test conducted at 142.4 bar (over 5 times that of the intended design pressure). This satisfies the appropriate level of technical readiness within Shell to qualify the part for a field application.

- In this case, the overall delivery lead time was longer than for a conventionally manufactured clamp as it was the first product. This is because it falls under the highest criticality category under the DNV B203 standard for Additive manufacturing of metallic parts*. Three sets of clamps were produced for extensive testing even though only one set was eventually installed. As it was a first of its kind demonstration project, the team focussed more on designing the clamp for a 100% success rate in inspection rather than on design optimisation. This increased lead time and costs was a design choice for the POC.

- The project involved shipment of the parts for printing and testing at different locations and countries, which contributed to the increased lead time and costs. This speaks in favour of our vision of integrated additive manufacturing ecosystems nearby operations.

- The different steps involved in procurement process as well as quality assurance and quality control account for more than 50% of the time required for the POC.

What is coming next?

The next phase will focus on ensuring the product quality and consistency, as well as reducing the lead time and costs for the additive manufacturing of selected clamps by streamlining the qualification process and reducing the need for duplicable parts. It is intended that the future projects will enable the following:

- the formation of a database with all inspection and qualification test results reflecting the quality variance in WAAM parts. Analysing this data can help reduce the criticality classification of the 3D printed spare parts or the among of non-destructive testing required prior to using the parts in production.

- the development of application specific qualification requirements, allowing more complex parts to be qualified based on case history and successful in-service use cases of simpler parts; and

- the creation a library of qualified configurations to reduce qualification efforts of same or similar products in future.

Collaboration is key to reduce lead time and costs

Activities to create extensive data sets about 3D printing spare parts are resource intensive. We achieve greater knowledge faster by collaborating with interested end users who have similar needs. Process standardisation of WAAM technology, specifically in quality control, is paramount to improve lead time and reduce costs. Shell believes that a great leap for the adoption of 3D printing technology in the energy sector can come from such a standardisation across the industry.

ABOUT THE AUTHOR

Angeline Goh

Digital Manager Supply Chain at Shell

Experienced Supply Chain Professional with a penchant for technology and a demonstrated history of implementing supply chain process optimization and organizational transformation to achieve improvement in business results. Demonstrated leadership capability to lead and coach direct as well as virtual teams for high performance. Highly analytical and a quick learner who has worked in both commercial and technical roles in Asia, Europe and America and fluent in 4 languages.

https://www.shell.com/3d-printing

Additive manufacturing is helping accelerate the drone revolution

Bralco Advanced Materials

Additive Manufacturing is one of the Industry 4.0 innovations that will accelerate the drone revolution.

Unmanned aerial vehicles (UAVs) and Urban Air Mobility (UAMs) such as drones and eVTOLs used for recreational, industrial and mobility purposes are a classic examples of how we can use technology to enrich our lives and solve many problems which were hitherto left unresolved or required taking on huge risks to solve them. Drones are used to survey areas which were thus far inaccessible, hazardous, needed aerial viewpoint, last mile cargo delivery, weather monitoring, delivering emergency medical supplies, agriculture seeding, search & rescue operations, disaster relief and the use cases are growing by the day. UAMs are used to carry passengers in over congested cities as air taxis. Drone application is not restricted to the military; during the past decade, it has increased significantly in both the commercial and mobility sectors. Drones will be a significant component of the 21st century economy due to their cutting edge capabilities and life cycle low cost of manufacturing and operations compared to the traditional methods.

3D printing or Additive Manufacturing is one of the Industry 4.0 innovations that will accelerate the drone revolution. The advancement of 3D printing technology makes it feasible to build necessary parts quickly, accurately, and economically for these UAVs. The benefits are advancing UAV technology for unheard of applications. In the aerospace and defence sectors, 3D printing has already been shown to be incredibly beneficial. Seven out of ten decision-makers in Jabil's Aerospace and Defence Manufacturing Trends survey claimed that 3D printing had already altered their thinking and function.

Image in Sculpteo

When it comes to the production of drones, 3D printers serve as a “must have” technology. Several design limitations are being solved by this technique thereby unleashing the full creativity of the drone designers to come up with the most advanced solutions. The advantage of using additive manufacturing to develop drones is that almost every part of the assembly can be 3D printed, except for the electronic components. In addition to the main elements, many other accessories such as boosters, mounts, coverings and cases for properly storing the drones, can also be created.

With regard to creating these UAVs, 3D printing has several benefits.

Light Weight Components

One of the main difficulties in UAV design and manufacturing is achieving an aerodynamic, minimal operational weight. A careful balance between weight and power is necessary for drones. They are battery-operated and require more power while hauling payloads. They need higher battery power to achieve desired distance, speed and altitude. However, larger batteries add weight. Therefore, other than electronic components, all structural components should be light weighted to compensate.

One of the versatile materials that can be 3D printed is Carbon Fiber Reinforced polymer (CFRP) aka carbon fiber composites (CFRC). CFRC by 3D printing is one of the methods that allows obtaining materials with high mechanical parameters at low density. Different types of carbon fibers viz. chopped and continuous can be incorporated into the component through 3D printing. For lightweight UAVs, composites provide various benefits. The density of carbon fiber, which is about 2 g/cm3, makes it naturally lightweight. Aluminum weighs 2.7 g/cm3, and titanium weighs 4.5 g/cm3. The matrix material for carbon fiber composites, which is often a thermoplastic substance, has a density of between 1 and 1.3 g/cm3 and encases the carbon fiber. Since carbon composites typically consist of 20% to 50% of carbon fiber, their combined density ranges from 1.2 to 1.5 g/cm3.

For example, a UAV frame 3D printed with continuous carbon fiber weighs 75g as compared to existing metal frames which weigh in the range of 130g to 230g with similar dimensions. And still, this 3D-printed frame can operate with a payload of up to 294 N. Apart from this, the whole frame can be fabricated as a single part which reduces the weight by eliminating the connecting hardware. Also, through Design for Additive Manufacturing (DfAM), the weight of the frame can be further reduced by optimizing the material usage.

Complex Design Fabrication and Fiber Arrangement

Another major drawback of conventional layup composite manufacturing is design and assembly. The structure can become weaker when holes are drilled for fasteners to connect components, which might result in a large weight increase. Also, some complex structures cannot be made in a single piece using these traditional technologies. Using 3D printing, not only whole structure can be made in a single piece, but also it can print the complex geometry components that traditionally would require complex attachments. With the freedom of design from 3D printing, mechanisms and structures are now possible that were not possible previously to manufacture with conventional techniques.

In the CFRP components, usually, the load is carried out by the fiber (from 70-90% of the load), while rigidity & shape are provided by the matrix, which transfers the load to the fibers. However, one of the most important characteristics to take into consideration when working with composites is that their mechanical properties, such as strength, usually depend upon the direction of the applied load. However, this particular drawback can be eliminated using the 3D printing technique, fibers can be added in a particular direction and particular area as per the loading condition. So, fibers can be applied in that portion only where higher loading is expected, thus minimizing the fiber content, which ultimately helps from a cost point of view as well as weight consideration.

Materials for 3D printing drone components

The choice of material used for 3D printing also plays an essential role in making the parts lightweight and yet have good mechanical, thermal and electrical properties. Drone manufacturers need to look into new material possibilities as drone use continues to increase. For instance, drones can be used in chimneys for inspection; firefighters may monitor and aid in the containment of wildfires using UAVs. However, in these cases, the material for the drone should be heat, smoke and chemical resistant. Specially engineered composite materials can be used in such types of applications.

Various thermoplastic polymers can be used to make drone components using 3D printing viz. ABS, Nylon, TPU etc. ABS is a robust and durable material that is used to make protective covers for drones. ABS has a density of 1.05 g/cm3 with 40 MPa tensile strength. Nylon is a strong and lightweight material that is used to make drone components as it retains its strength despite frequent use. It has a density of 1.12 g/cm3 with 55 MPa tensile strength. TPU (80A-90A shore hardness) is a flexible polymer material used to make special drone components without impacting performance. TPU has a density of 1.16 g/cm3 with 55 MPa tensile strength. However, due to high elongation (more than 500 %), it is ideal for many components where high performance is required. By adding chopped carbon fibers into the polymer matrix, the mechanical properties can be enhanced. Different reinforcement can also be added to the polymer matrix to achieve specific properties like electrical conductivity, thermal properties, flame retardant properties etc. By using continuous carbon fiber into the polymer or polymer with chopped fiber matrix, the part performance is enhanced to a great extent. Carbon fiber has a density of 1.4 g/cm3 with 800 MPa tensile strength. Therefore, by incorporating the continuous carbon fiber into the polymer matrix, the final 3D printed component is as strong as the Aluminium 6061.

On-Demand Manufacturing and Easy Upgradation

Applications for drones in the military are wide-ranging, including intelligence, surveillance, target acquisition and reconnaissance. For drones working in these types of applications, maintenance and availability of spare parts are very important. The rapid adaption and new use cases of drone technology make it essential for manufacturers to deliver spare parts on demand. 3D printing can provide on-demand manufacturing with the shortest lead time. Apart from that, design iterations are very economical with 3D printing compared to traditional manufacturing processes. Parts can be manufactured with an upgraded design and fitted into the existing drones for better performance.

BRALCO's solutions for Drone Manufactures

Bralco has developed a unique combination of very lightweight, high strength, and temperature resistant polymer composite 3D printed products with electrical and magnetic properties. In combination with in-house engineered high speed 3D printers and 3D printing composite filaments, Bralco can deliver a variety of drone components at a low cost, short lead time and with properties that far exceed the currently available materials.

Bralco can provide solutions for different components of drones from the vast variety of materials developed in-house. Bralco provides drone frame, antenna mounts, drone fins, protective drone cases, landing gear, propellers, camera mount and functional parts manufactured from the specially-designed materials as per the requirements. In addition to this, Bralco's composites solutions can improve the UAV's electromagnetic (EMI) performance. These systems need effective and dependable wireless or satellite connectivity with ground stations because they are unmanned. Bralco materials allow for fail safe communication while obstructing unwanted and harmful noise (EMI signals) from the external sources.

Drones are changing the world as we know it. There is no way to predict what the future may bring, but 3D printing technology and composite materials for drones are a game changer. Bralco's materials and 3D printing capabilities are at the forefront of this revolution.

ABOUT THE AUTHOR

Bralco Advanced Materials

Bralco Advanced Materials

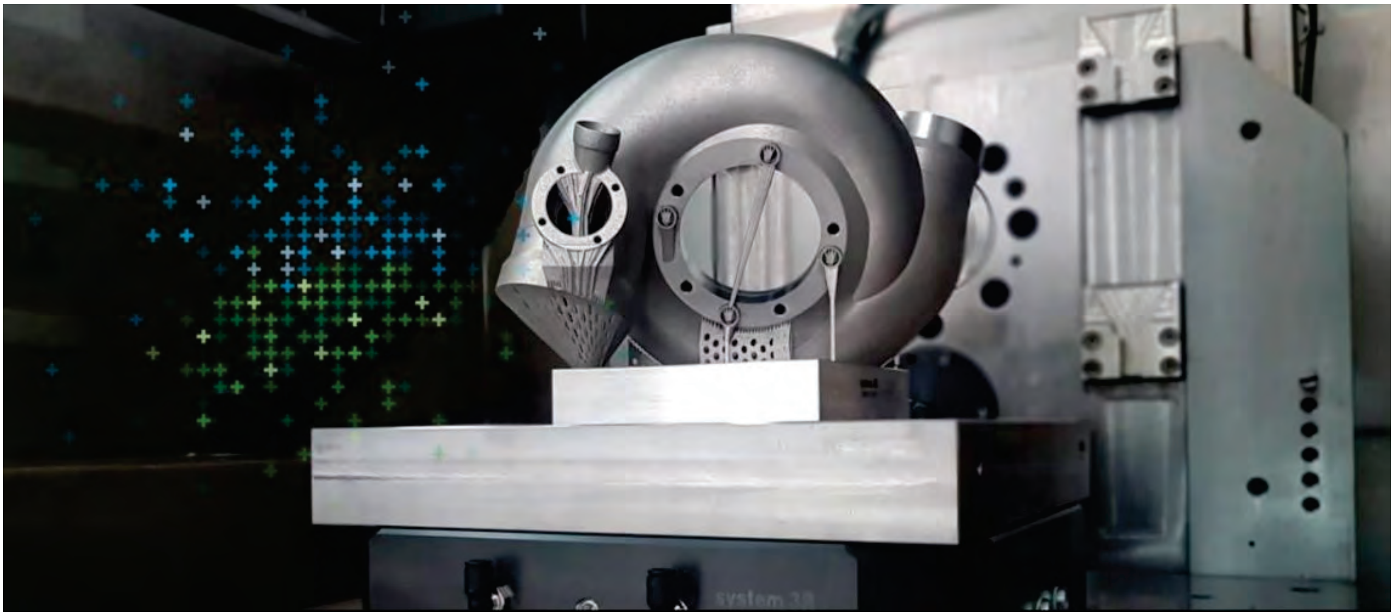
Engineered functional materials on demand

We believe that innovation in functional materials and devices is a key ingredient in building a sustainable future. At Bralco, we design and manufacture cutting-edge engineered functional materials using the flexibility of additive manufacturing and the power of machine learning .

Additive Manufacturing speeds part development for motorsports

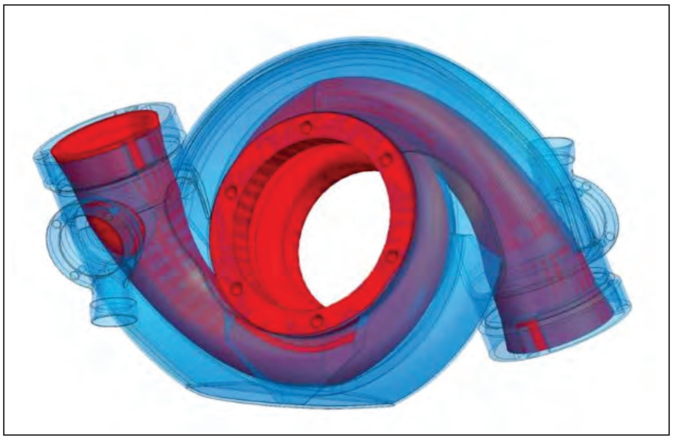
GF Machining Solutions

The article elaborates on the role of additive manufacturing in solving the design and production challenges for the motorsports industry.



At the highest levels of motorsports competition, speed is king, both on the track and behind the scenes. Unlike the maximized production volume and long design cycles of consumer automotive manufacturing, Formula 1 race teams must create and produce complicated parts between races and even overnight. Traditional production cycles and manufacturing processes cannot keep up with the demands of the sport, but Additive Manufacturing (AM) can revolutionize the process.

For Formula 1 teams, AM has become integral to quick but precise production of parts such as turbochargers, replacing time-consuming methods with rapid part-



design and prototyping. The consumer automotive industry uses sand or high-pressure die casting to make these parts, with design steps completed long before production. Motorsports teams cannot afford to wait for suppliers to build mold after mold so they can test and finesse turbocharger functionality. With turnkey AM systems from GF Machining Solutions, race shops can design and produce turbochargers in a single digital workflow.

Turbochargers supply an enriched, compressed mixture of air and fuel into the combustion chamber of an engine, heightening power or torque. On the track, these devices include complex internal features and surfaces that casting struggles to produce – and closed cavities that molds and post processing simply cannot create.

Software, Tooling, Additive and Subtractive Manufacturing

Additive manufacturing excels at these types of tasks and part features. GF Machining Solutions has leveraged its extensive technology portfolio to create a truly end-to-end AM production methodology that saves manufacturers time and money while it revolutionizes their production cycles. This turnkey system draws on software, tooling, additive and subtractive manufacturing, all developed by or with GF Machining Solutions.

A single software environment created with 3DXpert™ and Cimatron handles part design, build and CNC preparation, in-process inspection and part validation. The Cimatron software bundle includes CAD/CAM for part design and milling toolpath development, and works seamlessly with 3DXpert to manage data integrity. It also handles the milling tasks that remove supports for metal AM. 3DXpert tools simplify part programming for metal AM, automatically applying AM-specific structures, geometries and print strategies. Software simulation helps identify and rule out potential problems, including stress accumulation or elevated displacement.

GF Machining Solutions created industry-leading selective laser sintering technology for its Direct Metal Printing (DMP) series of machines. Designed for simplicity and speed, the DMP Flex 350 metal AM machine acts as the center of the turbocharger workflow. High printer utilization and a consistently low-oxygen environment (fewer than 25 parts per million), as well as fast, bidirectional material deposition, make it easy to achieve outstanding AM throughput.

The DMP software suite uses powder-bed images and meltpool data to identify defects such as warping, poor fusion, rough surfaces or recoating errors, track their root causes and correct them within 3DXpert. This enables shops to minimize the costs of post-build processing and part validation while they prepare data for toolpath generation.

Most additive processes require operators to remove AM support structures manually, but the unified GF

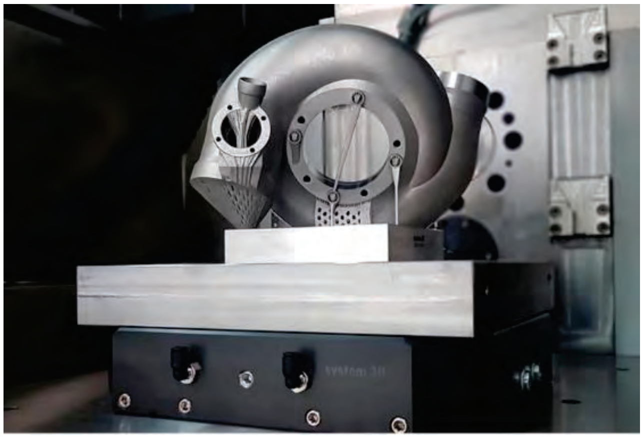
Machining Solutions system handles this step automatically during post-processing. The CUT AM 500 removes AM parts from their build plates with a unique tilting table that reorients AM parts for a horizontal-wire EDM process. The system integrates with an automation-ready clamping system, virtually eliminating the risk of part damage.

The MILL E 700 U high-performance milling machine performs post-build machining on a full 5-axis platform that's ideal for complex parts. This high-value, efficient solution uses large guideways, a double-side-supported direct drive rotary table and optimal chip removal rates to handle a wide range of milling applications. These features, along with advanced milling strategies through Cimatron and flexible, automation-ready design, make it an ideal machine for post processing of demanding AM parts.

System 3R Tooling

For palletized automation throughout the additive and subtractive workflow, System 3R tooling – the Delphin TableTop Chuck, AMCarrier and BuildPal – preserves reference points and alignments from machine to machine to ensure full additive scalability and easy access to automation.

Through System 3R, the BuildPal and AMCarrier system connects every machine in the GF additive workflow, with thin build plates and a clever design to maximize print area. At the same time, it integrates easily with



other System 3R automation for even greater productivity and post-processing speed.

Manufacturers who serve the motorsports industry need speedy performance to produce high-performance components on a competitive schedule. As part of an end-to-end manufacturing solution, 3D metal printing reduces the production time and cost of critical parts such as F1 turbocharger housings.

As increasing numbers of high-end automotive manufacturers integrate this technology, many partner with GF Machining Solutions for fast, reliable results. From industry-leading design and production software to the additive, milling and EDM equipment required for part production excellence – and the turnkey AM workflow that links it all together – GF Machining Solutions can provide everything that automotive manufacturers need for additive success.

ABOUT THE AUTHOR

GF Machining Solutions

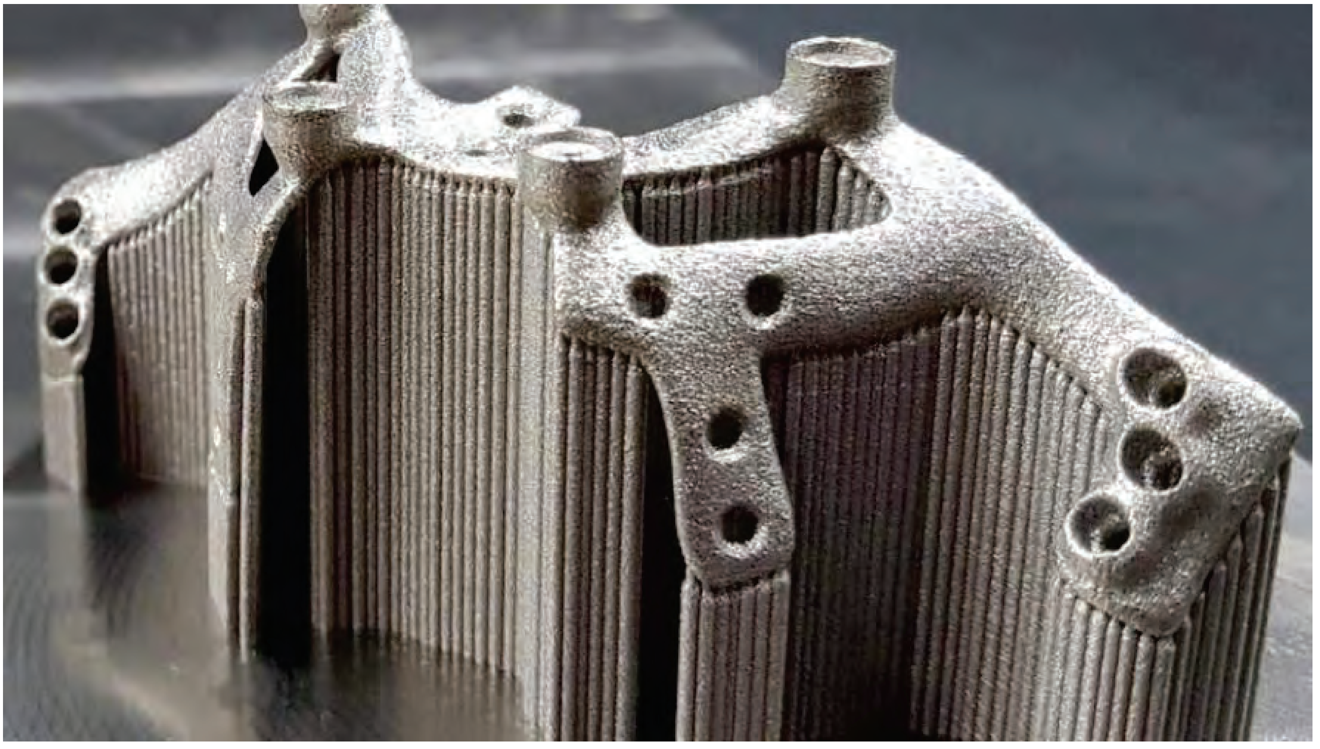
GF Machining Solutions is—along with GF Piping Systems and GF Casting Solutions—one of the three divisions within the Georg Fischer Group (Switzerland) and the world's leading provider of machines, technical solutions and services to the tool and mold making industry and to manufacturers of precision components.

The portfolio ranges from Electrical Discharge Machines (EDM), high-speed and high-performance Milling machines—including clamping and palletization systems, 3D Laser surface texturing machines and Spindles—to solutions for Tooling and Automation, services, spare parts, expendable parts, consumables and Digitalization solutions. Our key customer segments are the aerospace, ICT, medical, and automotive industries.

Heat Treatment to Improve Patient-Specific Implants Manufactured Using Metal AM

Dr. Satyam Suwas, Kaushik Chatterjee, Saurabh Kumar Gupta and Satya Vamsi Krishna

The article discusses innovation by the IISC team to improve Implants Manufactured Using Metal AM



The article discuses about innovative heat treatment used by researchers at IISC to transform martensitic microstructure of Ti-6Al-4V into a bimodal microstructure. The manufacturing method was SLM followed by innovative heat treatment. The results indicated improvement in ductility and performance comparable to conventionally manufactured medical devices.

Additive manufacturing (AM) is a layer-by-layer fabrication process in which thin layers are deposited over a substrate progressively to build a three-dimensional (3D) object. Metal AM processes are grouped into two categories based on ASTM standards: powder bed fusion and directed energy deposition. Laser powder bed fusion/ selective laser melting (SLM) has emerged as a mature technology with the availability of manufacturing units from several suppliers. The fabrication of dense parts necessitates optimization of the processing parameters, such as laser power, laser speed, hatch spacing, powder layer thickness, etc. Our research group at the Indian Institute of Science (IISc) is actively working on additive manufacturing of several metallic biomaterials, including SLM of popular biomedical alloys such as Ti-6Al-4V, SS316, and Co-26Cr-8Mo, and wire arc additive manufacturing of Zn, which is recognized as an emerging class of resorbable metallic biomaterials.

The team have extensively studied the effect of processing parameters on fabricated alloys by characterizing the porosity, residual stress, mechanical behavior, and crystallographic texture. It is well known in the AM community that additively manufactured parts must be subject to stress relieving treatment for the release of residual stress to minimize warping of the fabricated components after wire cutting. Another critical challenge associated with several fabricated components, particularly of Ti6Al4V, is their mechanical performance. This limitation arises because the microstructure of the additively manufactured part is different from its cast and wrought counterparts. The cooling rate in AM is very high as compared to conventional arc melting resulting in altered microstructures. This difference has motivated researchers globally to work towards optimized heat treatments and surface engineering strategies for the parts produced by AM to alter bulk and surface microstructure for enhanced performance. This article describes our activities on AM Ti-6Al-4V and its successful clinical translation.

In the research work conducted by IISc, the team fabricated near-net-shape bone plates by SLM of Ti-6Al-4V powder. The resultant parts exhibited martensitic microstructure, which results in poor ductility, thereby limiting the application for components. To address this challenge, an innovative heat treatment based on repeated heating and cooling below but close to the β-transus was applied to bone plates after fabrication. This heat treatment resulted in the transformation of the martensitic microstructure into a bimodal microstructure. three-point bend test and tensile test performed on the heat-treated plates revealed a large improvement in ductility, and the results were comparable to plates that were conventionally manufactured from wrought alloy. The design of the bone plate used in the study and its mechanical behavior is shown in Fig.1. The corrosion behavior and cytocompatibility of all the plates were similar. Thus, this heat treatment enables us to additively manufacture Ti6Al4V orthopedic parts to achieve biomechanical performance comparable to conventionally manufactured medical devices.

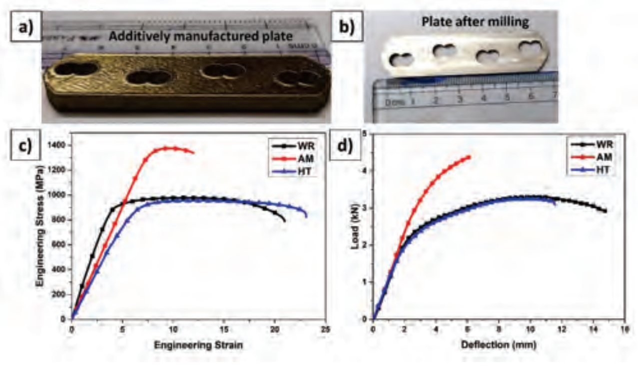


Figure 1 a) A simple design of additively manufactured bone plate used in the study, b) Plate after milling, c) Stress-strain behavior during tensile testing, d) Bending behavior during 3-point bend test; AM: Additively manufactured, HT: Heat treated plate, WR: Plate manufactured using wrought Ti-6Al-4V

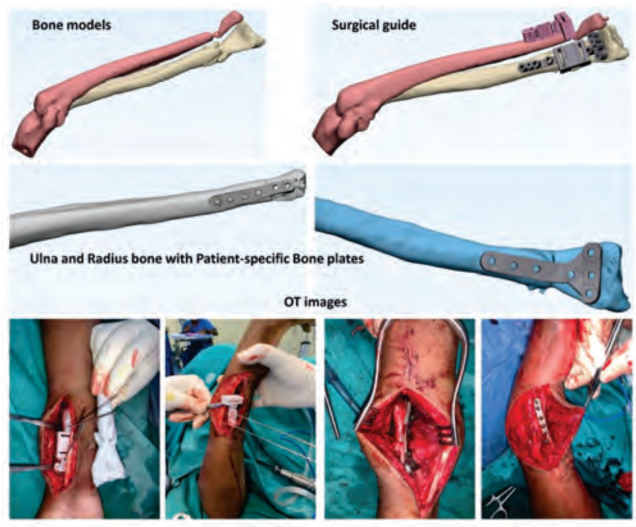


Figure 2 Case study depicting the treatment of a patient with a patient-specific additively manufactured bone plate.

This technology is now being applied for the treatment of malunions of the arm. In collaboration with orthopedic surgeons at the Sanjay Gandhi Institute Of Trauma and Orthopaedics, our group at IISc is designing and fabricating patient-specific bone plates for defects in the distal humerus, radius, and ulna bones, followed by heat treatment prior to implantation. A patient with above mentioned clinical deformity was treated with additively manufactured Ti-6Al-4V alloy, as shown in Fig.2. The use of these additively manufactured implants results in reduced surgery time and nearly full restoration of the functionality in the upper limb of the patient post-surgery in contrast to the conventional mass-produced implants, as assessed by the surgeon. Malunions are common in India, where patients receive inadequate healthcare resulting in loss of hand function. The emergence of additive manufacturing can, thus, open new avenues for improved healthcare through patient-specific implants leading to a better quality of life for the patients.

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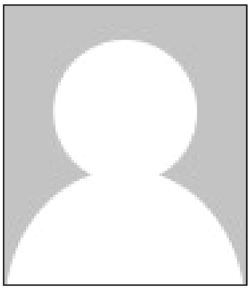

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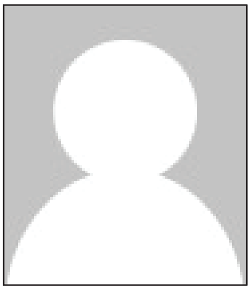

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Unpacking The Myths About 3D-Printed Prosthetics

Larry Borowsky

3D Printing has started to change the prosthetists business, yet a few myths exist. The article discusses the key myths in the 3D Printed prosthetists

Courtesy Quorum Prosthetics.

"Reprinted by permission from the January 2023 issue of Amplitude Magazine."

As attendees walked the exhibit floor at the American Orthotic and Prosthetic Association's annual conference last fall, some might have wondered if they'd come to the wrong hotel by mistake. Booth after booth greeted visitors with displays about 3D printing rather than prosthetics. Plenty of 3D-printed sockets and limbs were available for inspection, of course. But there were also trays of resin and filament and powder, computer screens with demos of modeling software, and stacks of brochures and white papers about digital prosthetics' cost, comfort, and strength. For the first time in its history, the AOPA conference offered a Digital Care education track featuring half a dozen sessions about 3D printing. And anyone who wanted an up-close-and-personal peek at the technology could attend a two-hour Digital Care Showcase, also making its debut at the 2022 conference.

The 3D-printing revolution has been approaching for so long that most of us in the limb-loss community feel pretty well informed on the subject. But we've generally glimpsed this technology as an indistinct blip on the horizon. Now that the ship is actually sailing into port, people are realizing how much we don't know about 3D-printed prosthetics, and how the hazy outline we're familiar with leaves a lot of blanks to fill in.

It's also becoming clear that much of our attention has been focused on devices that don't fully reflect the technology's potential impact on amputees' lives. We see the daring aesthetics that can be achieved via 3D printers, and we read about the uplifting humanitarian projects. Occasionally we hear about possible improvements to cost, comfort, and usability. What's generally left out is the most exciting part—the paradigm shift in how prosthetic devices are produced, distributed, and paid for.

In a nutshell, 3D printing equips the industry to churn out custom devices—designed and built to fit individual bodies—at vastly greater speed and volume than traditional production methods. “It's a new platform,” says prosthetist Chris Hutchinson, co-founder and chief technology officer of ProsFit, one of 3D-printed prosthetics' pioneering firms. “It's much more flexible and mobile (than the current model), and it not only provides better care for amputees but also brings new opportunities for professionals in prosthetics, so they become more entrepreneurial and more hands-on.”

That explains why 3D printing had such a strong presence at the AOPA conference. It's already starting to change the way prosthetists do business, and that has obvious implications for the amputees they serve. Change can be scary and confusing, and it's inherently prone to misunderstandings and mistaken impressions. So as 3D printing cruises into the harbor, we thought we'd challenge a few myths about the technology.

MYTH #1

3D-printed prosthetics are cheap, inferior knockoffs of conventionally produced devices.

This misperception arises in part from the media's fascination with brainy teens who design and 3D-print fully functioning bionic limbs. The most visible US manufacturer of 3D-printed prosthetics, Unlimited Tomorrow, has its roots in that narrative: Company founder Easton LaChappelle first gained notoriety a decade ago as a science-fair whiz kid with a homemade bionic hand.

But LaChappelle will be the first to tell you that his company's TrueLimb is no science-fair project. It's an elaborately engineered machine that's fabricated on industrial-grade 3D printers using state-of-the-art composites, high-level sensors, and advanced algorithms. Time will tell whether the TrueLimb endures as a prosthetic solution, but it's already established as a credible competitor in its market.

A corresponding staple of mass media coverage involves the widespread disbursement of 3D-printed limbs in developing regions at little or no cost. These devices improve the lives of thousands of amputees who would otherwise lack access to even a basic prosthesis. But because they're virtually given away, they feed the belief that 3D printers can only manufacture rudimentary, low-cost gadgets.

“It's a spectrum,” says Hutchinson. “It runs from middle-schoolers 3D-printing limbs out of melted bottle tops, all the way to the type of manufacturing we're doing, which is literally using the same technology that go into building rockets.”

Founded in 2016, ProsFit (which is based in Bulgaria) provides a seamless end-to-end solution for 3D-printed sockets, saving clinicians the trouble and expense of buying, mastering, and maintaining all the underlying technology. Prosthetists scan patients' limbs at the point of care and build a preliminary model using a cloud-based software platform. They release the files to ProsFit's engineers, who refine the model and vet it for regulatory compliance and quality assurance. The final output files are transmitted to a commercial 3D-printing facility (ProsFit has affiliates around the world), where the socket is manufactured. Total turnaround time, from scan to delivery, is usually less than two weeks. (See below for a step-by-step summary of the production sequence.)

"This is very serious, high-end manufacturing," Hutchinson says. "We work with BASF, one of the largest materials companies in the world, and SGL Carbon, one of the largest carbon manufacturers in the world. We're doing the same type of thing that's being done in the aerospace, defense, and automotive industries." He adds that ProsFit's sockets meet the European Union's rigorous specs for medical-device designation. They also have achieved the same quality certification (ISO 10328) as conventionally produced devices. "We have to be extremely rigorous. All our research and testing and procedures are reviewed and audited very thoroughly by the government agencies."
Early generations of 3D-printed arms and sockets were largely fabricated from materials of a similar grade to the thermoplastics that go into conventional check sockets. They were therefore prone to weakness, cracking, and outright failure. But today's leading-edge devices use sophisticated powders and resins that compare favorably with carbon fiber in terms of strength and structural integrity.

That came as a pleasant surprise to actor and athlete Aristotle Domingo, a Canadian bilateral amputee who'd formed a dim view of 3D-printed sockets after trying some in the late 2010s. "The stuff they printed out was completely useless to me," he says. When he grudgingly agreed to try a pair of ProsFit sockets in 2020, they greatly exceeded his low expectations. "I thought it was going to be garbage," he laughs. "But their socket fit like a glove right away. It relieved all the pressure points on my (right) distal end, so I got rid of all my sores there. On my left, my fib head isn't rubbing at all. We didn't need to add any padding or cushioning. It just fit that way."

"It felt like a natural extension of my body, and the fit was perfect," adds martial artist Rustin Hughes, who's also been wearing a 3D-printed socket since 2020. "The sockets are built off a scan of your leg, so it's way more precise than the conventional method. And the 3D(-printed) socket is crazy light. Ounces mean a lot in above-the-knee amputees. That's something I noticed immediately."

Domingo's opinion of 3D-printed sockets has done a 180. "I've been wearing my ProsFits since the day I got them," he says. "It's coming up on three years. I wouldn't switch back to my old socket system."

MYTH #2

3D-printed prosthetics are still untested.

This idea springs in part from the same source as Myth #1: Popular media tend to overrepresent the DIY end of the 3D-printing spectrum, while underrepresenting the evidence-supported scientific/industrial end. As a result, most people don't realize how much data underpins the current generation of 3D-printed prosthetics.

That body of evidence is at least 18 years old and probably older. The earliest peer-reviewed study of 3D-printed prosthetics we could find, titled "A Preliminary Investigation Into the Development of 3-D Printing of Prosthetic Sockets," appeared in 2005 in the Journal of Rehabilitation Research and Development. "Under normal circumstances, printed components are weak and relatively fragile," the authors of that paper wrote. However, "with careful resin selection, the mechanical strength of a 3DP component has been shown to increase to an extent that would make it suitable for use in prosthetic devices."

Hundreds of academic investigations have ensued, and private-sector companies have invested untold millions in proprietary R&D. Engineers have refined every step of the production sequence for 3D-printed prosthetics, from raw materials to design, manufacturing, and waste recovery. On the clinical side, healthcare researchers have measured patient outcomes such as mobility, dexterity, pain, and overall fitness.

“Our clinic has 100 patients who are living proof that this technology works,” says certified prosthetist Joe Johnson, owner of Quorum Prosthetics. “We know it works, and we have the data to back it up.”

One of just a handful of US prosthetic clinics with in-house 3D-printing capacity, Quorum has partnered with the Department of Veterans Affairs and two Colorado universities to gather outcomes data about Quorum's 3D-printed socket (called the Quatro). One study showed that the Quatro improved amputees' gait symmetry and reduced their overall walking effort. Another compared pressure distribution in the Quatro to that of a conventional socket, yielding quantitative evidence that affirms patients' subjective reports of socket comfort.

As 3D-printed limbs inch closer to commercial viability, research activity is accelerating. Limbitless Solutions, a Florida-based nonprofit startup, is conducting an ongoing series of clinical trials to gather data about its 3D-printed bionic arm. Quorum is launching a new study with the University of Colorado to test whether 3D-printed sockets can improve proprioception. ProsFit recently published the results of a year-long study involving mobile, in-home scanning and fitting of their sockets. In 2022 alone, nearly 100 new papers about 3D-printed prosthetics appeared in peer-reviewed medical, scientific, and technical journals.

One of those 2022 papers, a systemic literature review that aggregated data from multiple studies, concluded that “preliminary experimental clinical data suggests that [3D-printed sockets] may be safe and effective for daily use.” That's not to say the efficacy of 3D-printed models is definitively proven. But you can rest assured that the technology has been, and will continue to be, evaluated for its safety, performance, and health impacts.

MYTH #3

3D printing will drive prosthetists out of business.

Amputees tend to push back reflexively on anything that threatens to alter their relationship with their prosthetist. And few are enthusiastic about having their limb care transferred from an attentive, hands-on clinical team to a crew of Geek Squad techies—or, worse, a bot from Hewlett-Packard's help desk.

But that's not what 3D printing will do, says Domingo. When he went through the design process for his ProsFit sockets, he collaborated with his prosthetist (a Toronto-based ProsFit affiliate) as closely as he would have for a conventional plaster-and-lamination fitting.
“She scanned my limb,” he says, “and then we looked at the image together. When we started building the model, I threw a whole bunch of things at her: 'Let's put some padding here and a shim there. This feature is hitting the bottom of my leg, and that one's pushing up on my knee. Must have this, cannot have that.' It was all the same information you would convey to an old-school prosthetic tech.”

“What we've seen is that being involved in the design process—actually being there during the CAD/CAM process—has meant that people can give more detailed feedback than ever,” notes Hutchinson. “They feel more involved, and they're psychologically more prepared for the final result because they have buy-in. They literally helped build it.”

Amputees aren't the only ones who are anxious about how 3D printing might upend patient-prosthetist dynamics. Many clinicians regard this new technology the same way John Henry viewed the steam-powered drill—as a senseless brute with plenty of muscle but no brains or heart. It's a natural reaction for practitioners who take pride in their craft and are sensitive to patients' needs. But as the AOPA conference suggests, the industry as a whole is beginning to view 3D printing as a help, not a hindrance, to their professional mission.

“Two years ago, when I was looking into this, there were definitely still people who were bad-mouthing the whole idea,” says Johnson. “They were going out of their way to look for reasons why it wouldn't work. But now it's generally accepted that this is happening, and everyone's got to get on the train.”

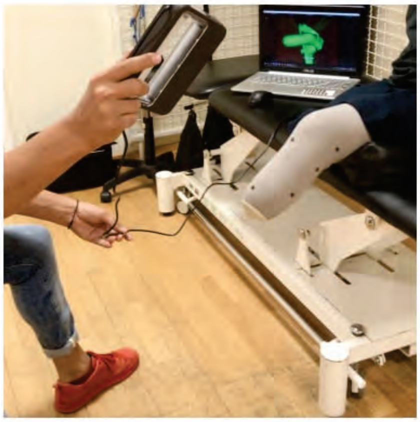
An amputee since the age of 15, Johnson has witnessed multiple stages of technological change. “I remember when silicone liners came out in the late 1980s,” he says. “There were people who said, 'Silicone liners will never work. I don't understand why you'd even bother, wool socks are just as good.' And then carbon fiber feet came out, and it was the same thing: 'Seattle Feet are the best, don't bother walking on carbon fiber.'”

“Professionals tend to have a fear of the unknown,” says Hutchinson. “And right now, fear of the unknown is greater than the fear of missing out. But people are starting to see that this is an incredible tool set that takes them far beyond what they were capable of achieving before. ”

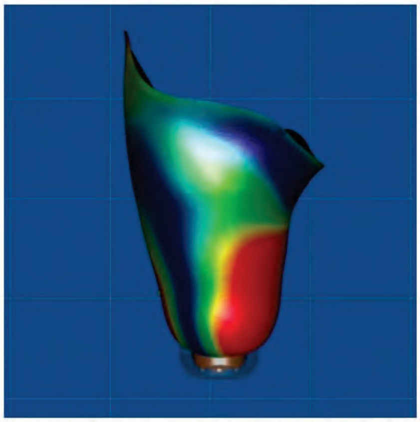
ProsFit, which already has affiliate clinics throughout Europe, southeast Asia, and Africa, is planning to enter the US market in 2023, although Hutchinson says “it's more important for us to do it correctly than to do it quickly.” In the meantime, American consumers who are curious about 3D prosthetic devices have plenty of other options. Upper-limb amputees can purchase a TrueLimb or an Open Bionics Hero Arm. And many clinicians now offer 3D-printed sockets to leg amputees, though often on a limited basis. A very small number (Quorum and North Carolina-based EastPoint Prosthetics are two examples) have developed their own comprehensive, end-to-end 3D-printing capacity. Last year Protosthetics, a central fabricating facility based in North Dakota, launched an affiliate-based scan-design-print model that resembles ProsFit's end-to-end solution. And dozens of clinics have dipped their toes in the water, performing routine production steps such as scanning (and, possibly, 3D modeling) in-house while outsourcing the more complex engineering and manufacturing operations.

Hutchinson didn't attend the AOPA conference, but he's taken note of 3D-printing colonies at other O&P trade shows. “We're seeing things at booths that look like things we built five years ago,” he laughs. “So that's kind of comforting, because it means 3D printing is coming. And we think it will make the whole system more flexible so it's better for amputees in receiving care.”

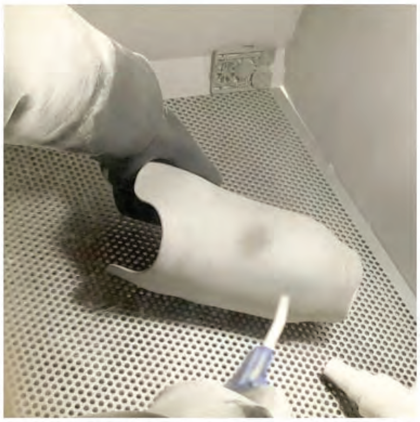
3D-Printed Prosthetic Devices: Step by Step



1: Your prosthetist scans your limb at the clinic to produce a basic 3D image. Elapsed time: a few minutes.



2: Design software translates the image of your residual limb into a custom-designed 3D model. Elapsed time: 1 to 2 hours,



3: The finished model is transmitted to a 3D printing facility for manufacturing. Elapsed time: 2 to 5 business days.

4: The completed device gets shipped back to your clinic for final fitting. Total turnaround time: 1 to 2 weeks.

How will 3D printing change your visit to the O&P clinic? Here's an abridged guide to the process of getting a 3D-printed prosthetic socket. Images courtesy ProsFit Technologies.

"This article originally appeared in Amplitude Magazine, the nation's #1 lifestyle publication for people with limb loss and limb difference."

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Larry Borowsky is editor of Amplitude Media Group and has rich experience working in media companies.

Inflexion point: The transition to AM mass production and print on demand (Digital Inventory)

Benjamin Moey

Know about the Vision-Controlled Jetting by InkbitVista system for mass production of polymer 3D printed parts

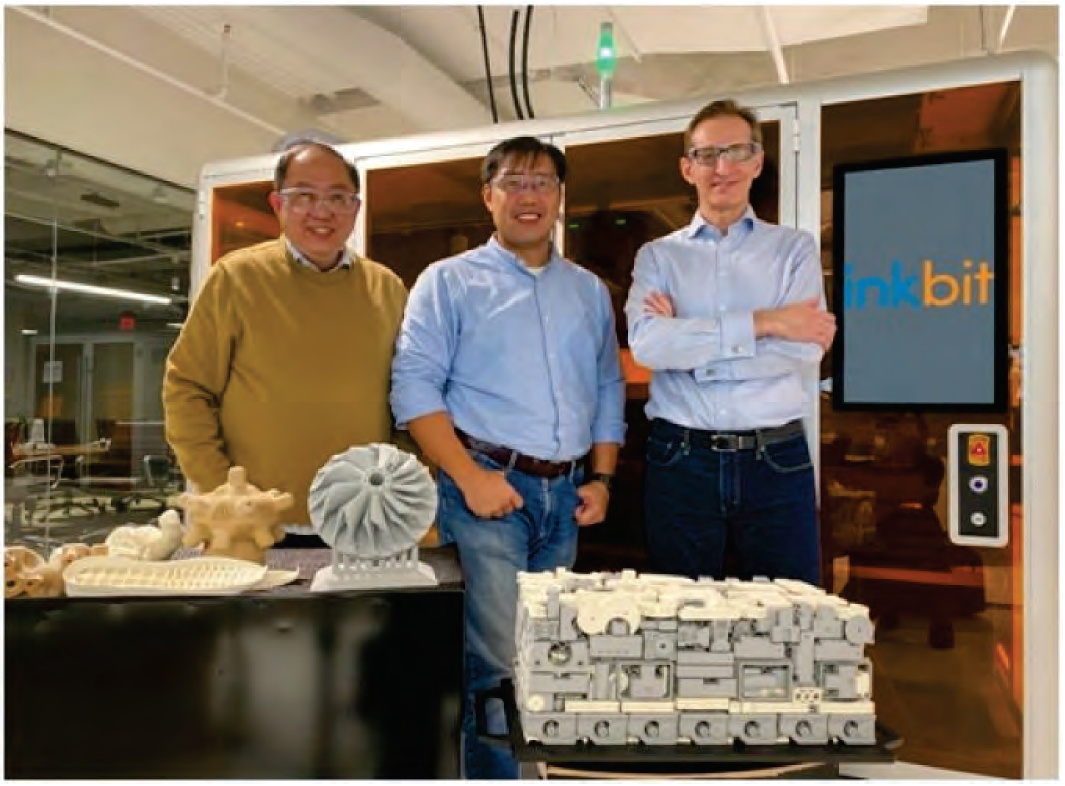

Figure-1-R-L-Davide-Marini-(CEO,-Inkbit),-Benjamin-Moey-(MD,-I2Mavericks),-Edmond-Wong-(Board-Member,-Inkbit)

Founded in 2017, Inkbit is an additive manufacturing company located in Medford, Massachusetts. They have developed their InkbitVistaTM system for mass production of end-use polymer 3D printed parts. The system incorporates a novel technology called Vision-Controlled Jetting (VJC) that delivers high-resolution print capability enabling users to print parts with dimensional accuracy and precision at high volume.

Game-changer – Production Repeatability

This novel Vision-Controlled Jetting (VCJ) technology addresses one of Additive Manufacturing's key barriers to mass production – repeatability.

VCJ uses vision based closed loop control to compensate for the natural variation of the printing process. Each layer is dynamically created based on the data of the previous layer scanned data which ensures high levels of print accuracy and allows for defined micro features (down to 40μm features) to printed.

With InkbitVista$_{TM}$ system high-resolution and accuracy capability[i], the transition to industrial AM mass production is truly on its way to widespread implementation.

[1]White Paper – Dimensional Accuracy & Precision Study (ASTM/ISO 52902) to be released.

Game-changer II – Production Portability

High levels of portability and accuracy allows for harnessing the real value of the digital inventory, where CAD designs can be printed directly from source files, with minimal Design for Additive Manufacturing (DfAM) and high levels of accuracy.

Game-changer III – Maximum packing density

Maximum nesting density has always been a feature for polymer based printers. However, maximizing packing density requires orienting parts in different print axis, which affects end-product properties depending on orientation of print.

In the case of InkbitVistaTM, printed parts exhibit uniform directional tensional strengthwith minimal deviations.

Game-changer IV – Speed of Process Cycle

InkbitVistaTM technology enables fast printing cycles and comparatively shorter post processing times, with easy to remove wax support.

The R&D team is working towards automation to further improve productivity.

AM creating Competitive Advantage

Adopting an AM product design mindset will enable companies to gain an unfair competitive advantage over its competitors, such as a few keys ones as follows,

- Product Design control
    1. Once products are designed with AM concepts, replication of these would be difficult both by traditional manufacturing methods but also the difficulty in reverse engineering an AM structure filled with internal channels.

- Product Simplification
    1. Through design build-of-materials (BOM) can be reduced (reduction in inventory holding, costs, and lead times)
    2. Weight and handling of the parts and product can be more ergonomic.

- Green Manufacturing (ESG focused)
    1. Unlike other AM platforms, InkbitVistaTMrecycles a large amount of the support material.
    2. Waste materials from the Inkbit printers are non-toxic.

Deployment

The InkbitVistaTM has been commercially available since 2022 and has been deployed at a number of customer sites, and continues to get the attention of the industrial manufacturing community.

Key Application areas

Inkbit's material suite that materials that have properties such as chemical inertness, soft elastomer, and the R&D team continues to work with its customers to develop new materials for applications.

Product designs that require high accuracy and resolution with chemical inertness are suitable target applications.

Some examples of applications, below

Figure 2 – Manifolds (chemical inertness)

Figure 4 Complex Features (Static Mixer)

Figure 3 High Resolution features (high tolerance fittings)

Figure 5 Gaskets

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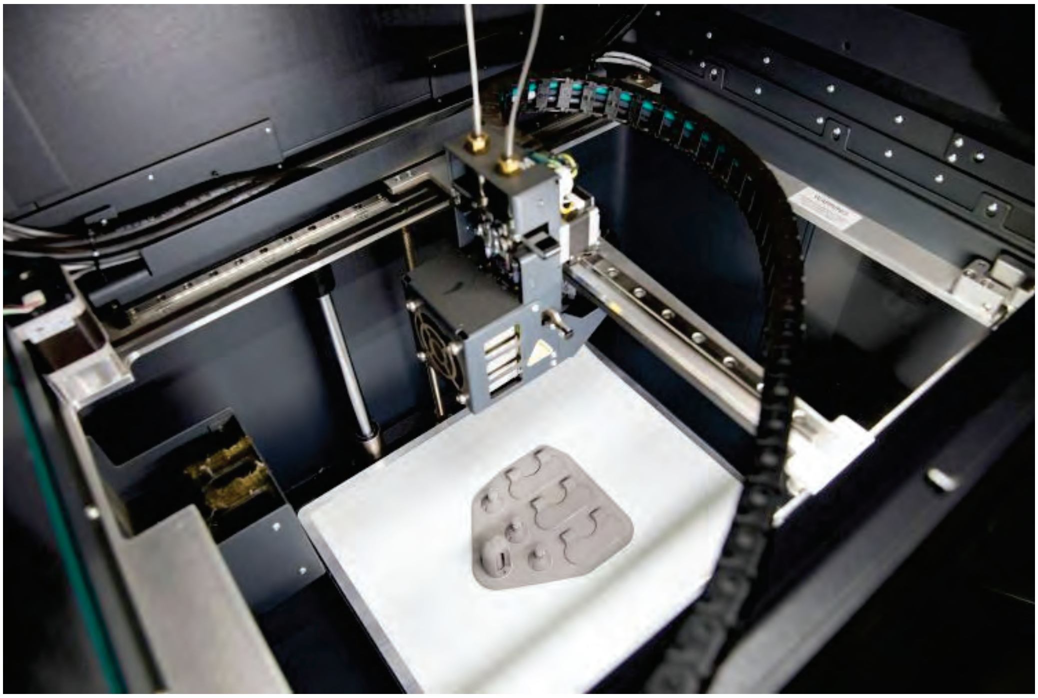
Benjamin Moey is an engineer & technologist and has been a strong advocate for the additive manufacturing (AM) technology. He is an industrial AM designer who regularly does AM consulting and conducts workshops to support customers in their adoption of additive manufacturing.

Standard Practices for Classification of Additively Manufactured Parts

Khalid Rafi

The importance of ASTM F3572 and NASA STD 6030 standard for the aerospace industry



Additive manufacturing provides endless potential to revolutionize manufacturing, from creating complex structures to producing personalized products. It is crucial to demonstrate that these parts are safe and reliable for end-use applications. The parts need to qualify for use according to the requirements applicable to the intended use. However, the qualification requirements applicable for one part may not be the same for another part. Therefore, the parts need to be classified based on some criterion so that qualification requirements can be created accordingly. To createsuch a criterion,it is important to understand the intended function of the part: whether the part is safety critical or mission critical, the chances of failure of the part, and what would be the consequence if the part fails.

The part classification helps to determine an appropriate level of process control, qualification, and inspection. Based on the consequence of failure, parts can be grouped into different classes, and proper procedures that apply to each class can be developed. Two standards provide guidance and requirements in classifying additive manufactured parts; ASTM F3572 and NASA STD 6030. Although these standards are developed specifically for use in Aviation and Space applications, the modalities can also be applied to other industry sectors.

ASTM F3572

This standard practice provides the general principles in classification of additively manufactured parts used in aviation produced by all the AM technologies defined in ISO/ASTM 52900. This practice establishes a consistent methodology to define and communicate the consequence of failure associated with AM aviation part. The same methodology could be used for other industry sectors by adequately identifying the risk associated with the field of use. Four part classes are established in this standard. The parts are classified as A, B, C, and D based on consequence of failure levels as High, Medium, Low and Negligible or No effect, respectively

Class A – High refers to a part whose failure can directly affect the safe operation of the flight

Class B- Medium refers to a part whose failure indirectly affects the safe operation of the flight

Class C- Low refers to a part whose failure has less impact in the operational and functional capabilities

Class D- Negligible or No impact refers to a part whose failure has no impact in the regular operation of the flight

This standard can be used to establish specific methods of compliance but should refer to the original regulations.The standard allows a cognizant engineering organization to assign part classification based on the consequence of part failure. The potential of this standard is that it allows for every additive manufactured part design in aviation to be assigned a classification that can drive all aspects of the part life cycle.

NASA STD 6030

NASA STD 6030establishes the additive manufacturing requirements for spaceflight systems. The standard covers all aspects of AM processes from feedstock to qualification and process control. Section 4.3 of this standard defines the classification of AM parts. The part classification system uses a two-tier approach based on relative risk;

Primary Classification based on the consequence of failure.

Table 1: Considerations for part classification based on consequence of failure

Class A	Class B	Class C
• High Consequence of Failure, if failure of the part leads to a catastrophic, critical, or safety hazard and/or the part is defined as mission critical by the program or project. • more stringent controls on the AM process to manage risks associated with their use • Shall not be made from polymeric materials, be fasteners, contain printed threads	• Part failures falling short of catastrophic failures but cause significant delays due to failure • To be aerospace-quality parts of high quality • Shall not be fasteners and contain printed threads	Negligible consequence of failure. Failure of part does not: • lead to any form of hazardous condition. • eliminate a critical redundancy. • serve as primary or secondary containment. • cause debris or contamination concerns

The parts are classified as Class Awith high consequence of failure, Class Bwith consequence of failure falling short of catastrophe, and Class C,with negligible consequence of failure. The considerations in determining a part to be categorized under these classes are listed in Table 1.

Secondary Classification based on combination of structural demand on the part and the risk associated with AM implementation for the part.

For Class A and Class B parts based on the primary classification, a secondary classification is assigned according to its structural demand and AM risk. Determining how high are the structural demands such as the stress and how high are the risks due to the AM design or build process are critical in the classification of a part.

The secondary classificationsfor a Class A part aredesignated as A1, A2, A3, or A4. If the structural demand and the AM risk for a Class A part is High, then the secondary classification for that part is Class A1.Similarly, secondary classification for a Class B part is designated as B1, B2, B3, B4. Table 2 shows secondary classification for Class A and Class B parts based on the combination of structural demand and AM risk.

Table 2. Secondary part classification for Class A and Class B parts

Secondary classification factors	**Structural Demand**	**High**	**High**	**Low**	**Low**
	AM Risk	High	Low	High	Low
Class	Class A	A1	A2	A3	A4
	Class B	B1	B2	B3	B4

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Aidro contributes to the guidelines for additively manufactured parts in oil&gas and maritime industry

AIDRO Hydraulics & 3D printing

The article discusses the key outputs from the Joint Innovation Projects (JIPs) on the qualification of additive manufacturing in Oil&Gas and Maritime industries.

On January 30th, the 20 partners celebrated the official closing of Joint Innovation Projects (JIPs) on the qualification of additive manufacturing in Oil&Gas and Maritime industry.

After 2 years of intensive work and discussion between the members, the two seamlessly aligned JIPs were concluded with the coordination of DNV GL and Berenschot. The JIPs goal was to develop a guidelines for the qualification of parts produced by Laser Powder Bed Fusion (LPBF) and Wire Arc Additive Manufacturing (WAAM) and an accompanying economic model, to be used in the Oil & Gas and Maritime industries.

An important prerequisite for the success of this project was the participation of partners representing

the complete value chain. In Additive Manufacturing, the collaboration of multiple partners with expertise in specific processes and activities, is essential.

JIPs Members are the following : Equinor, BP, Total, Shell, Kongsberg, Aidro, OCAS/ Guaranteed (spin-off from Arcelor Mittal), Ivaldi Group, TechnipFMC, Siemens, Voestalpine, Vallourec, SLM Solutions, Additive Industries, Quintus Technologies, HIPtec, IMI CCI, Advanced Forming Research Centre of the University of Strathclyde, Immensa Lab and Sandvik.

The partners collaborated in two coherent and seamlessly aligned programs:

- A Guideline towards certified parts managed by DNV-GL: The final guideline provides a framework to ensure that metal spare parts and components, produced via Wire Arc Additive Manufacturing (WAAM) and Laser-based Powder Bed Fusion (LPBF), are according to specifications. This means that the parts meet stated quality and are manufactured in a safe and repeatable manner.

- A Toolbox for part selection, supply chain set-up and economic viability managed by Berenschot.

In addition, real parts were produced as case study to ensure the development of a highquality guideline that is in tune with realistic manufacturing practices. The parts production enabled the consortium to assess all activities that need to be monitored and qualified to ensure a complete guideline. At the end of JIP, many case studies were developed and parts produced with AM to support the AM guidelines.

One of the Case Study is the Crank Disk produced with LPBF by Aidro for Kongsberg. The original part produced with conventional manufacturing takes from 8 to 10 weeks while the 3D printed part required less than one week to be printed in Inconel 718, using EOS M290 printer. This is a good example of how AM can accelerate the replacement of parts and avoid long downtimes of the equipments and plants.

the crack disk 3D printed by Aidro with EOS M290 and machined by Kongsberg

Other case studies were made with LPBF or WAAM and all the JIPs members contributed to the production and testing of these 3D printed parts.

Parts were produced using Laser Powder Bed Fusion:

- An Equinor impeller in Inconel 625 (printed by SLM Solution)
- The same impeller in Ti-6Al-4V (printed by Additive Industries)
- A Kongsberg propeller blade in titanium (printed by SLM Solution)
- A Kongsberg crank disk ring in Inconel 718 (printed by Aidro with EOS printer) shown above

Parts were produced using Wire Arc Additive Manufacturing:

- A Vallourec circulating head using X90 low-alloy construction steel
- A BP cross-over in Inconel wire, in two versions: limited scale and full scale
- A Kongsberg crank pin, using S700 low-alloyed wire
- A Technip FMC/Total-designed crossover, using F22 alloy steel

Using real world parts is essential in a project like this. Both the guideline and the business impact model need to be tested under conditions that resemble real life situations.

By using real world parts, it is possible to assess the variations between traditional manufacturing processes and the Additive Manufacturing process. These variations are found along the entire value chain, not only in the discrete production phase.

The guideline offers a quality assurance methodology for the selected Additive Manufacturing processes and parts. Parts are divided into three categories depending on the consequence of failure: AM Class 1 (AMC 1) is intended for non-critical components, AM Class 2 (AMC 2) is intended for less critical components and AM Class 3 (AMC 3) is intended for critical components.

Depending on the AM Class, different assurance steps are involved based on the AM technology used, such as build process qualification testing, production testing and part qualification testing:

- All parts shall be manufactured using a qualified build process. A build process is qualified through a defined Build Process Qualification Testing (BPQT) procedure.

- The purpose of the BPQT is to prove and provide a baseline that, when using a certain set of essential parameters, a certain quality is achieved

- Production testing is intended as a control to ensure that the manufacturing process produces parts according to the qualified build process not just once, but also on, for example, the second, tenth or twentieth build. The extent of production testing and type of tests carried out are different for the different AM technologies

- Depending on the criticality of the part to be manufactured, the part itself or a representative geometry may need to be tested. This is due to the unique possibility AM brings to produce the material and geometry simultaneously. The methodology and extent of part qualification testing depends on both AM Class and AM technology.

The closely aligned set-up of the two JIPs secured maximum knowledge exchange and learning between members, research institutes, designers, manufacturers, certifying bodies and end-users.

At the end of the ceremony, DNV GL launched two new JIPs to continue the investigation of AM technologies and develop Digital Warehouse program.

The 20 members of the JIPs are listed in alphabetic order:

- Additive Industries
- AFRC of the University of Strathclyde
- Aidro Hydraulics & 3D Printing
- BP

- Equinor
- HIPtec
- IMI CCI
- Immensa Lab
- Ivaldi Group
- Kongsberg
- OCAS / Guaranteed (spin-off from Arcelor Mittal)
- Quintus Technologies
- Sandvik
- Shell
- Siemens
- SLM Solutions
- TechnipFMC
- Total
- Vallourec
- Voestalpine

The article is reprinted from the Aidro Website

ABOUT THE AUTHOR

AIDRO Hydraulics & 3D printing

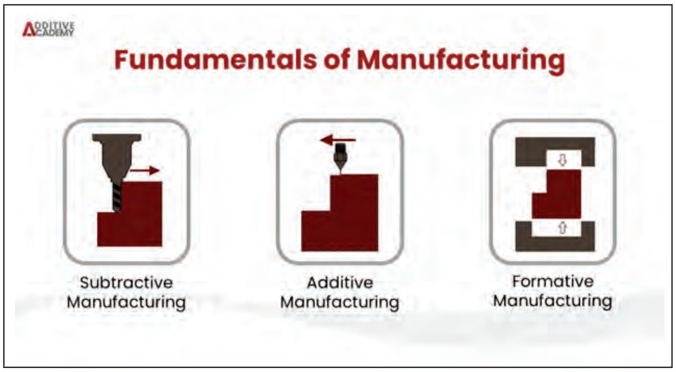
Aidro is a hydraulics specialist and a pioneer in Additive Manufacturing to create innovative Fluid Power solutions. With almost 40 years experience, Aidro's main activities are the design, production and fast deliveries of hydraulic products. One of the internal department is dedicated to design for AM and metal 3D printing, including CNC finishing, reverse engineering, heat treatments. Aidro Team is committed to making the expertise and creativity at clients' disposal, to overcome the challenges of the hydraulic market together.

AM101 Series: Decoding the AM technology spectrum

Pavan Kapnadak

Discover the world of additive manufacturing with Additive Academy. This series gives a glimpse of the basics of AM, straight from the pages of our AM101 course, starting from an understanding of AM technology, and providing insight into the technology, applications, economics, operations and design aspects that one needs to know to harness the full potential of AM.

There are many types of additive manufacturing processes, but the most known and common one we see is the desktop 3D printer. 3D printing is a more commonly used synonym for Additive Manufacturing (AM), but with the advances that are coming up now, we are transitioning from simple prototyping to manufacturing with these technologies, making Additive Manufacturing a more appropriate terminology.



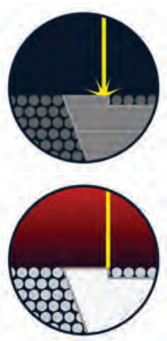
All forms of Additive Manufacturing have one thing in common with the common desktop FFF printer- They build objects layer by layer to form a 3d object which can be created with digital 3d data. This process of “adding” material in the right space to build an object differentiates it from other forms of manufacturing- Subtractive forms such as milling, sculpting and laser cutting; and Formative processes like moulding. It is therefore, one of the most material-efficient ways of production. The difference between traditional manufacturing and additive manufacturing can be viewed as follows. Consider a traditional manufacturing process(machining), a process where the material is removed where to make any part, they must start with a large workpiece. The waste generated, holds very little value, when compared to the raw material, in many cases also cooling fluids, gets contaminated with chips from the machine.

In the cases of moulding and casting which are called formative processes, where parts can be made at extremely high quantities, but before you make one part, the tooling cost in most cases is also extremely high, which takes lots of time and money in terms of investment. It is widely accepted that AM has a flat cost per part versus volume curve. The cost per part is the same whether you produce one or many pieces of the same part, though this began to change. But this is changing and improvement to the AM workflow is increasing at a tremendous rate.

We can compare the cost of making the same part by Additive manufacturing versus Machining. But with AM we can leverage the design, and get better and more enhanced parts. Tooling made by additive manufacturing includes, for example, higher performance injection moulds with conformal internal cooling channels. Those channels can reduce cycle time and improve part quality. Or jigs and fixtures that let us better optimise assembly workflows and make human tasks more ergonomic. Tools used to improve other manufacturing processes is a major and really fast-growing application of AM. Using AM, we can also think about consolidating assemblies into fewer parts. That's because a lot of assemblies are so because we have to respect the constraints of existing manufacturing techniques. Therefore, by 3D printing, we can consolidate several parts into one and save a lot of cost and time. With 3D printing, we can also design parts to be made of multiple materials. And we're starting to design materials directly for additive manufacturing.

Many challenges remain, but we're still gathering the momentum and resources to address those. The cost of desktop printing still remains expensive, the raw materials needed for these printers are still expensive and, in many cases, difficult to source. But most importantly, the biggest challenge still remains the gaps in knowledge present within the people having these technologies. There are more technologies that are expensive only due to the fact that they are held back by intellectual property (IP) rights leading to an increase in capital expenditures when investing in such technologies. But there is a steady subtle decrease in the cost of printers, raw materials, and other services.

Seven types of AM

Icon	**Process Category**	**Process Names**
	Material extrusion: material is selectively dispensed through a nozzle or orifice, which is typically heated to soften or melt the material	• Fused Deposition Modelling (FDM) • Fused Filament Fabrication (FFF) • Bound Metal Deposition (BMD) • Atomic Diffusion Additive Manufacturing (ADAM) • Big Area Additive Manufacturing (BAAM)
	Vat photopolymerization: liquid photopolymer in a vat is selectively cured by light-activated photopolymerization	• Stereolithography (SLA) • Digital Light Processing (DLP) • Digital Light Synthesis (DLS) • Gel Dispensing Printing (GDP)
	Powder bed fusion: focused thermal energy selectively fuses regions of a powder bed	• Selective Laser Melting (SLM) • Direct Metal Laser Sintering (DMLS) • 3D Metal Printing (3DMP) • Selective Laser Sintering (SLS) • High-Speed Sintering (HSS) • Multi-Jet Fusion (MJF)
	Material jetting: droplets of build material are selectively deposited	• Polyjet • Multijet • Nanoparticle Jetting

	Binder jetting: a liquid bonding agent is selectively deposited to bind powder materials, typically followed by sintering to densify the bound powder	• Binder Jetting (BJ) • Powder Inkjet Printing • Powder Inkjet Printing • 3D Printing (3DP) • Digital Metal, Single-Pass Jetting (SPJ)
	Directed energy deposition: focused thermal energy is used to fuse materials by melting as they are being deposited	• Directed energy deposition (DED) • Electron Beam Additive Manufacturing (EBAM) • Rapid Plasma Deposition (RPD) • Laser Deposition Technology (LDT) • Laser Metal Deposition (LMD) • Many others
	Sheet lamination: sheets of material are bonded to join consecutive layers of a part	• Composite-Based Additive Manufacturing (CBAM) • Ultrasonic Additive Manufacturing (UAM) • Selective Deposition Lamination (SDL)

AM Material Space

Process	Acronyms	Feedstock	Thermoplastics	Photopolymers	Metals	Ceramics	Composites	Biomaterials	Multimaterial	Other
Extrusion	FFF, FDM, BMD	Filament, rod pellets	●	● [1]	● (blue)	○	●	●	●	Food, Concrete
Photopolymerization	SLA, DLP, CLIP	Liquid		●	● (blue) [2]	● (blue) [3]	●	●		
Selective Laser Sintering	SLS, HSS, MJF	Powder	●			●	●			
Selective Laser Melting	SLM, DMLS, EBM	Powder			●					
Binder Jetting	BJ, 3DP	Powder			● (blue)	● (blue)		●		Sugar, Sand, Plaster, Pharmaceuticals
Material Jetting	MJ, Polyjet, Multijet	Liquid	●	●	● (blue) [4]	● (blue)		●	●	
Directed Energy Deposition	DED, LENS, EBAM	Wire, powder			●	○			●	
Sheet Lamination	LOM, UAM	Sheet	● [5]		●	○	● [6]		●	Paper

In the table:

- A full circle means that the commercially available machines using the noted process are capable of processing the noted material.
- A hollow circle means the process-material combination has been demonstrated in research or pre-release commercial announcements, but machines are not yet shipping to customers.
- Circles shaded black represent direct processes, i.e., the printing process produces a part with the desired final density and dimensions. Circles shaded blue are indirect processes, meaning that a densification step such as sintering is needed to give the part its final density and dimensions. That said, every AM process requires post-processing steps after printing, as described in the forthcoming process-specific modules.

With Additive Academy, the future of manufacturing is in your hands. Join us on a journey of exploration and mastery, where you will gain expertise in the latest polymer and metal technologies. Get ready to be a part of the revolution and leave your mark in the world of additive manufacturing. For any queries, contact contact@additiveacademy.com.

ABOUT THE AUTHOR

Pavan Kapnadak
Lead Additive Academy

Pavan is currently working as lead at Additive Academy and has rich extensive experience in additive manufacturing, sustainability and new product development.

AM NEWS

NASA Validates Propulsion Design for Deep Space Missions Made from Novel AM Methods

Rotating detonation rocket engine, or RDRE hot fire test at Marshall Space Flight Center. Credits: NASA

As NASA takes its first steps toward establishing a long-term presence on the Moon's surface, a team of propulsion development engineers at NASA have developed and tested NASA's first full-scale rotating detonation rocket engine, or RDRE, an advanced rocket engine design that could significantly change how future propulsion systems are built. The RDRE is made using novel additive manufacturing methods that allows operation in extreme conditions.

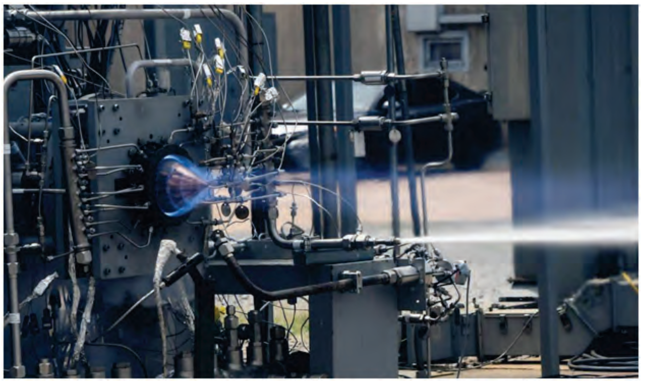
The RDRE differs from a traditional rocket engine by generating thrust using a supersonic combustion phenomenon known as a detonation. This design produces more power while using less fuel than today's propulsion systems and has the potential to power both human landers and interplanetary vehicles to deep space destinations, such as the Moon and Mars.

Engineers at NASA's Marshall Space Flight Center in Huntsville, Alabama, and primary collaborator IN Space LLC, located in West Lafayette, Indiana, are confirming data from RDRE hot fire tests conducted in 2022 at Marshall's East Test Area. The engine was fired over a dozen times, totaling nearly 10 minutes in duration.

The RDRE achieved its primary test objective by demonstrating that its hardware – made from novel additive manufacturing, or 3D printing, designs and processes – could operate for long durations while withstanding the extreme heat and pressure environments generated by detonations. While operating at full throttle, the RDRE produced over 4,000 pounds of thrust for nearly a minute at an average chamber pressure of 622 pounds per square inch, the highest pressure rating for this design on record.

The RDRE incorporates the NASA-developed copper-alloy GRCop-42 with the powder bed fusion additive manufacturing process, allowing the engine to operate under extreme conditions for longer durations without overheating.

Additional milestones achieved during the test include the successful performance of both deep throttling and internal ignition. This successful demonstration brings the technology closer to being used with future flight vehicles, enabling NASA and commercial space to move more payload and mass to deep space destinations, an essential component to making space exploration more sustainable. Because of NASA's recent success with the RDRE, follow-on work is being conducted by NASA engineers to develop a fully reusable 10,000-pound class RDRE to identify performance benefits over traditional liquid rocket engines.



Credits: NASA

RDRE is managed and funded by the Game Changing Development Program in NASA's Space Technology Mission Directorate.

UltiMaker Launches the S7 Printer

UltiMaker(R) S7

The UltiMaker S7 builds on the award winning S-Series printers, with new features including an integrated Air Manager and a flexible build plate which takes ease-of-use and reliability to a new level

UltiMaker, a global leader in desktop 3D printing, today announced the launch of the UltiMaker® S7 – the latest entry in the company's best-selling series of 'S' 3D printers.

"Over 25,000 customers innovate with the UltiMaker S5 every day, making the award-winning machine one of the market's most used professional 3D printers," says UltiMaker CEO Nadav Goshen. "With the S7, we took everything our customers loved about the S5 and made it even better." The UltiMaker S7 introduces a range of new features designed for ease of use and print reliability. A new flexible build plate makes removing prints a breeze and the integrated Air Manager filters out up to 95% of UFPs and improves temperature regulation. The S7 also features improved automated bed leveling for reliable first-layer adhesion.

Material partner, igus – who aims to deliver plastic materials for longer life – had the opportunity to preview the S7 and test the system. Their AM Development Engineer, Niklas Eutebach states: "We saw that the new bed leveling system on the S7 really helps us print very precise parts with the right mechanical properties using our materials."

Advances in temperature regulation on the S7 allow users to capitalize on the large 330 x 240 x 300 mm build volume – with reliable accuracy from the first printed layer to the last. The flexplate also provides easy part removal post printing, reducing labor so users can get on with other tasks.

Luke Taylor, Marketing Manager at Polymaker – a producer of high-performance 3D printing materials – also had the chance to test the S7 with a real customer application, printing a carbon fiber mold for the spoiler of a race car. "This part is just about as big as you can print on the S7," he explains. "It has some sharp corners, so I thought we could test out the adhesion to the new flexplate, and see how our CoPA material works with such a large part. And the results were great!"

The S7 will be compatible with the UltiMaker ecosystem of over 200 materials and offers seamless integration with industry-leading software, UltiMaker Cura, easy printing with the widest range of materials on the market, and support dedicated to customer success. "Of all the ecosystems that are available, the UltiMaker ecosystem is the most comprehensive," states Taylor.

With the S7 Pro Bundle, users can also pair the S7 with the UltiMaker Material Station to print with up to six spools with automatic material switching and humidity control.

“The UltiMaker S7 is a fantastic addition to our S-Series of printers,” says Goshen, concluding, “As more customers are using 3D printing to grow and innovate their business, our goal is to provide them with a complete solution to be successful. With the new S7, customers can be setup and running in minutes: managing printers, users, and designs with our Digital Factory software, improving their 3D printing knowledge with e-learning courses on the UltiMaker Academy, and choosing from hundreds of materials and plugins using the UltiMaker Cura Marketplace.”

Sakuu Selects Porsche Consulting for Design of Commercial-Scale Battery Manufacturing Plants

Porsche Consulting to design Sakuu's first-of-its-kind additive manufacturing gigafactory for commercial production of 3D printed lithium-metal and solid-state batteries

Sakuu, pioneer of 3D printed Swift Print™ solid-state battery technology, today announces that it has selected Porsche Consulting (“Porsche Consulting, Inc.”), a subsidiary of the automotive manufacturer Porsche, to lead all aspects of design for its planned global gigafactories. The relationship will ensure that Sakuu has preeminent expertise secured for building state-of-the-art gigafactories to meet its 2030 annual energy output goal of 200GWh across its developing energy storage product line.

“Their seminal and scalable additive manufacturing approach can bring incredible innovation to major industries transitioning to new energy solutions—automotive and beyond.”

“We're thrilled to become an integral part of Sakuu's journey as it embarks on building gigafactories that break all norms in commercial-scale energy manufacturing,” said Gregor Harman, CEO of Porsche Consulting, North America. “Their seminal and scalable additive manufacturing approach can bring incredible innovation to major industries transitioning to new energy solutions— automotive and beyond.”

Porsche Consulting's expertise in large-scale factory design, particularly in the automotive space, will enable Sakuu gigafactories that prioritize sustainable design, while maximizing manufacturing efficiencies that can be replicated efficiently across locations around the globe.

Sakuu's first plant design will accommodate roll-to-roll manufacturing for its novel line of safe, high energy density lithium-metal batteries, followed by a series of first-of-their-kind plants utilizing Sakuu's pioneering Kavian™ platform solution to produce its Swift Print™ solid-state battery line via advanced multi-material additive manufacturing.

“With respect for its deep expertise in automotive plant ideation and execution, we ultimately selected Porsche Consulting due to our belief that its team exhibits mastery in designing large-scale manufacturing plants—start to finish,” said Robert Bagheri, Founder and CEO at Sakuu. “We look forward to breaking ground on our first gigafactory with Porsche Consulting's contributions and support.”

Dior Releases its 3D-Printed Shoes

In the Paris Fashion Week, Dior offers a up-close look at its newly unveiled 3D printed shoes. The launch, which includes a Derby and boot, has been realized under the direction of Dior Menswear artistic director Kim Jones and head men's footwear designer, Thibo Denis.

While 3D printing in design has been the vision of the future for years, designers have continued pushing the envelope — from ICON's 3D-printed houses in Austin to 3D-printed turbines which generate electricity without blades. This latest shoe with its textural lattice-like surface, echoes that of the Adidas futurecraft 3D running shoe launched back in 2015. This time, the full body of the shoe is transformed with an ultra-high tech and lightweight three-dimensional patterning.

© Dior / Andrea Cenetiempo

© Dior / Andrea Cenetiempo

This newest line of 3D printed shoes by Dior is a futuristic translation of the fashion house's Carlo model. The team 3D scanned the Carlo Derby shoe and applied a digital texture to its surface. Once transformed in digital space, the new rendition emerges from a powder bed and receives final finishing touches. Unlike the originals, the new Derby is closed with a quicklace system over their glossy black leather tongue tabs. Meanwhile, the mid-calf boot is laceless. As the designers note, the new version is 'visually solid, but ultra-lightweight when worn.'

Chromatic 3D Materials qualifies for airworthiness

Passing 14 CFR vertical burn tests and demonstrating compliance with anti-flammability aviation standards

Chromatic 3D Materials, a 3D printing materials and technology provider, has passed 14 CFR vertical burn tests – which demonstrate compliance with anti-flammability standards for airworthiness. Chromatic's durable, abrasion-resistant thermoset polyurethanes are suitable for a wide variety of airline parts, including elastomeric components used in stowage compartments and decorative panels, as well as ductwork, cargo liners, fabric sealing, and many other applications.

Testing conducted by the National Institute for Aviation Research at Wichita State University showed that multiple polyurethanes 3D printed by Chromatic are compliant with United States standards for use in aircraft interiors. ChromaLast 65, ChromaMotive 70, and ChromaFlow 90 each passed the 12-second vertical burn test necessary for use in floor coverings, textiles and cushions, decorative parts, galley furnishings, electrical conduits, insulating components, ducts, cargo liners, and more. Furthermore, both ChromaLast 65 and ChromaFlow 90 passed the 60-second vertical burn test for interior panels, galleys, and under-seat stowage areas.

Having met these crucial requirements, Chromatic can now offer the aerospace market the benefits of its RX-AM materials and technology platform for additive manufacturing. These benefits include low tooling costs for low- and medium-volume manufacturing, as well as cost-effective prototyping and high-mix production. In addition to this, RX-AM makes it possible to produce high-quality components with limited material stock – allowing aerospace companies to print parts on demand, outside of traditional manufacturing environments.

"Additive manufacturing can revolutionize product design and supply chains – and it all starts with the type of materials that are available. The aviation industry has some of the most stringent materials requirements, and we are pleased that test results from the National Institute for Aviation Research prove Chromatic's materials pass with flying colors. We're confident that our industrial-strength polyurethanes will open doors for 3D printed applications in aviation as well as other industries that require safe, flame-resistant materials, including automotive, furniture, and apparel," said Dr. Cora Leibig, Founder and CEO of Chromatic.

Imaginarium and Formlabs Announce APM as a Value Added Reseller

New Delhi based 3D scanner solution provider, APM has joined the Formlabs and Imaginarium VAD Ecosystem as a value added reseller.

APM, India's largest 3D scanner solution provider joins the Formlabs Imaginarium VAD ecosystem. The New

Formlabs and Imaginarium on-boards leaders of domains and industries to become part of the VAD Ecosystem

Delhi Headquartered 3D scanner solution provider, APM has become a value added reseller of Formlabs. Through this new partnership APM will become part of an ecosystem of industry and domain leaders enabling a new age of additive manufacturing technology adoption. APM will be able to utilise Formlabs' Manufacturing Solutions to cater to a large variety of industries enabling end-use manufacturing of industrial grade parts for industries such as but not limited to automotive, healthcare and aviation. APM has revolutionised the digital, reverse-engineering & 3D scanning adoption in India and is looking to replicate their success with the adoption of additive manufacturing. in India.

The VAD ecosystem enables partners to be able to resolve customer demand for manufacturing across key industries and applications, highlighting key benefits such as but limited to, industrial-grade standards, rapid innovation, material flexibility and on-demand, localised manufacturing. The VAD ecosystem between Imaginarium and Formlabs creates a space for leaders of industry to drive innovation and foster application development for a vast range of industries. With a core ethos of driving the adoption of advanced digital manufacturing, this ecosystem educates, develops and empowers partners to challenge the status quo of manufacturing by providing ground-breaking hardware and software solutions.

Anil Gupta, Managing Director APM has stated, "This association brings together world class products from

Formlabs, coupled with extensive knowledge base of additive manufacturing from Imaginarium and more than 23 years of technical expertise and application knowledge of APM in 3D domain which is going to create a never before user experience and delight. APM is very enthusiastic to go to the industry and cater to its additive manufacturing needs knowing well that its customers will be served well in all aspects."

Imaginarium's extensive 15+ years of experience in the additive field is propelling India to become a leader in advanced and digital manufacturing. Samkitt Shah, Business Head of Imaginarium Solutions has stated, "We are ecstatic to build a family of industry leaders to enable an ecosystem of advanced industrial-grade, high-value digital manufacturing. APM, Imaginarium and Formlabs are aligned towards a common vision of democratising manufacturing hence, empowering India's ambition needs."

Formlabs is the professional 3D printer of choice for engineers, designers, manufacturers, and decision makers around the globe. As a driving force of additive manufacturing adoption across the globe, Formlabs has created an ecosystem of software, hardware and qualified applications for a range of industries. With a material library of over 30 resins and powders, Formlabs caters to a melting pot of industries across the world, ranging from healthcare and dental to engineering and jewellery.

Imaginarium's vision is focused on evangelising the manufacturing landscape in India; enabling the country to become a powerhouse of advanced manufacturing. To facilitate this vision, Imaginarium is fostering partnerships with leading 3D printer manufacturers across the globe, creating a gateway for innovation and technology-advancement.

Energy companies set out to standardize digital supply of spare parts

ConocoPhillips, Equinor, Shell,TotalEnergies and VårEnergi- together with the software company Fieldnode- show a firm commitment to develop a digital foundation to build a network forsupply of spare parts produced on demand through additive manufacturing technology.

Some of the world's largest energy companies have now signed an Industry Collaboration Agreement to set an industry standard for a digital inventory ecosystem.

The agreement is a two-year partnership with the goal to scale up the digital ecosystem to drastically reduce lead times, physical inventories, total cost of ownership, materials waste and reduce shipping distances, improving the overall environmental impact, efficiency, and security of the supply chain.

The technology to achieve the above-mentioned benefits is available,however to really scale this, the partners in the collaboration see it necessary to establish a fit for purpose standard process to utilize the technology and transact in the new ecosystem and have therefore entered the collaboration, to solve the challenges together which the whole energy sector would benefit from.

Standardization around qualification processes,a new commercial model that caters for mass customization and improved total cost of ownership for customer vs. traditional volume-based incentives, are some of the areas that are set out to be addressed in the collaboration project.

To reach the set goals the partners in the collaboration intend to progressively invite their current suppliers, independent additive manufacturers as well as other suppliers to collaborate on the platform throughout the two years to ensure the whole industry can benefit from this transformation. By collaborating with the above-mentioned entities, the project partners intend to both test the technical and commercial solutions as well as fill the digital inventory with content.

The foundational technical solution is the Fieldnode platform which was developed through a Joint Industry Project with Fieldnode, Equinor and TotalEnergies. The platform facilitates efficient and resilient operation of supply networks to support the oil and gas operators to share limited supply chain resources. The collaboration agreement gives the opportunity to further develop needed industry standards to scale this and thereby secure supply of spare parts and at the same time reduce the environmental footprint.

Shree Rapid Technologies announces partnership with API Metrology in India

Shree Rapid Technologies (SRT) is a leading 3D Printing and 3D Scanning solutions providers in India. SRT is proud to announce the partnership with the Pune based API Metrology India, a subsidiary of Automated Precision Inc., manufacturer of world class 3D metrology solutions.

This partnership that will aid manufacturers to effectively conduct Reverse Engineering, Inspection and Alignment, First Article Inspection, Production Measurement, Prototype Inspection, Calibration, etc. API has pioneered advancements in laser-based metrology equipment for industrial

inspection and calibration. API is continually developing products to deliver innovation and automation to the manufacturing floor.

With the backing of decades of 3D Scanning and Inspection experience, SRT saw a synergy with API Metrology India in serving the Indian Manufacturing industry, by providing a technology that would propel the time and precision to manufacture.

Mr. Nitin Chaudhari, Partner – Shree Rapid Technologies stated:

"Shree Rapid Technologies is excited to add another product in its portfolio for measurements of small sized parts (in mm) up to very large parts (of up to 80 mts) be it optical mode contact Scanning mode or Laser source measurements. This partnership with API Metrology completes our search for measurement of intricate shapes, sizes and processes that are now in demand for Space, Aeronautics and Defence Manufacturing organizations."

Mr. Vaibhav Shah, Managing Director, API Metrology India expressed excitement about the collaboration with SRT:

"API India is growing at a rapid pace and closed one of the best year of business in 2022, looking forward with much bigger goals for next 3 years, API believes to have a strong reseller network and SRT fits perfectly with the past 14 years' experience in metrology and scanning with a strong team and excellent market presence. API's brand new 9D LADAR is the future of automated scanning and the best way to measure small to large component of any shape and size. It will completely change the way 3d scanning is done today. We wish SRT team all the best and support to

make 2023 a great start of this new journey and to make it successful."

About Shree Rapid Technologies

Shree Rapid Technologies, an industry leader in supplying Additive Manufacturing & 3D Scanning Technology and Services through global brands such as 3D Systems, Formlabs, 3D Ceram, Miicraft, DyeMansion, ZEISS, Hands on Metrology, BMF, BCN3D, MAE, Cartacci, Techmata, Titomic and more was founded in 2007 by Mr.Nitin Chaudhari & Mr. Shashidhar Kumar who were one of the first promoters of Additive Manufacturing in India. With their continuous efforts SRT became the backbone of 3D printing services. SRT also launched a unique Customer Innovation Centre in Mumbai to give clients a glimpse of the 3D Printing world housing all the technologies under one roof, enabling 3D technologies and AM workflows in India aiming to grow and make a Atmanirbhar Bharat.

About API Metrology India

API Metrology India, based in Pune, is the subsidiary of Automated Precision Inc. and it is into portable metrology solutions. API is the known name in laser trackers and machine tool calibration market in India. For more than three decades, API's advanced dimensional metrology equipment has developed customized solutions for leading companies, like Boeing, Lockheed Martin, Northrop Grumman, Voith Hydro, and Ford. API's award-winning products, including Radian Laser Tracker, XD Laser, and automated inspection equipment, are manufactured in the US for companies globally. API Services specializes in 3D measurements and high-volume metrology solutions and is home to some of the world's leading metrology technical experts. With over 200 years combined experience, they are the authority on 3D measurement systems from trackers to digital photogrammetry to 3D Scanning and beyond. API's products and services can be used for part inspection, assembly, calibration, machine tool error mapping, 3D CAD modelling, and reverse engineering.

Dubai To Build World's First 3D-Printed Mosque

An artist's impression of the mosque. Photo: Islamic Affairs and Charitable Activities Department in Dubai

Plans to build the world's first fully functional 3D-printed mosque have been unveiled in Dubai. The construction of the 2,000-square-metre mosque in Bur Dubai will start in October and the mosque will be ready for 600 worshippers early in 2025.

It will take about four months to complete the 3D printing of the building's structure and a further 12 months to fully fit it out with the appropriate facilities,

Samples of 3D printed structures that will be used for the mosque in Dubai. Ali Al Shouk / The National

Dubai's Islamic Affairs and Charitable Activities Department (IACAD) said. Three workers will operate the 3D robotic printer which will print two square metres an hour.

Ali Al Suwaidi, director of IACAD's engineering department, said the printer will mix raw materials and a special mix of concrete. The printing process works by layering a fluid material along a predetermined route mapped out by a computer, similar to an inkjet printer. The mineral-infused fluids solidify into concrete almost instantly to convert the digital model into a three-dimensional object.

"The cost is 30 per cent higher than building the mosque in the normal way because it is the first of its kind in the world," Mr Al Suwaidi told a press conference on Thursday.

"We expect the cost will be similar in the future with 30 years building guarantee."
The IACAD is co-ordinating with Dubai Municipality to get final approvals on the design. The mosque marks the latest step in Dubai's 3D Printing Strategy, which is a global initiative to harness the technology for the good of humanity and position the city as a leader in the field by 2030.

Hamad Al Shaibani, Director General of IACAD, said Dubai is a pioneer in using 3D printing technology and sustainability that will reduce carbon footprint.

"Using 3D printing will reduce the construction material wastes. It is friendly to the environment. The mosque represents the vision of our wise leadership," he said.

In 2015, Dubai unveiled plans to build the world's first 3D-printed office which was opened outside Emirates Towers in May 2016. Three years later Dubai built the largest 3D-printed building — a two-storey property in Warsan that became Dubai Municipality's Centre for Innovation.

In August 2021, Sheikh Mohammed bin Rashid, Vice President and Ruler of Dubai, issued a decree to regulate the use of 3D printing in the construction industry in Dubai, to promote the emirate as a regional and global centre for the technology. The legislation was aimed at ensuring that a quarter of the emirate's buildings are built using the technology by 2030. Expo 2020 Dubai had a specialised 3D-printing area which included a research centre, an academy and laboratories to help to develop the technology.

Tvasta Constructs Kolkata's First 3D Printed Structure at Garden Reach Shipbuilders and Engineers (GRSE)

Source: TvastaShare on twitter

Tvasta Manufacturing Solutions, which specializes in Construction 3D Printing, has constructed Kolkata's first 3D Printed structure at Garden Reach Shipbuilders and Engineers (GRSE) Limited, a nationalised shipyard. This is the first project in a series of potential large-scale construction projects using 3D printing for GRSE.

The structure, constructed in 10 days by Tvasta at this Nationalized shipyard, demonstrates the capability of advanced construction technology

Giridhar Aramane, IAS, Defence Secretary, Government of India, inaugurated the Structure during a ceremony on 31December 2022. The 3D printed Site Office Project, which was built as a technology Demonstrator, would be utilized by GRSE for monitoring Anti-submarine Warfare Shallow Water Crafts (ASWSWCs).

The 3D Printed Modular Site Office was designed and executed in 10 days. It has a size of 180 square feet and has a customized design providing a comfortable working space for 6 to 8 people. An Offsite Construction Methodology was followed for this project.

The printing of modules of the structure was completed in 2.5 days at Tvasta's factory in Chennai. It was transported to the site location in the form of modules, which enables swift assembly and finishing and efficient use of labor.

Garden Reach Shipbuilders and Engineers (GRSE) Limited is a Mini Ratna Category 1 Company that has so far delivered 108 warships to India and other countries. It is an integral part of Indian Defense preparedness to produce the most modern warships through indigenization for the country aimed at self-reliance

Elaborating on the need for such projects, Adithya VS, Co-Founder and Chief Executive Officer, Tvasta Manufacturing, said, “This project depicts the necessity and capability of advanced construction technology in the infrastructure development of the country across various sectors. The execution strategy for the current project incorporated an optimal use of durable materials to ensure robustness and sustainability, thereby generating less wastage and a lower carbon footprint. Tvasta is currently focusing on modular construction such as this structure which will be a useful solution for quick infrastructure and 'assemblable buildings'.”

Construction 3D printing is an additive manufacturing process where the material is added layer by layer to build a structure. Operated through an automated system, this is a purely Industry 4.0 era technology and can be termed as 'digitized construction.' 3D Printing is a modern technology adapted to automate the construction process to a considerable degree.

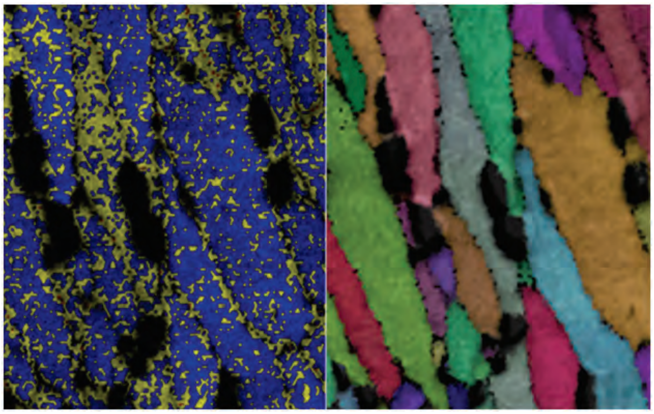
Founded in 2016 by IIT Madras Alumni, Tvasta developed a 'Made in India' technology focusing on leveraging Automation and Robotics in 3D Printing Platforms for faster, economical and sustainable construction methods compared to conventional technologies. The start-up is currently based out of Chennai and Bengaluru.

India's First 3D Printed House was constructed by Tvasta in the IIT Madras Campus, demonstrating its capabilities and feasibility in the actualization of a physical structure. This pilot structure along with the indigenously developed technology also marks the start-up's endeavours in highlighting a potential alternative solution that may address India's housing and infrastructure challenges.

Additionally, Tvasta has successfully constructed India's first 3D printed Monument, “Ananta Siras” for the 75th Anniversary of The India Cements Ltd. in Chennai last year.

Research and Development News

Scientists use neutrons to discover strengthening behavior in alloys



A team of ORNL researchers used neutron diffraction experiments to study the 3D-printed ACMZ alloy and observed a phenomenon called "load shuffling" that could inform the design of stronger, better-performing lightweight materials for vehicles. Credit: ORNL, U.S. Dept. of Energy

A team of ORNL researchers used neutron diffraction experiments to study the 3D-printed ACMZ alloy and observed a phenomenon called "load shuffling" that could inform the design of stronger, better-performing lightweight materials for vehicles.

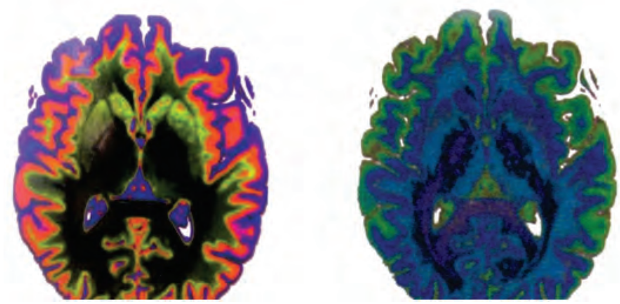
Oak Ridge National Laboratory researchers have identified a mechanism in a 3D-printed alloy – termed "load shuffling" — that could enable the design of better-performing lightweight materials for vehicles.

One way to improve energy efficiency in vehicles is to make them lighter with aluminum-based materials. Researchers monitored a version of ORNL's ACMZ — aluminum, copper, manganese and zirconium — alloy for deformation that occurs when the material is under persistent mechanical stress at high temperatures.

Using neutron diffraction, researchers studied the material's atomic structure and observed that the overall stress was absorbed by one part of the alloy but transferred to another part during deformation. This back-and-forth shuffling prevents strengthening in some areas.

"Neutrons offer opportunities to study metallurgical phenomena in multiphase structural materials," ORNL's Amit Shyam said. "We've gained unprecedented insight into elevated-temperature material behavior that will allow us to design improved aluminum alloys for extreme conditions."

CU research team moves one step closer to printing models of life-like 3D organs



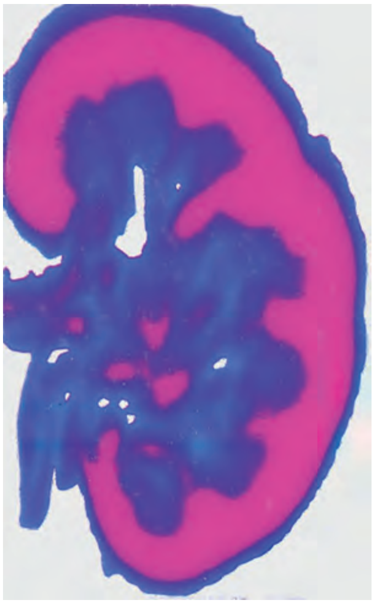
Digital representations of a human brain created using a technique developed by researchers at CU Boulder and the CU Anschutz Medical Campus. (Credit: Jacobson, et al., 2022, 3D Printing and Additive Manufacturing; CC-BY 4.0)

A team of University of Colorado researchers has developed a new strategy for transforming medical images, such as CT or MRI scans, into incredibly detailed 3D models on the computer.

The advance marks an important step toward printing lifelike representations of human anatomy that medical professionals can squish, poke and prod in the real world.

The researchers describe their results in a paper published in December in the journal 3D Printing and Additive Manufacturing.

The discovery stems from a collaboration between


Voxel map of a cross section of a human kidney. (Credit: Nicholas Jacobson)

scientists at CU Boulder and CU Anschutz Medical Campus designed to address a major need in the medical world: Surgeons have long used imaging tools to plan out their procedures before stepping into the operating room. But you can't touch an MRI scan, said Robert MacCurdy, assistant professor of mechanical engineering and senior author of the new study.

His team wants to fix that, giving doctors a new way to print realistic, and graspable, models of their patients' various body parts, down to the detail of their tiny blood vessels—in other words, a model of your very own kidney entirely fabricated from soft and pliable polymers.

“Our method addresses the critical need to provide surgeons and patients with a greater understanding of patient-specific anatomy before the surgery ever takes place,” said Robert MacCurdy, senior author of the new paper and an assistant professor of mechanical engineering at CU Boulder.

The latest study gets the team closer to achieving that goal. In it, MacCurdy and his colleagues lay out a method for using scan data to develop maps of organs made up of billions of volumetric pixels, or “voxels”—like the pixels that make up a digital photograph, only three-dimensional.

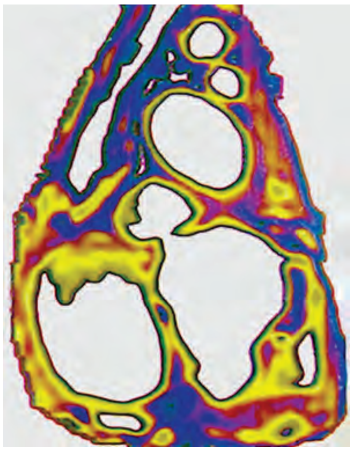
The researchers are currently experimenting with how they can use 3D printers to turn those maps into physical models that are more accurate than those available through existing tools.

The project, which is led by MacCurdy and CU Anschutz' Nicholas Jacobson, is funded by AB Nexus, a grant program that seeks to spur new collaborations between the two Colorado campuses.

“In my lab we look for alternative ways of representation that will feed, rather than interrupt, the thinking process of surgeons,” said Jacobson, a clinical design researcher at the Inworks Innovation Initiative. “These representations become sources of ideas that help us and our surgical collaborators see and react to more of what is in the available data.”

Slicing the orange

Human organs are complicated—made up of networks of tissue, blood vessels, nerves and more, all with their own texture and colors.


Voxel map of a cross section of a human heart. (Credit: Nicholas Jacobson)

Currently, medical professionals try to capture these structures using “boundary surface” mapping, which, essentially, represents an object as a series of surfaces.

“Think of existing methods as representing an entire orange by only considering the exterior orange peel,” MacCurdy said. “When viewed that way, the entire orange is peel.”

His team's method, in contrast, is all juicy insides.

The approach begins with a Digital Imaging and Communications in Medicine (DICOM) file, the standard 3D data that CT and MRI scans produce. Using custom software, MacCurdy and his colleagues convert that

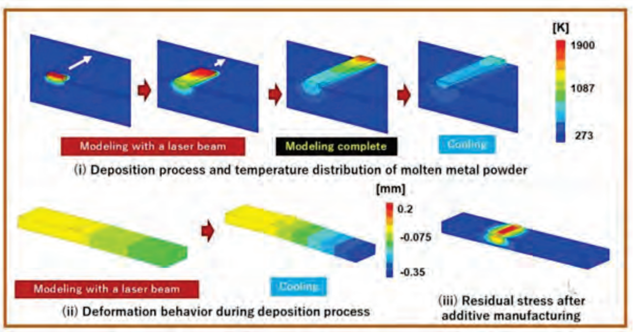
information into voxels, essentially slicing an organ into tiny cubes with a volume much smaller than a typical tear drop.
And, MacCurdy said, the group can do all that without losing any information about the organs in the process—something that's impossible with existing mapping methods.

To test these tools, the team took real scan data of a human heart, kidney and brain, then created a map for each of those structures. The resulting maps were detailed enough that they could, for example, distinguish between the kidney's fleshy interior, or medulla, and its outer layer or, cortex—both of which look pink to the human eye.

“Surgeons are constantly touching and interacting with tissues,” MacCurdy said, “So we want to give them models that are both visual and tactile and as representative of what they're going to face as they can be.”

A New “Digital Twin” of Laser-Directed Energy Deposition Repair Technology

Conventional metal 3D-printed repair of damaged mechanical parts in machines requires bulky equipment and wastes metal powder. Although laser-directed energy deposition overcomes this challenge, the optimum forming conditions had to be hitherto determined by trial and error. To this end, a team of researchers from Tokyo University of Science have developed a numerical method that automatically generates metal powder deposition elements and predicts forming process conditions, temperature distribution, deformation state, and residual stress distribution in advance.



A diagram showing how the TUS team's mathematical model works. Image via the Tokyo University of Science.
Researchers develop a numerical processing analysis system that automatically determines optimum forming conditions using digital twin

Mechanical parts in industrial machinery and structures that develop thinning or cracks need to be replaced with new ones. In recent years, attempts to repair them have been considered, in order to improve industrial sustainability. So, repair technology for machines has been a hot topic of research and development. Conventional metal 3D-printed fabrication uses the surface of a mechanically laid powder bed that is irradiated with a laser or electron beam to melt the metal particles and fuse them. However, this method requires bulky fabrication equipment. Also, a large amount of metal powder is disposed after the fabrication process. However, laser-directed energy deposition (LDED) is a promising technology that overcomes the challenges. In this technique, metal powders are deposited at the focus of a laser beam, then melted and stacked.

The advantages of LDED are not only related to the compactness of the equipment, but also the significant reduction of metal powder waste. Furthermore, this technology enables in-situ metal powder fabrication in a 3D shape on the surface of a substrate. This means it can be used to repair machines made of metal as well!
A group of researchers, which include Professor Masayuki Arai from the Department of Mechanical Engineering, Faculty of Engineering, Tokyo University of Science (TUS), Japan, Mr. Toshikazu Muramatsu, also from TUS, and Dr. Kiyohiro Ito from Department of Mechanical and Electrical Engineering, Suwa University of Science, Japan, has, in collaboration with the Thermal Spray Technology Development Laboratory of TOCALO Co. Ltd., Japan, developed a repair technique using LDED.“Using our technique, the surface shape of a metal structure can be completely restored on-site, and the disposal of the metal powder required for repair can be significantly reduced. However, the optimum forming conditions required for the

widespread application of this technology in industry had to be hitherto determined by a trial-and-error process," explains Prof. Arai, who has been actively involved in the research of damage mechanics and repair technology.

In a recent article published in Journal of Thermal Spray Technology on November 23, 2022, the researchers have devised a mathematical model of LDED that automatically generates a metal powder deposition region using a death-birth algorithm, eliminating the guesswork needed to optimize the production."The thermal radiation-thermal conduction model and the viscoplastic-thermoplastic constitutive model are applied to the stacked elements that constitute the deposited region, so that a wide range of state changes from melting to solidification of the deposited layer of metal powder can be faithfully simulated. By incorporating these models into a finite element analysis program, we have developed a new machining analysis system that has never been used before", notes Prof. Arai. The team numerically simulated the restoration process, and thus, predicted the forming process conditions, temperature distribution, deformation state, and residual stress distribution in advance and verified the findings through experiments. They found that the residual stresses in the deposited layer were much lower than those obtained via conventional repair processes.

This novel 3D machining numerical analysis system is a digital twin of the existing core machining technology based on the fusion of metal in the area to be repaired. The numerical analysis method developed here could be applied to various industrial applications in the future, such as planning the repair of cavitation thinning on the surface of a blade used in power plant's circulating pump and devising a method for reducing residual deformation after repairing the thinning of the tip of a gas turbine's rotor blade. Taken together, the features of automation and advance prediction of process conditions by the numerical machining analysis system make 3D metal layered metal fabrication by LDED repair technology more effective, with efficient resource management to improve its sustainability.

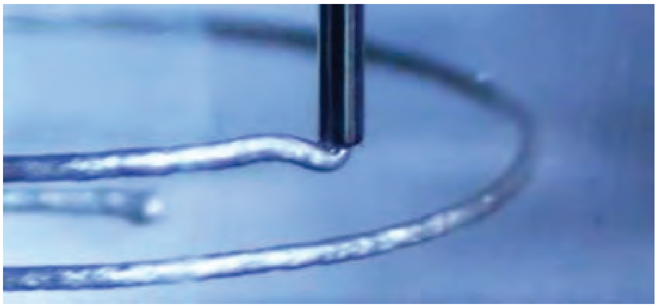
A new approach for the 3D printing of hydrogel-based electronics

3D printed all-hydrogel ECG electrode. Credit: Hui et al.

A research team led by Dr. Nanjia Zhou at Westlake University and Westlake Institute of Advanced Studies in China have recently introduced a new strategy to enable the 3D printing of soft hydrogel electronics. Their approach, introduced in a paper published in Nature Electronics, could help to lower the production costs of numerous hydrogel-based devices, including strain sensors, inductors, and biological electrodes.

Hydrogels are three-dimensional (3D) polymer networks that do not dissolve in water but retain large amounts of liquids. Due to this advantageous property, hydrogels are particularly promising material platforms for both biomedical and environmental applications, as they can survive in bodily fluids or in wet natural environments without dissipating.

Over the past decade, engineers and materials scientists have been developing numerous electronic devices based on soft hydrogels, including environmental and biomedical sensors, drug delivery devices, and artificial tissue. Despite the huge potential of these hydrogel-based devices, their widespread implementation has so far been hindered by their high production costs.

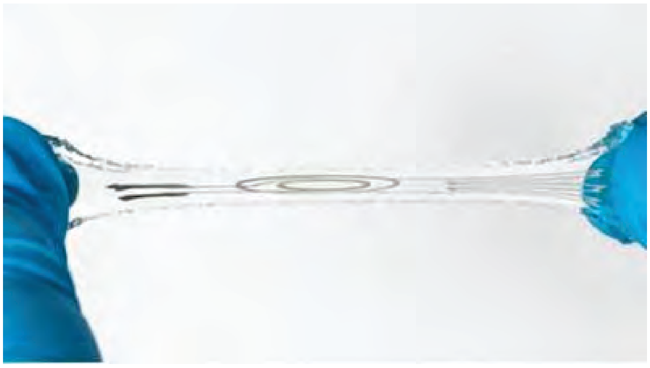


Freeform printing of the conductive ink in hydrogel supporting matrix. Credit: Hui et al.

"We choose to study hydrogel production because while most of the current soft electronics are based on flexible elastomers and polymers, undeniably hydrogel is more similar to the human body and may lead to better tissue integration and less immune responses," Dr. Yue Hui, one of the researchers who carried out the study, told TechXplore. "As suggested by previously studies, we think that hydrogel is a promising candidate for the creation of future health care electronic devices."

The primarily goal of the recent study by Hui and his colleagues was to devise an efficient strategy to fabricate increasingly complex and biomedically useful hydrogel-based electronics. Their proposed approach is based on 3D printing technology, specifically utilizing a hydrogel-based supporting matrix and a stretchable silver-hydrogel ink.

"The embedded 3D printing method we developed involves the freeform printing of a conductive hydrogel ink into a hydrogel supporting matrix, and the subsequent curing of the two parts to form a soft and stretchable electronic device," Hui explained. "These are based on the suitable rheological properties of the matrix and the ink, as well as the orthogonal curing mechanism of alginate and polyacrylamide, which are the main components of the hydrogel."

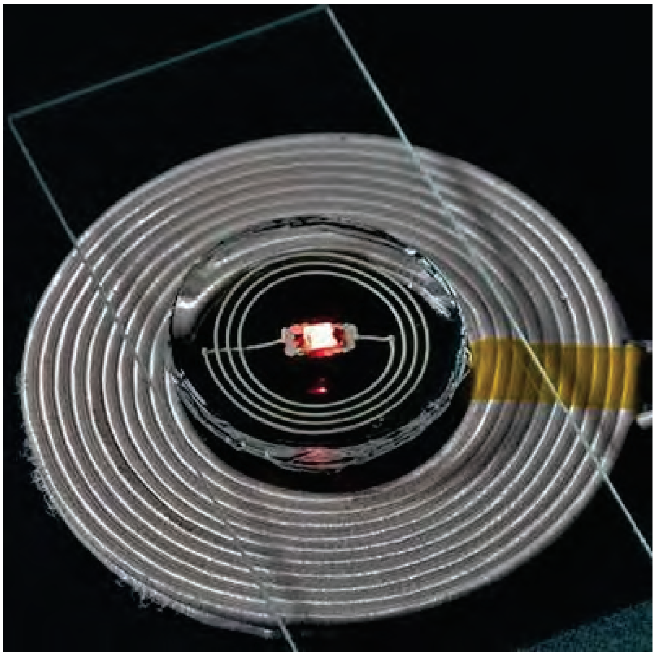


Stretchable 3D printed hydrogel electronics. Credit: Hui et al.

The researchers found that combining a conductive filler (i.e., silver flakes) with granular gel particles led to the formation of a segregated structure in the conductive 3D printing ink. This ink exhibited a remarkable electrical conductivity of over 1,400 S/cm.

To demonstrate the feasibility of their proposed strategy, Hui and his colleagues used it to create a series of hydrogel-based electronics, including strain sensors, inductors and biological electrodes. The resulting devices were found to perform exceptionally well, suggesting that this approach could be used to create a range of new hydrogel-based technologies.

"As we demonstrate in our paper, our method can be used to make various hydrogel electronic devices with different functionalities," Hui said. "Particularly, we can directly print exposed electrodes that can



LED lit up wirelessly by a 3D printed hydrogel inductor. Credit: Hui et al.

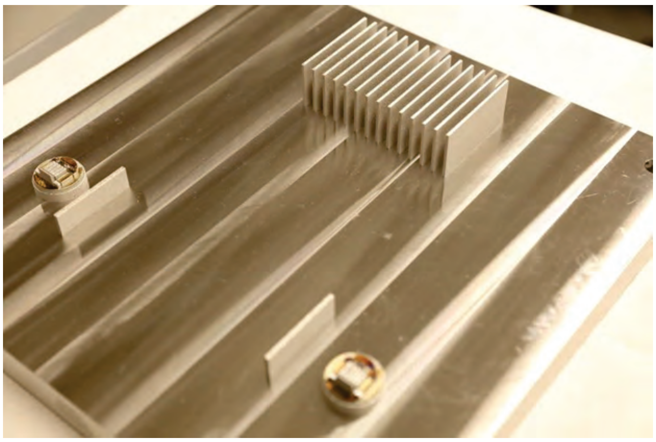
communicate with the outside world, and we can incorporate components such as LEDs and chips into the circuitry via printing. Our findings imply that with delicate design we can really make functional hydrogel electronic devices."

In the future, the recent work by this team of researchers could enable the fabrication of more complex and sophisticated hydrogel-based electronics, including biomedical devices and new technologies to monitor the environment. Hui and his colleagues are now working to improve their 3D printing strategy to further facilitate its real-world and large-scale implementation.

"We will now keep optimizing the materials and methods," Hui added. "For example, a systematic and theoretical study regarding the conductive ink with segregated structure is still lacking, which may be the key to further improve its conductivity. We also plan to design and fabricate biomedical devices and validate their functionalities in animals."

Detecting additive manufacturing defects in real-time

A research team led by Tao Sun, associate professor of materials science and engineering at the University of Virginia, has made new discoveries that can expand additive manufacturing in aerospace and other industries that rely on strong metal parts. Their peer-reviewed paper was published Jan. 6, 2023, in Science. It addresses the issue of detecting the formation of keyhole pores, one of the major defects in a common additive manufacturing technique called laser powder bed fusion, or LPBF.



A sample of additive metal manufacturing produced using a machine learning approach in combination with operando synchrotron x-ray imaging. Credit: Photo by Tom Cogill for UVA Engineering

Introduced in the 1990s, LPBF uses metal powder and lasers to 3-D print metal parts. But porosity defects remain a challenge for fatigue-sensitive applications like aircraft wings. Some porosity is associated with deep and narrow vapor depressions which are the keyholes.

The formation and size of the keyhole is a function of laser power and scanning velocity, as well as the materials' capacity to absorb laser energy. If the keyhole walls are stable, it enhances the surrounding material's laser absorption and improves laser manufacturing efficiency. If, however, the walls are wobbly or collapse, the material solidifies around the keyhole, trapping the air pocket inside the newly formed layer of material. This makes the material more brittle and more likely to crack under environmental stress.

Sun and his team, including materials science and engineering professor Anthony Rollett from Carnegie Mellon University and mechanical engineering professor Lianyi Chen from the University of Wisconsin-Madison, developed an approach to detect the exact moment when a keyhole pore forms during the printing process.

"By integrating operando synchrotron X-ray imaging, near-infrared imaging, and machine learning, our approach can capture the unique thermal signature associated with keyhole pore generation with sub-millisecond temporal resolution and 100% prediction rate," Sun said.

In developing their real-time keyhole detection method, the researchers also advanced the way a state-of-the-art tool—operando synchrotron X-ray imaging—can be used. Utilizing machine learning, they additionally discovered two modes of keyhole oscillation.

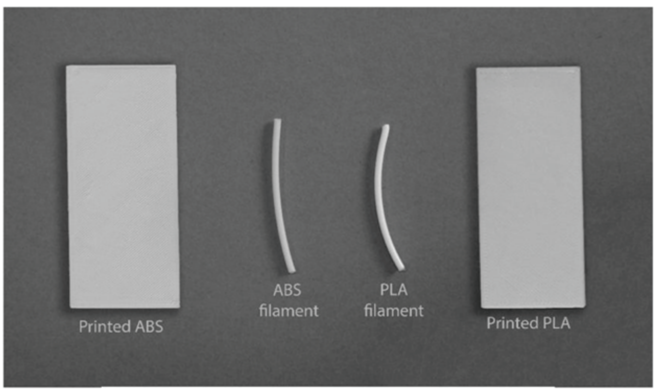
"Our findings not only advance additive manufacturing research, but they can also practically serve to expand the commercial use of LPBF for metal parts manufacturing," said Rollett. Rollet is also the co-director of the NextManufacturing Center at CMU.

"Porosity in metal parts remains a major hurdle for wider adoption of LPBF technique in some industries. Keyhole porosity is the most challenging defect type when it comes to real-time detection using lab-scale sensors because it occurs stochastically beneath the surface," Sun said. "Our approach provides a viable solution for high-fidelity, high-resolution detection of keyhole pore generation that can be readily applied in many additive manufacturing scenarios."

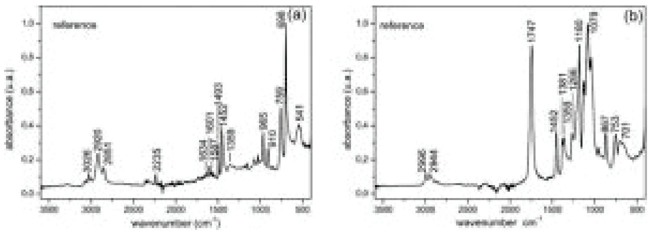
More information: Zhongshu Ren et al, Machine learning–aided real-time detection of keyhole pore generation in laser powder bed fusion, Science (2023). DOI: 10.1126/science.add4667

Researchers Tested Time Depended Performance of 3D Printing Materials Used for Art Projects

A team of researchers at Universidad Complutense de Madrid, has tested two of the most popular materials used to 3D print useful objects, including those used for art projects, to see how well they might stand the test of time. In their paper published in Journal of Cultural Heritage, the group describes subjecting 3D printed objects to heat and UV radiation.



The researchers began by noting that many of the materials used to create art objects in the past have shown strong resilience to the passage of time. For instance, drawings on rocks made thousands of years ago, or sculptures and paintings made hundreds of years ago, are still around today. They then noted that many future art objects may be created using 3D printing, which got them to wondering if such objects may last as long as more traditional media.



Reference FTIR spectrum of ABS (a) and PLA (b). Credit: Journal of Cultural Heritage (2022). DOI: 10.1016/j.culher.2022.12.005

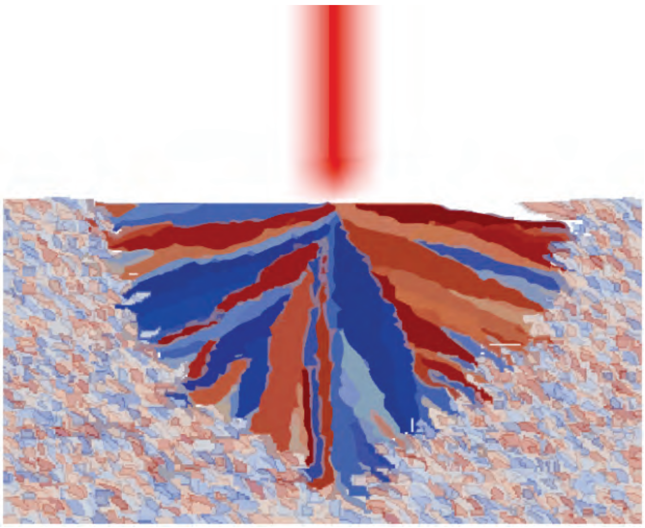
To find out, they tested two of the main materials currently used to print 3D objects: polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS). Testing involved applying two of the main things that lead to degradation of materials—heat and UV radiation—in an accelerated way.

The researchers placed 3D-printed objects (along with some samples of the "ink" used to print the objects) in an oven and heated them to different temperatures over different time periods. They did the same with objects placed in a chamber that emitted different amounts of UV radiation. They also subjected some of the objects to both tests.

The researchers found that both types of materials underwent some degree of chemical change, though PLA tended to do better. They also found that ABS tended to lose more of its color and lost more of its structural integrity than PLA. The researchers suggest that art objects made with current 3D-printing technology are not likely to last as well as more traditional materials. They plan to continue their work by testing other materials and other stressors.

References: Margarita San Andrés et al, Use of 3D printing PLA and ABS materials for fine art. Analysis of composition and long-term behaviour of raw filament and printed parts, Journal of Cultural Heritage (2022). DOI: 10.1016/j.culher.2022.12.005

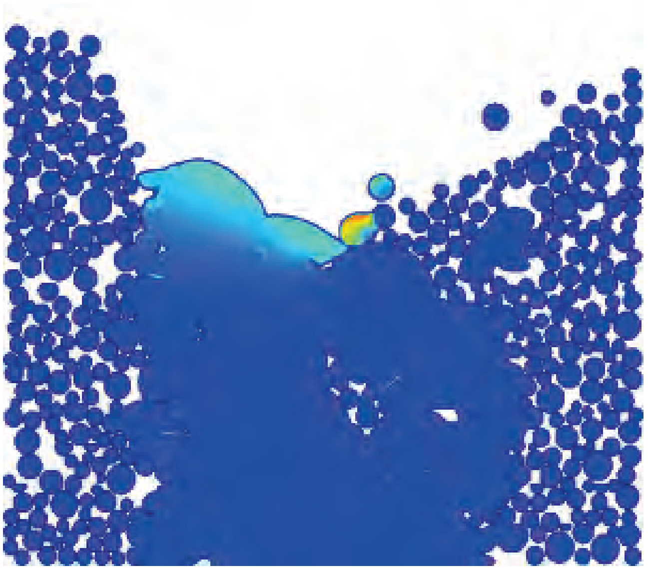
Fraunhofer Institute Researchers Develop Solution To Simulate the Entire Process Chain of Laser Powder Bed Fusion



© Fraunhofer IWM Simulation of the formation of a columnar microstructure in the laser melt pool

Additive manufacturing of tools using a laser powder bed fusion process offers a great number of advantages: It is economical, precise and allows for customized solutions. That said, it can be difficult to determine the optimal process parameters, such as the scan speed or power of the laser. For the first time, researchers at Fraunhofer are now simulating the process at the microstructure level in order to identify direct correlations between the workpiece properties and the selected process parameters. To do this, they are combining a number of different simulation methods.

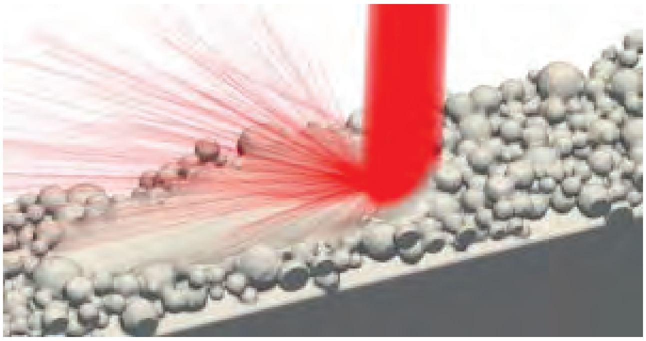
Additive manufacturing offers numerous advantages. Most notably, energy and materials can be saved, and complex component geometries and customized products can also be realized. The laser powder bed fusion process, or LPBF for short, is a widely used process for the additive manufacturing of components and tools: This process impresses with its short innovation cycles and high cost-effectiveness. The principle here is that a powder bed up to 50 micrometers thick is heated with pinpoint accuracy by a laser. The powder liquefies, the particles fuse and the melt pool solidifies as soon as the laser moves on. In areas where the laser beam does not come into contact with the powder, no fusion occurs. This process is repeated numerous times, causing the component to grow in height layer by layer.



© Fraunhofer IWM: Simulation of the LPBF pro-cess with lack of fusion defects and residual porosity

It is important that the finished component has a density of one hundred percent, no pores, and that each newly applied layer binds firmly to the layer below. This is achieved by adjusting the process parameters, such as the scan speed and power of the laser. The microstructure of metallic grains is particularly important for the mechanical properties of the workpiece. These have certain orientations, sizes and shapes and have a considerable impact on the mechanical properties, such as the material's elastic modulus or the yield stress – i.e., the load above which the material deforms plastically.

So the question is: How do you control the process in such a way that the resulting microstructure is suited to the component's future conditions of use? Furthermore, components and workpieces are often made out of different metallic alloys: steels, aluminum alloys, titanium alloys with various compositions and mixing ratios. Each alloy material has different properties and forms different microstructures. Finding the optimal process parameters and materials and matching them to each other has, up to this point, been an experimental and therefore time-consuming endeavor.



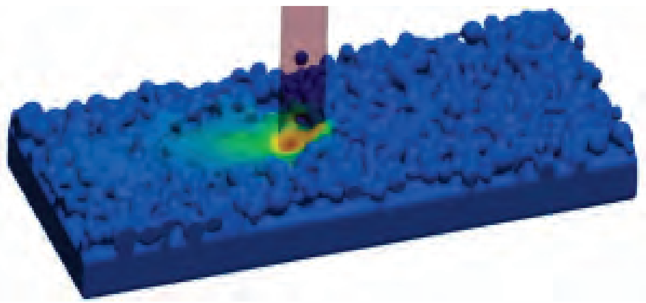
© Fraunhofer IWM: Raytracing simulation of the LPBF process

Simulating the entire process chain

Researchers at the Fraunhofer Institute for Mechanics of Materials IWM are now taking a different approach. "Because the laser powder bed fusion process is becoming increasingly complex due to new materials and requirements, we have decided to simulate the entire process chain," explains Dr. Claas Bierwisch, team leader at Fraunhofer IWM. "This enables us not only to minimize trial-and-error cycles, but also to quickly and effectively evaluate variations in the overall process and eliminate undesirable effects during manufacturing."

The important thing here is that the researchers have combined different simulation methods. Using the discrete element method, they first simulate how the individual powder particles are spread in the building chamber with the aid of a special tool, namely the doctor blade. Next, the way in which the powder particles melt is simulated using the smoothed particle hydrodynamics method – both the laser interaction and heat conduction are calculated, as well as the surface tension that causes the melt to flow. The calculation also accounts for gravity and the recoil pressure that occurs when the material vaporizes.

The simulation must also describe the microstructure of the material in order to predict mechanical material properties. "To analyze this microstructure, we have incorporated another simulation method, known as cellular automaton. This describes how the metallic grains grow as a function of the temperature gradient," explains Bierwisch. This is because temperatures can reach up to 3,000 degrees Celsius where the laser meets the powder, but only a few millimeters away, the material is cool. Furthermore, the laser moves over the powder bed at a speed of up to several meters per second. As a result, the material heats up extremely quickly but then also cools down again within milliseconds. All of this has an impact on how the microstructure is formed. The final step is the finite element simulation: The research team uses this to perform tensile tests in different directions on a representative volume element of the material in order to find out how the material reacts to these loads.



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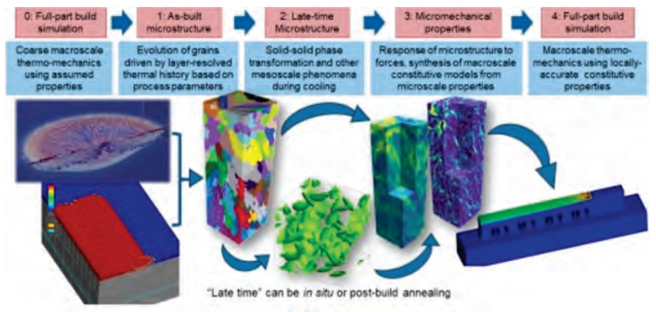
Simulation of the LPBF process with color-coded temperature field

"In the experiment, we can only study the final result, whereas in the simulation, we can watch what happens in real time. In other words, we create a process-structure-property relationship: For example, if we increase the laser power, the microstructure changes. This, in turn, significantly affects the yield stress of the material. The quality of this is completely different to what is possible in an experiment," says Bierwisch, enthusiastically. "You can detect interrelationships in an almost investigative way."

DOE labs using exascale computing to advance additive manufacturing



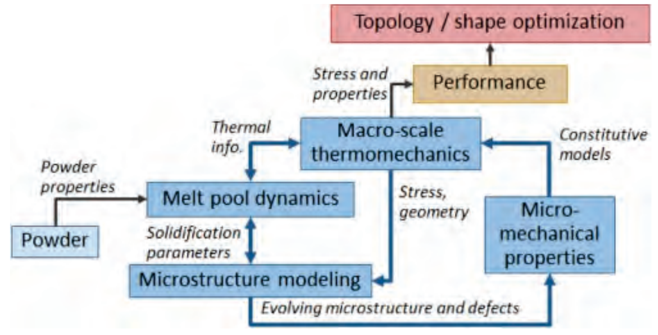
The five stages of the ExaAM simulation workflow. Turner et al.

Researchers at Oak Ridge National Laboratory (ORNL) and Lawrence Livermore National Laboratory, with collaborators from Los Alamos National Laboratory, National Institute of Standards and Technology and the University of Tennessee, Knoxville, are advancing the Exascale Additive Manufacturing project (ExaAM). ExaAM seeks to use exascale simulation to enable the design of additive manufacturing (AM) components with location-specific properties and the acceleration of performance

ExaAM aims to develop the Integrated Platform for Additive Manufacturing Simulation (IPAMS), a suite of exascale-optimized capabilities that directly incorporate microstructure evolution and the effects of microstructure within AM process simulation.

In AM, a geometric description of the part is processed into 2D slices. A feedstock material is melted, and the part is built layer by layer. In metal AM, the feedstock is often in wire or powder form, and the energy source is a laser or electron beam.

ExaAM focuses on powder bed processes in which each layer is approximately 50 µm. For example, a part that is 1 cm tall would require 200 layers, each requiring the spreading of new feedstock powder and one or more passes of the laser or electron beam to sinter and/or melt the powder in appropriate locations.



Coupled multiscale physical phenomena inherent in metal additive manufacturing. Turner et al.

The ExaAM team has developed the ExaAM tool set to provide insights into how metals behave throughout the AM process (i.e., melting, solidifying) and how they perform—critical information for designing new parts as well as gauging their reliability and functionality.

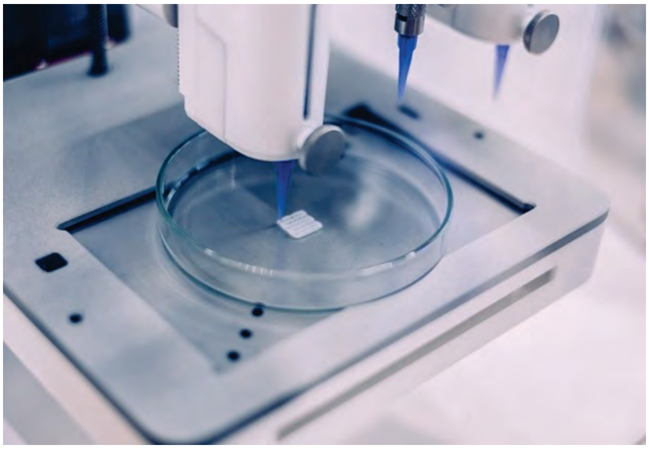
The purpose of ExaAM is to model the AM manufacturing process—you've got heat being deposited, metal melting, metal solidifying, and then you're going to the next layer with more metal remelting and then solidifying. So, you get all this thermal cycling, which makes for a very complicated process.

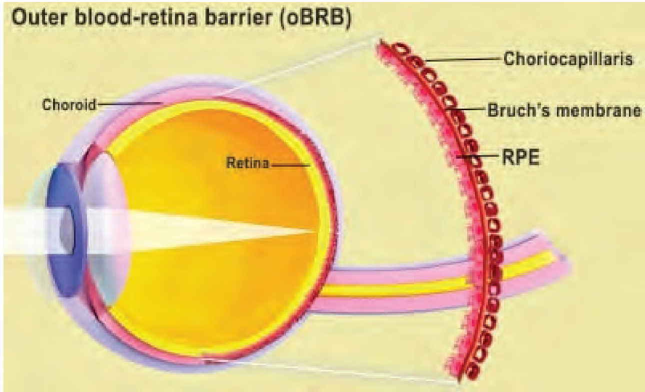
Being able to understand how that process gives you a microstructure and what that microstructure tells you about its properties—that's what we're trying to do. If you can do that accurately, then you could start printing 3D parts and qualify them for critical missions because you really do understand what it is you just made.

—Matt Bement, head of ORNL's Scalable Algorithms and Coupled Physics group and ExaAM's principal investigator

Researchers at National Eye Institute use 3D bioprinting to create eye tissue

Scientists used patient stem cells and 3D bioprinting to produce eye tissue that will advance understanding of





The outer blood-retina barrier is the interface of the retina and the choroid, including Bruch's membrane and the choriocapillaris. (Image: National Eye Institute)

the mechanisms of blinding diseases. The research team from the National Eye Institute (NEI), part of the National Institutes of Health, printed a combination of cells that form the outer blood-retina barrier—eye tissue that supports the retina's light-sensing photoreceptors. The technique provides a theoretically unlimited supply of patient-derived tissue to study degenerative retinal diseases such as age-related macular degeneration (AMD).

Scientists used patient stem cells and 3D bioprinting to produce eye tissue that will advance understanding of the mechanisms of blinding diseases.

“We know that AMD starts in the outer blood-retina barrier,” said Kapil Bharti, Ph.D., who heads the NEI Section on Ocular and Stem Cell Translational Research. “However, mechanisms of AMD initiation and progression to advanced dry and wet stages remain poorly understood due to the lack of physiologically relevant human models.”

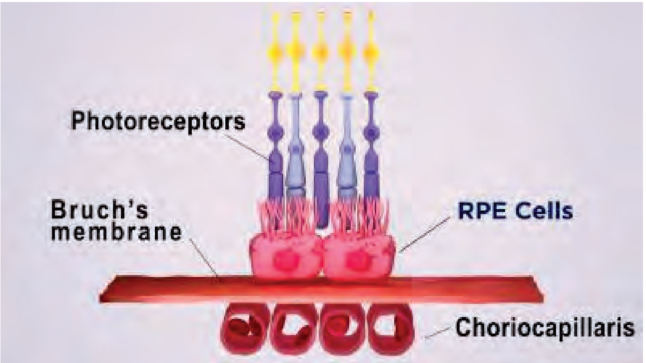
The outer blood-retina barrier consists of the retinal pigment epithelium (RPE), separated by Bruch's membrane from the blood-vessel rich choriocapillaris. Bruch's membrane regulates the exchange of nutrients and waste between the choriocapillaris and the RPE. In AMD, lipoprotein deposits called drusen form outside Bruch's membrane, impeding its function. Over time, the RPE break down leading to photoreceptor degeneration and vision loss.

Bharti and colleagues combined three immature choroidal cell types in a hydrogel: pericytes and endothelial cells, which are key components of capillaries; and fibroblasts, which give tissues structure. The scientists then printed the gel on a biodegrada ble scaffold. Within days, the cells began to mature into a dense capillary network.

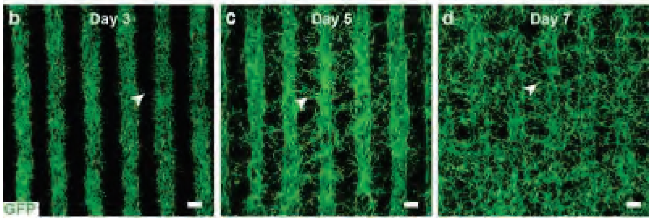
On day nine, the scientists seeded retinal pigment epithelial cells on the flip side of the scaffold. The printed tissue reached full maturity on day 42. Tissue analyses and genetic and functional testing showed that the printed tissue looked and behaved similarly to native outer blood-retina barrier. Under induced stress, printed tissue exhibited patterns of early AMD such as drusen deposits underneath the RPE and progression to late dry stage AMD, where tissue degradation was observed. Low oxygen induced wet AMD-like appearance, with hyperproliferation of choroidal vessels that migrated into the sub-RPE zone. Anti-VEGF drugs, used to treat AMD suppressed this vessel overgrowth and migration and restored tissue morphology.

Growth of blood vessels across printed rows of an endothelial-pericyte-fibroblast cell mixture. By day 7, blood vessels fill in the space between the rows, forming a network of capillaries. Image credit: Kapil Bharti.

"By printing cells, we're facilitating the exchange of cellular cues that are necessary for normal outer blood-retina barrier anatomy," said Bharti. "For example, presence of RPE cells induces gene expression changes in fibroblasts that contribute to the formation of Bruch's membrane – something that was suggested many years ago but wasn't proven until our model."



The eye's outer blood-retina barrier comprises retinal pigment epithelium, Bruch's membrane and the choriocapillaris. (Image: National Eye Institute)



Growth of blood vessels across printed rows of an endothelial-pericyte-fibroblast cell mixture. By day 7, blood vessels fill in the space between the rows, forming a network of capillaries. (Image: Kapil Bharti)

Among the technical challenges that Bharti's team addressed were generating a suitable biodegradable scaffold and achieving a consistent printing pattern through the development of a temperature-sensitive hydrogel that achieved distinct rows when cold but that dissolved when the gel warmed. Good row consistency enabled a more precise system of quantifying tissue structures. They also optimized the cell mixture ratio of pericytes, endothelial cells, and fibroblasts.

Co-author Marc Ferrer, Ph.D., director of the 3D Tissue Bioprinting Laboratory at NIH's National Center for Advancing Translational Sciences, and his team provided expertise for the biofabrication of the outer blood-retina barrier tissues "in-a-well," along with analytical measurements to enable drug screening.

"Our collaborative efforts have resulted in very relevant retina tissue models of degenerative eye diseases," Ferrer said. "Such tissue models have many potential uses in translational applications, including therapeutics development."

Bharti and collaborators are using printed blood-retina barrier models to study AMD, and they are experimenting with adding additional cell types to the printing process, such as immune cells, to better recapitulate native tissue.