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NEWS 2.19

SPECIAL ISSUE FORMNEXT 2019

Editorial

Dear Readers,

The hot off the press issue of the Fraunhofer Additive Manufacturing Alliance NEWS is now available and I am pleased to present you the highlights of all exhibitors at the Fraunhofer joint booth, here at formnext 2019.

The article sequence corresponds to the exhibitors / exhibits arrangement at the booth to provide a quick overview for you.

You are cordially invited to dedicate yourself to the individual exhibits at the Fraunhofer joint booth and to discuss your research needs or problems with Fraunhofer colleagues on site. The latest innovations from Fraunhofer research in 3D printing include e.g. a resource-optimized design of an automobile damper fork (Fraunhofer EMI), additive manufacturing of sintered glass (Fraunhofer IKTS), textile composites (Fraunhofer UMSICHT), a multi-material gearbox, in which individual parts were produced by additive manufacturing (Fraunhofer IGCV) or an improved process quality in laser material deposition (Fraunhofer ILT).

I wish you an informative visit at formnext and enjoy reading!

Dr. Bernhard Mueller
Spokesman of the Fraunhofer Additive Manufacturing Alliance

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Acknowledgements for photographs
cover: Fraunhofer EMI
page 10: Fraunhofer IGCV,
Photographer: Bernd Müller
page 30: Technische Universität Dresden, Institute of Aerospace Engineering / Fraunhofer IWS Dresden
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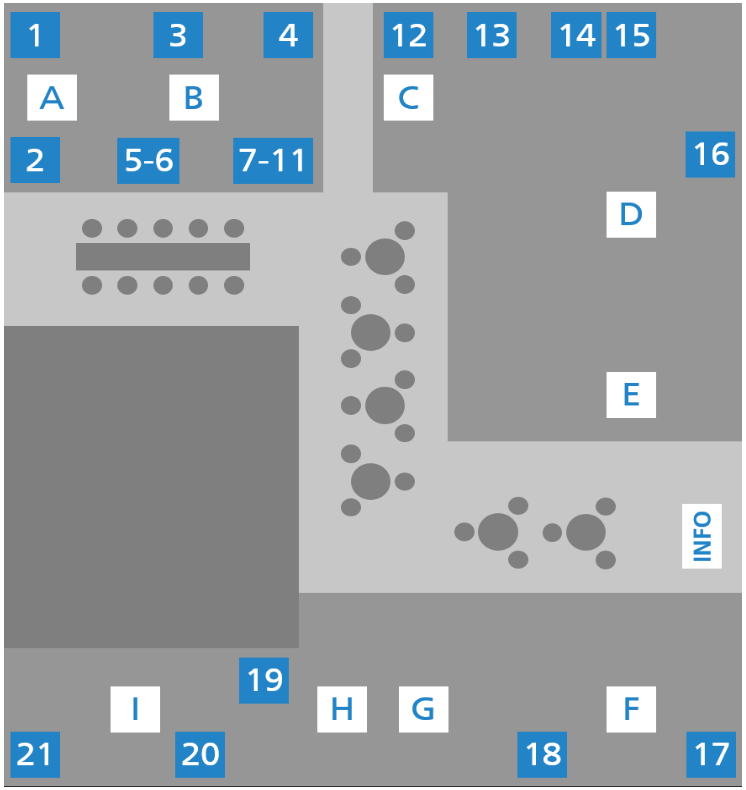
Location plan/ Table of Content

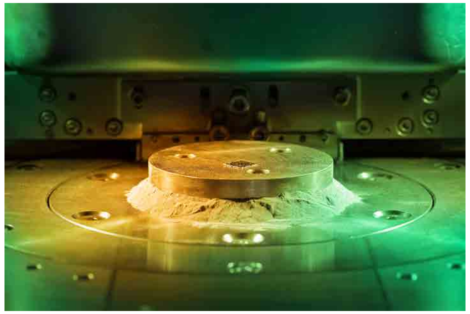


Our Exhibitors

Our Highlights

Fraunhofer Research Institution for Casting, Composite and Processing Technology IGCV

Application-oriented research and development in the field of production technology is the main goal of Fraunhofer IGCV. Core areas are lightweight-casting, fiber-reinforced composites and automated production. More than 80 scientists help to reinforce the competitive strength of the economy in the Bavarian region, and throughout Germany and Europe. Our competence and expertise extend from material science via structural mechanics to manufacturing technologies and production. This allows us to cover the needs of our customers and to accomplish reliable solutions.
An area of high interest is additive manufacturing. Here the Bavarian Ministry of Economic Affairs has recognized the high potential of multi-material production via additive manufacturing. In July 2017 the research project "MULTIMATERIALZENTRUM Augsburg" has started at Fraunhofer IGCV. The processing of multi-material in the fields of product development, process technology and process chain is explored within ten technology projects. The focus is on Laser Beam Melting, Cold Spray and DED-Technologies (Directed Energy Deposition). The aim is to build mechatronic components, which have sensors directly integrated within the part. This can be realized for example via the integration of components or via direct creation of the sensor during the manufacturing process.



Post-Processing of a Laser Powder Bed Fusion machine at Fraunhofer IGCV

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Automated integration of electrical components

Manufacturing of encapsulated mechatronic assemblies by additive manufacturing is the next step in the field of functional integration. This can be interesting for different industries like aerospace or automotive, as more detailed and reliable, design relevant data can be raised. Also by integrating sensors to monitor the lifetime and occasional incidents this is also a future area of application for medical implants.

Such assemblies can be realized by integrating and connecting mechatronic components during the manufacturing process. To reach this aim the additive manufacturing process of Laser Beam Melting (LBM) is complemented with a Pick-and-Place Kinematic, which realizes the integration of mechatronic components during the manufacturing process. Furthermore a concept is developed to wire the component, and therefore build a complete mechatronic system within a load bearing metallic part. Thus, the process chamber does not have to be opened, the inert gas atmosphere stays constant and the influence of a process interruption can be reduced to a minimum.

Multi-material component from the laser beam melting process made of tool steel and copper-chromium-zirconium

Kinematics for the integration of components during the laser beam melting process integrated in a laser beam melting plant

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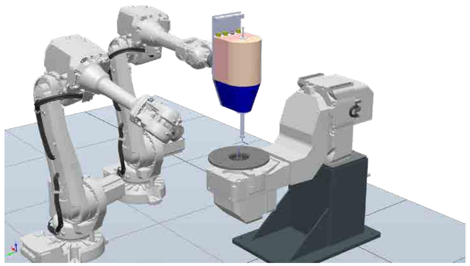
Additive Manufacturing by Cold Spraying

In the field of additive manufacturing cold spraying has recently received increasing attention. The process originates from coating technology.
In cold spraying, powder particles are accelerated through a DeLaval nozzle by means of a gas stream, deform plastically without melting when they hit the substrate, thus forming a dense layer. Cold spraying allows a near-net-shape production of parts.



Cold spraying at Fraunhofer IGCV: robot with spray gun (middle) in front of rotary table. Second robot (right side) could be used for component integration or other activities (left side).

For the production of several layers, only materials with ductile properties in the temperature range up to about 1100 °C are suitable. If there is a demand for filigree structures, reworking of the part is necessary. The advantages of cold spraying compared to laser beam melting are the very high built-up rate (approx. 4 to 14 kg/hour), the low thermal load and the possibility of producing discrete material transitions. Further properties are the high fatigue strength due to residual compressive stresses, the low oxidation and the absence of phase transition of the material due to the low spraying temperature.

The Fraunhofer IGCV will use this technology to manufacture large-scale components. Applications could be casting molds or turbine blades. Cold spraying can also be used to repair simply damaged components by applying new layers to the existing base part.

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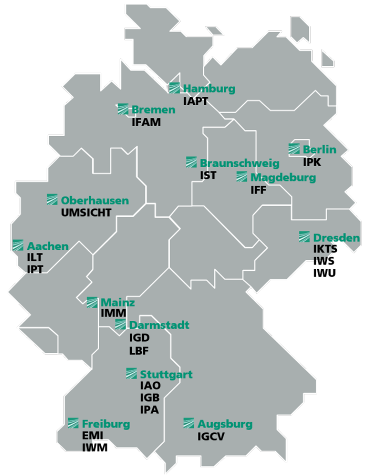
Fraunhofer Additive Manufacturing Alliance

The Fraunhofer Additive Manufacturing Alliance integrates 20 Fraunhofer institutes across Germany and represents the entire process chain of additive manufacturing. This includes the development, application and implementation of additive manufacturing methods and processes. Many years of experience from national and international industrial contracts and research projects form the basis to develop customer-specific concepts and master complex tasks.

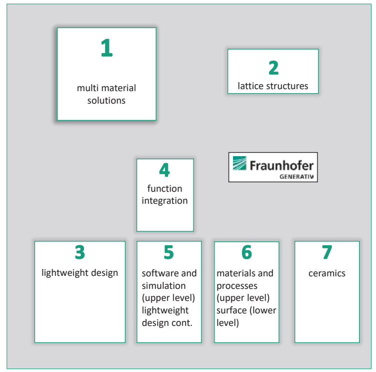


20 Institutes form the Fraunhofer Additive Manufacturing Alliance.

Research areas

The activities focus on five major research areas like:

- engineering (application development),
- materials (polymers, metal, ceramics),
- technology (powder-bed-based, extrusion-based, print-based),
- quality (reproducibility, reliability, quality management) as well as
- software and simulation (process control algorithmus, process and product simulation).



Cabinet positioning in the exhibition area of the Fraunhofer Additive Manufacturing Alliance

Aim of the alliance is to advance applied research and development and to start trends in additive manufacturing. The Fraunhofer Additive Manufacturing Alliance aims industry sectors such as automotive and aviation, but also biotechnology, medical and microsystems technology as well as tool manufacturing, mechanical and plant engineering.

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Lightweight design and functional integration through additive manufacturing implemented in a gearbox

In the gearbox shown, multi-material solutions and the possibilities of various additive manufacturing processes are combined. The drive shaft is designed along the flow of force and the gear wheel is integrated directly onto the shaft (component integration). This made it possible to eliminate the shaft-hub connection and achieve 70 % mass savings. The shaft and the output gear were manufactured from 16MnCr5 case-hardened steel by laser beam melting. The output shaft consists of a CFRP braid, which is connected to the output gear by blow forming. The resulting form-fit is capable of transmitting more than 600 Nm of torque. The housing parts were produced by indirect additive manufacturing. Sand molds and cores were produced using the Binder Jetting process and the final components were manufactured by aluminum casting. The freedom of design is exploited by the integration of an oil sump cooling, which cannot be manufactured in conventional mold production. Condition monitoring is possible via integrated sensors connected to the Virtual Fort Knox (VFK) cloud platform.

Multi-material gearbox; individual parts manufactured by additive manufacturing

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Manufacturing of filigree lattice structures using commercially widespread machines

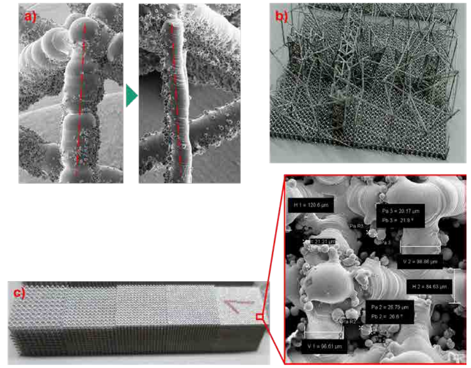
The use of laser beam melting (LBM) allows the production of filigree structures. Due to the cost structure of the process, it is even possible in many cases to make the production economically viable.

Based on the state of the art, strategies have been developed within the scope of the project in order to reduce the minimum manufacturable structure sizes on widely used LBM machines, to significantly increase the reliability and quality of the manufactured filigree lattice structures and to increase the productivity during their production.

For this purpose, the usual workflow was modified on the software side and adapted scan strategies for the production of the filigree lattice structures were developed and qualified. By developing our own slicing software which is directly integrated into a common CAD environment, it is possible to integrate almost arbitrarily arranged irregular lattice strut geometries with strut diameters of approx. 150 µm into solid components and to manufacture them using the adapted scan strategy.

The most filigree lattice structures manufactured on a conventional LBM system using this workflow have strut diameters of only approx. 100 µm, diameters of the cavity cross-sections of approx. 150 µm and are nevertheless permeable to media.

In the future, the technological developments shown should enable the easy integration of lattice structures into and the cost-efficient additive production of highly functionally integrated components.



a) Quality improvements of the lattice structures through the adapted workflow. b) Demonstrator with freely arranged grid lattice struts. c) Most filigree lattice structures manufactured using conventional LBM machinery.

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Topology-optimized and function-integrated tool for injection moulding

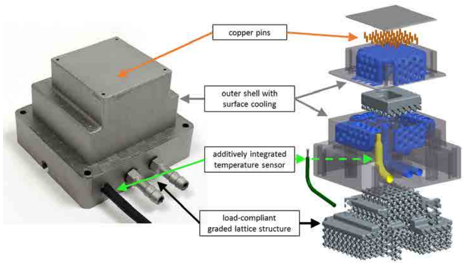
Main objective of the project was the development of novel process chains for the additive manufacturing of function-integrated and structureoptimised injection moulds in order to minimise production time/costs and maximise added value.

Based on the state of the art, the cooling was designed as a large, close-contour net in order to achieve the most efficient possible temperature control and thus significantly reduce cycle times in injection moulding and improve component quality (e.g. dimensional accuracy).

In addition, it was tested to what extent the efficiency of temperature control can be further increased by integrating copper pins. Aim was to improve heat dissipation even in areas where water cooling is not possible. The copper pins were inserted during additive manufacturing and it was later investigated whether the material metallurgically bonded with the tool steel.

The costs in additive manufacturing largely depend on the volume of the part. Therefore within the project a load-compliant internal structure was developed and calculated to reduce the tool's volume. Together with the reduced material use and the resulting significantly shortened manufacturing time, this also creates a lower thermal inertia of the mould and thus a higher dynamic of the cooling.

In the future, this dynamic should allow very accurate temperature management with very short reaction times (active temperature control). The control of process and system parameters, however, can only be achieved by fast and precise temperature readings. Therefore in the project, a process chain for the close-contour integration of temperature sensors during the additive manufacturing process was developed and succesfully tested.



Function-integrated injection mould, finished part (left) and exploded view (right)

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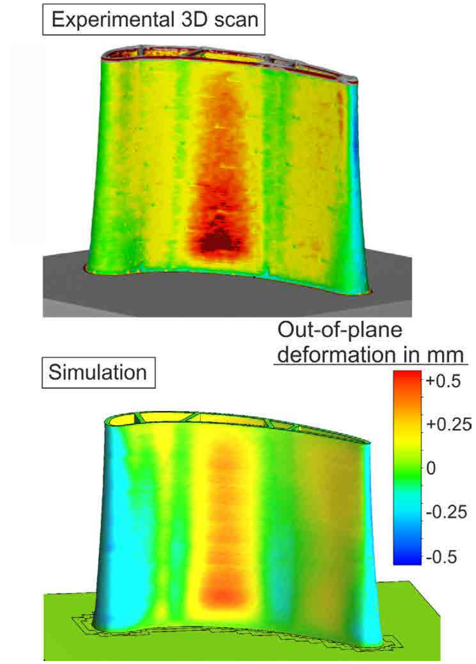
Distortion simulation in additive deposition welding

The Fraunhofer IPK in Berlin has developed a method to simulate additive manufacturing deposition welding (DED). Not only can the temperature flow through the layered structure be predicted, but also the development of residual stresses, distortion and phase formation. With the numerical simulation approaches, personnel- and material-intensive experiments can be carried out virtually on the computer and optimal parameters can be developed before the first setup. It is even possible to calculate distortion-compensated components: This means that the simulation specifies a "wrong" component that distorts to the desired dimensional accuracy during assembly. The graphic shows a validation component. Compared to the experimental result from the 3D scan, the simulation predicts the distortion with excellent accuracy.



The comparison of 3d-scan and simulation proves the capability oft he simulation predictions.

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Topology-optimized damper fork of a vehicle

As part of a comparative study on the ecological and economic evaluation of an additive as well as a conventionally produced component, a vehicle damper fork component, was chosen. The topology of the conventional design has been optimized for additive manufacturing to achieve mass savings. The optimized damper fork design was subsequently fabricated using the Laser Beam Melting (LBM) process. Overall, it could be deduced from the results of the comparative analysis that, in particular, the type and quantity of the product determines whether the use of additive manufacturing processes makes sense. Furthermore, the choice of materials has a significant effect on the ecological and economic impacts. In addition, it could be deduced that a permanent capacity utilization and the technical optimization of additive manufacturing plants have a positive impact on the ecological and economic balance and that in this way new fields of application can be tapped. In summary, the additive manufacturing of metallic components can be seen as a supplement to conventional production. It is on the threshold of small and medium batch production and plays an increasingly important role in various industries. The study presents assessment mechanisms that can be used to make decisions about investments in additive manufacturing technologies.

Resource-optimized design of a damper fork (automobile)

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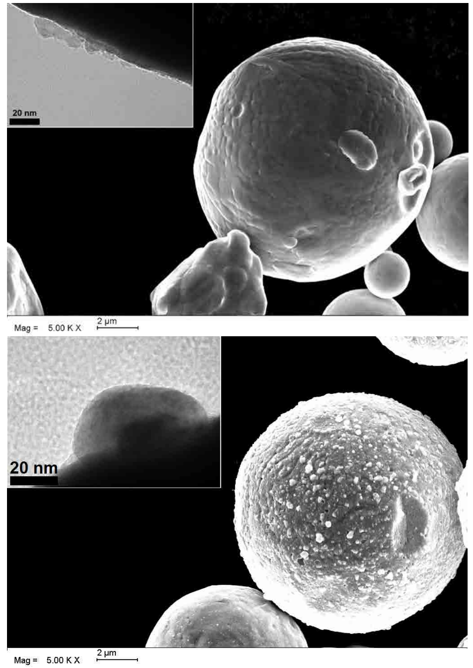
Tailor made powder materials

Metallic, ceramic and polymer powders are used directly or embedded in filaments as starting materials for most additive manufacturing processes. Their morphology and material composition influence not only the processability during the printing process, but also the achievable component properties. The Fraunhofer Institute for Surface Engineering and Thin Films IST uses technologies to modify powder materials as a foundation for new innovative products and for the optimization of additive manufacturing processes.

The powder materials are coated with a thin layer using Physical Vapour Deposition (PVD) or Atomic Layer Deposition (ALD). Depending on the coating material used, different functions can be addressed. For example, the coating material is used for micro alloying of metal powders in order to optimize critical material properties like crack tendency or ductility. The flowability can also be significantly increased so that highly agglomerating powder can be processed. In addition, the electrical conductivity of the powders - ergo of the final component - can be adjusted and their corrosion resistance improved.

Future research activities adresses it will also be possible to deposit hard thin film coatings on powder materials, which offers further opportunities for material development. Another focus is the up scaling of the production volume to in order to enable an industrial implementation.



PVD coating of stainless steel powder (top) – Adjustment of the electric conductivity by a silver coating (bottom)

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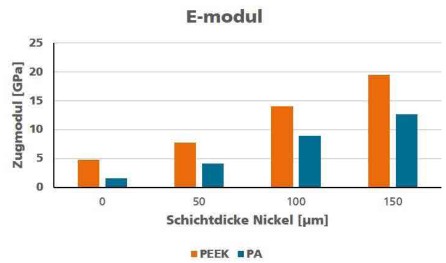
Electroplating of additive manufactured components made from polymers

The additive manufacturing of components from polymers is a perfect complement to traditional plastic injection moulding, especially for small batches or complex shaped components. The freedom of design of additive manufacturing allows not only optimized shapes but also considerable weight savings. This also makes these components interesting for technology markets with high benefit, such as medical technology or aerospace.

However, polymers also have a number of disadvantages, such as their lack of mechanical stability, lack of electrical conductivity and outgassing behaviour. Another disadvantage is often the inadequate surface quality, which can lead to problems when using the component.

Particularly with polymer components, galvanic metallization can eliminate the disadvantages listed above.

In a DLR funded project, the Fraunhofer IST together with OHB System AG and Rauch CNC Manufaktur GmbH produced additive manufactured components from polyetheretherketone (PEEK) and polyamide using the SLS process with a subsequent electroplating of metal. This showed that, depending on the thickness of the applied metal layer, the mechanical strength of the polymers improved significantly. For example, the Young´s modulus of uncoated PEEK increased from approx. 5 GPa to 20 GPa with a layer thickness of 150 µm nickel. The plastic polyamide showed similar behaviour. Coating adhesion, always a critical topic in plastic metallization, fulfilled the ESA standard ECSS-Q-ST-70-17C (Thermoshock Test).



Young´s modulus of PEEK and polyamide

Nickel plated component from PEEK, additive manufactured

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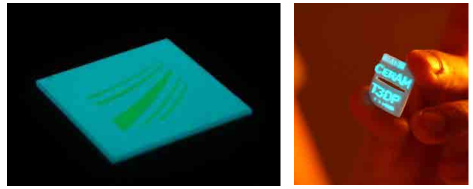
Additive manufacturing of sintered glass

The AM technologies Vat Photo Polymerization (CerAM VPP) and Thermoplastic 3D-Printing (CerAM T3DP) are very well suitable for the production of ceramic components. Furthermore both technologies have also been successfully used for the development of two-component sintered glass components. The sintered glass demonstrators produced consist of different luminescent, namely phosphorescent material compositions or a phosphorescent composition combined with pure sintered glass.

CerAM VPP, also known as Lithography-based Ceramic Manufacturing (LCM), enables the production of ceramic and sintered glass components with a very high final density (≥ 99 %). The 2-component glass components are manufactured by sequential additive manufacturing and material-locking joining during the sintering process. They are characterized by high geometric resolution and good edge sharpness.

The CerAM T3DP technology, on the other hand, enables the additive manufacturing of two-component or multi-component components in one manufacturing step. This process developed at Fraunhofer IKTS is based on the drop-wise deposition of particle-filled thermoplastic feedstocks. The droplet values can be adjusted by varying the process parameters. For example, characteristic droplet diameters from 200 µm to 2000 µm can be realized. In contrast to lithography-based processes, the physical and in particular optical properties of the powders used have almost no influence on the process. Thus ceramic, metal, hard-metal and glass feedstocks can be produced and processed.

The developed 2-component sinter glass demonstrators show the efficiency of the Thermoplastic 3D-Printing for the production of complex, multi-material components.



Additive manufactured, monolithic 2K sintered glas components with phosphorescent material

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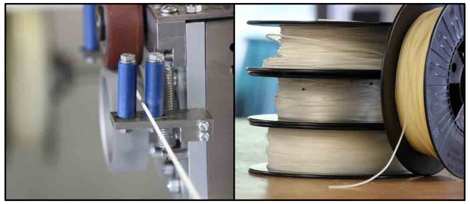
AddiTex - Textile composites from additive manufacturing

In order to give textiles functional properties by using additive manufacturing, plastics are deposited in layers onto the textile (fused deposition modeling, FDM). This allows a high degree of design freedom as well as functional optimization and integration. Until now, this was not possible with conventional manufacturing processes. Applications of textile composites are found in the area of sportswear and protective clothing as well as in acoustic optimization.
However, the required material properties have led to processing problems during FDM. Another challenge proved to be the permanent adhesion to the textile. The printed plastic should form a firm bond with the fibers and at the same time be sufficiently flexible to follow the movement and expansion of the textile. A flexible, flame-retardant compound with a Shore hardness of 70A was developed for this purpose. This is particularly suitable for applications in the field of textile sun and noise protecting textiles and has already been successfully tested for its suitability in the industry. FDM filaments in this Shore hardness range are currently not available on the market.
In addition, a stiff, glass fiber reinforced compound has been developed and is particularly suitable for the direct printing of plug connections or for reinforcing the shape of protective and functional clothing. This is intended to save production steps and reduce costs. In the future, bio-based plastics will be tested for additive manufacturing on textiles and further applications will be developed.



Filaments for 3D printing are made from developed materials.

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für regionale Entwicklung

EFRE.NRW
Investitionen in Wachstum
und Beschäftigung

This project was funded by the European Regional Development Fund (ERFE).

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Fraunhofer Institute for Computer Graphics Research IGD

The Fraunhofer Institute for Computer Graphics Research IGD is the internationally leading organization for applied research in Visual Computing. Our mission is to keep humans well enabled in mastering the ever-increasing complexity of computer systems and volume of data in the age of digitization. To this end, we are leveraging and constantly advancing our sophisticated Visual Computing technologies for the benefit of the individual, our society and our economy.

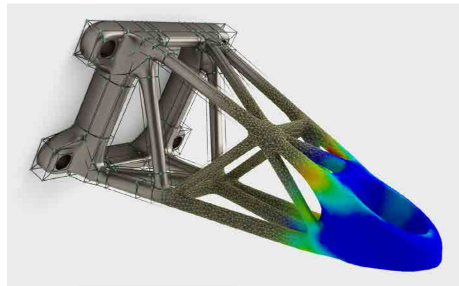
We integrate both methods, rapid simulation and volumetric modelling, into visual-interactive systems that can be used intuitively. Our software development approach focuses on memory and computational efficiency, as well as robustness.
We flexibly adapt to customer requirements to develop novel software solutions for CAD & CAE benefiting software providers and end users in many industrial sectors.

Competence Center Interactive Engineering Technologies

Our team of highly motivated and experienced people of computer science, mathematics and industrial design develops customized solutions for complex industrial challenges. Our goal is to rethink engineering processes and to support them with new software tools.

Our efficient algorithms and data structures reduce simulation time from minutes to seconds and enable the exploration of design spaces with interactive simulation.

Our modeling approaches for components with functionally graded materials open up the potential of 3D printing – especially with multiple material – and revolutionize the possibilities of CAD und additive manufacturing processes with novel geometric representations.



Interactive Engineering Technologies application

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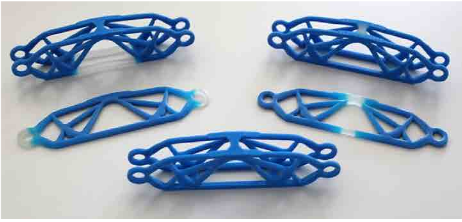
Simply add Functionally Graded Materials (FGM) to CAD models for 3D printing

Today providing CAD models with locally varying properties is difficult and time-consuming for designers, engineers and 3D printing service providers. Common practice is either to divide the model into partial models, to which different materials are then assigned, or to carry out the material assignment using images (textures) in a preparatory step for 3D printing. The former generally only allows discrete material transitions, while the latter requires grading to be generated as a variation of the texture information. The challenge is to easily and quickly generate continuous material gradients following the geometry, as they can be produced with modern multi-material printers.

With our software, we provide the user with intuitive and flexible interaction methods to define material distribution on any CAD geometry. The user has various options at his disposal. He can use CAD surfaces or auxiliary geometries. Auxiliary geometries can insert material gradients into the CAD geometry. Combinations of CAD surfaces and auxiliary geometries will also be possible. The user can adjust the material transition, i.e., the area over which the material gradient extends can be influenced.

We present a digital technology for the definition of material gradients within virtual products, which allows for interactive setting of grading characteristics to perform functional grading on the CAD model – independently of the CAD system.



Printed component examples with graded material properties

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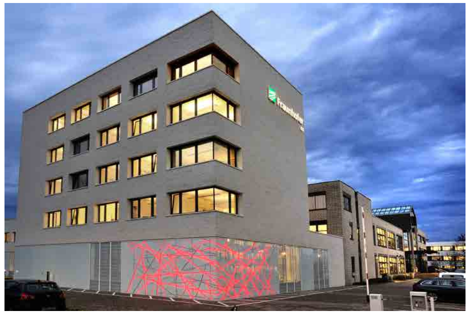
Fraunhofer Institute for Laser Technology ILT

ILT – this abbreviation has stood for combined know-how in the sector of laser technology for more than 30 years. Innovative solutions for manufacturing and production, development of new technical components, competent consultation and education, highly specialized personnel, state-of-the-art technology as well as international references: these are guarantees for long-term partnerships. The numerous customers of the Fraunhofer Institute for Laser Technology ILT come from branches such as automobile and machine construction, the chemical industry and electrical engineering, the aircraft industry, precision engineering, medical technology and optics. With more than 540 employees and more than 19,500 m² net floor space, the Fraunhofer ILT is among the most significant contracting research and development institutes in its sector worldwide.

The activities cover a wide range of areas such as the development of new laser beam sources and components, precise laser based metrology, testing technology and industrial laser processes. This includes laser cutting, caving, drilling, welding and soldering as well as surface treatment, micro processing and additive manufacturing. Furthermore, the Fraunhofer ILT is engaged in laser plant technology, process control, modelling and simulation as well as in the entire system technology. We offer feasibility studies, process qualification and laser integration in customer specific manufacturing lines.

To process the research and development contracts, we have numerous industrial laser systems from various manufacturers as well as an extensive infrastructure. In the nearby Research Campus "Digital Photonic Production DPP", companies cooperating with Fraunhofer ILT work in their own separate laboratories and offices.



With more than 540 employees, Fraunhofer ILT is among the most significant contracting research and development institutes in its sector worldwide.

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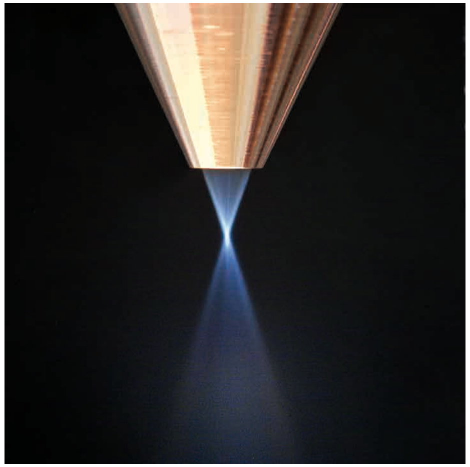
Powder Jet Monitor: Improved process quality in laser material deposition

Laser material deposition (LMD) has established itself for the repair and manufacture of metallic components in additive manufacturing (AM) and for the application of protective coatings. In this process, a powdery filler material is introduced into the melt generated by the laser beam via a nozzle, thus creating a layer metallurgically bonded to the workpiece.

The powder feed into the melt pool is of decisive importance here. Indeed, it significantly influences the degree of powder efficiency, the layer quality and the economic efficiency of the process. The shape of the powder gas jet is determined by several parameters: particle size, powder mass flow, carrier and protective gas flows as well as the setting and wear of the powder nozzle itself. In order to guarantee high process quality, the »powder gas jet« needs to be characterized and documented. Until now, this was not possible.

The "Powder Jet Monitor (PJM)" has now been developed at Fraunhofer ILT. The PJM system uses a laser that illuminates the powder gas flow in one layer and a camera that records the powder articles and their position. This way, digitally processed images can be produced, which are then superimposed into a 2D image of the distribution of particle density in one layer. This process is repeated automatically for several, previously freely selectable layers. In this way, the user receives the entire distribution of the particle density. With the PJM, the institute has provided the industry with a system for measuring the powder gas jet and enables manufacturer to produce more efficently.



For the first time, the Powder Jet Monitor can be used to document how nozzles influence the powder gas flow, particle density distribution and other parameters.

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Wire laser deposition welding in hybrid processes

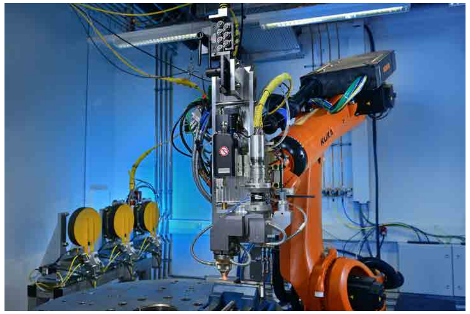
Conventional manufacturing processes are increasingly reaching their limits for the manufacture of complex, individual metal components: For example, laser-based additive manufacturing processes are usually constrained in their build-up rate. Here, it makes sense to combine conventional and additive manufacturing processes. Moreover, the manufacturing costs of metallic components can be significantly reduced through the use of robot technology.

Within the BMBF-funded project ProLMD, the Fraunhofer ILT is developing new system technology and processes with which, for example, reinforcements and other geometric elements can be applied to cast or forged parts with laser material deposition (LMD).

A processing head for coaxial Wire-LMD with a ring shaped beam plays an important role here. The optical system was developed at Fraunhofer ILT and is now being refined for use within the collaborative ProLMD project.

This Wire-LMD process offers true directional independence and ensures uniform intensity distribution across the laser beam ring. The combination with a six-axis industrial robot makes the additive process very flexible. High powers of up to 4 kW can be used for a wide wavelength range thanks to the use of reflective optics (copper).

What speaks for the wire-based LMD process? It not only utilizes nearly 100 % of the filler material, but can also use the more cost-effective wire-shaped filler material. Furthermore, it eliminates the need for metal powder as an additive, thereby providing further advantages by increasing work safety and reducing contamination of the machining system.



The system technology for wire LMD developed in the ProLMD project (BMBF funding measure ProMat3D) enables the build-up and processing of large components in high quality with optimum material utilization, thus reducing process costs.

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Less distortion thanks to near infrared (NIR) preheating

In laser powder bed fusion (LPBF) the laser is used to build components layer by layer from a powder bed. Internal stresses, however, are caused by temperature differences in the component. Depending on the geometry and material, they can even result in the material cracking.

For these reasons, experts from the Fraunhofer Institute for Laser Technology ILT have joined forces with industrial partners to implement ideas in which the component is heated from above. As early as 2018, vertically emitting laser bars (Vertical Cavity Surface Emitting Laser, VCSEL) were presented as part of the research campus for Digital Photonic Production (DPP) at RWTH Aachen University. The VCSEL-Module emits up to 2.4 kW of power into the chamber from above that can be controlled locally.
Now, the ILT team has developed a solution together with its partner adphos GmbH, in which a near infrared (NIR) emitter is attached to the powder deposition unit and heats the material in the process plane with broadband radiation.

With a power of up to 12 kW, the NIR emitter achieves temperatures of 500 to over 800 °C in the component. The NIR illumination is spatially more homogeneous and can also be scaled very well. This means that warpage in titanium components, for example, can be significantly reduced, and is even less than with conventional base plate heating.

In the follow-up project AddSchneid, the temperature range is to be extended to 1,000 °C. The new NIR lighting system is to be used in a wide range of applications. Now with 18 partners and support from the German Federation of Industrial Research Associations (AiF), the group aims to process particularly hard materials such as tungsten carbide-cobalt (WC-Co) for use as cutting materials in tool construction.

With an NIR emitter attached to the powder deposition unit, distortion in the component can be significantly reduced.

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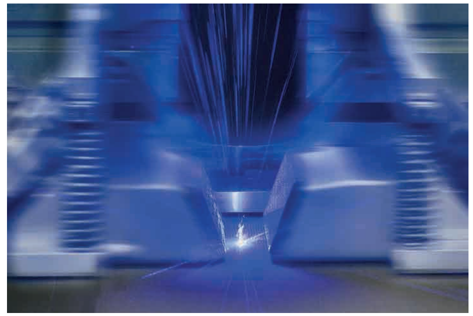
3D printing of high purity copper with green and blue light

Metallic 3D printing with high-purity copper using laser powder bed fusion (LPBF) and in-frared light (wavelength: 1070 nm) has been difficult to implement so far. Low build-up rates and inhomogeneous component quality owing to an unstable remelting process are not satisfactory for end users. High-purity copper, i.e. a material with a copper content of more than 99.9 %, has a significantly lower absorptivity in the infrared spectral range compared to other materials and copper alloys. This means that this material reflects a large part of the irradiated laser power required to form a sufficiently large molten pool.

The use of a new laser beam source in the "green" spectral range is a game changer: Thanks to this new laser beam source, the Fraunhofer ILT has been able to manufacture components from high-purity copper with a relative density of more than 99.8 % and a high specific electrical conductivity of 58 MS/m, for the very first time. It is also investigating the use of a "blue" emitting laser beam source in additive manufacturing.

Together with partners from industry and science, Fraunhofer ILT is doing research on new application-oriented uses for green and blue beam sources. It has developed LPBF laboratory systems for green and blue wavelengths for this purpose and offers to support users in first feasibility studies all the way to application development projects.

First components demonstrate how functionally improved components can be produced with green light for electrotechnical applications. However, the process can also be used for heat management applications – for example, to manufacture microcoolers or other copper components that have to satisfy requirements for high functional density and integral design besides conducting electrical currents.



Green and blue laser light opens up new opportunities in additive manufacturing - particularly for materials that are difficult to process until now, such as pure copper.

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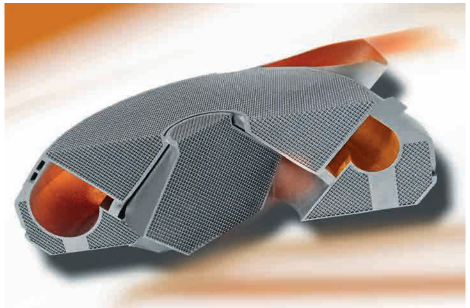
futureAM – Next Generation Additive Manufacturing

In many industries there is a world of optimism regarding additive manufacturing with metallic materials (metal AM): While these were previously only niche applications, now the breakthrough in series production seems to be imminent. In November 2017, the Fraunhofer lighthouse project futureAM was launched with the aim of accelerating the metal AM by at least a factor of 10, reducing manufacturing costs at the same time and abolishing the current limitations of size with the help of new plant design concepts. The focus of the activities is on the one hand the holistic view of the digital and physical value chain from order entry to the finished metallic 3D-component, and on the other hand the leap into a new technology generation of additive manufacturing.

Five other Fraunhofer Institutes are participating in this project under the leadership of the Fraunhofer ILT: IWS, IWU, IAPT, IGD and IFAM. For the leap into a new technology generation of additive manufacturing, the project partners have defined four fields of activity:

1. Industrie 4.0 und Digital Process Chains
2. Scalable and Robust AM Processes
3. Materials
4. System Technology and Automation

In addition to the four fields of activity, which all institutions service with their own R&D capacities, a "Virtual Lab" is being set up. This lab aims to map the competences and equipment of the institutes involved in a closed and digital manner. Every entity – machine or product – is assigned and described a "digital twin". On the basis of these digital twins, real systems can be optimized by means of modeling and simulation.



At formnext, Fraunhofer experts will show how the leap into a new technology generation of additive manufacturing can be successful, comprehensively looking at digital and physical added value right from the order to the finished part.

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Fraunhofer Institute for Production Technology IPT

The Fraunhofer IPT develops system solutions for networked, adaptive production. Our clients and cooperation partners come from the entire manufacturing industry – from aerospace engineering, automotive engineering and its suppliers, especially from tool and die making, the precision engineering and optical industries as well as from the life sciences and many other sectors.

In our institute, we combine know-how in all fields of production technology and offer our project partners and clients individual solutions and immediately realizable results for the production of sophisticated components and high-tech products, which we develop and test in our laboratories and machine hall.

As one of the key technologies of digitalized production set out in Industry 4.0, additive manufacturing will change existing value chains and generate new business models. We regard additive manufacturing processes not as replacements for classical production, but rather as an enrichment of existing processes and process chains: Intelligent combination of production processes and their integration into comprehensive value chains is the future of manufacturing. Process networking and adaptability hold out the promise of an unprecedented range of more customizable products.

Our cooperation enables us to solve interdisciplinary tasks beyond the boundaries of our institute. In Aachen, we cooperate closely with institutes and research centers such as the Machine Tool Laboratory WZL of the RWTH Aachen University and the ACAM Aachen Center for Additive Manufacturing. For example, we use our location, one of the most important locations of production technology, to support companies in various industries in all questions relating to research, development and further education.

On a lab and hall space of around 9,000 m² the Fraunhofer IPT in Aachen develops solutions for networked, adaptive production.

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From semi-finished part to product:

Post-processing of additively manufactured components

Additively manufactured components usually require further processing in order to remove support structures or optimize surfaces. The Fraunhofer IPT has in-depth expertise in various manufacturing technologies that are particularly suitable for this purpose. Machining processes such as milling and grinding are often used for the final contour machining of additively manufactured components. In the case of thin-walled components such as compressor blades for modern aircraft engines, however, vibrations can occur in the milling process which reduce the surface quality of the components. In order to avoid such vibrations, support structures are specifically designed to increase the stiffness of the unstable components during milling. These support structures are much easier to remove while machining compared to solid material. Additionally, the structures must be designed in such a way that their supporting function remains intact after additive production until completion of the subsequent milling process.

The surface of components is often a decisive factor in their function. Finish grinding and polishing operations, which reduce surface waviness and roughness, are particularly time-consuming and labor-intensive. High-gloss surfaces for technical applications can be produced using robot-based and machine-integrated processing technologies. Alternatively, the use of pulsed laser radiation can be used to create almost any design and functional structures, even on complex freeform surfaces.

Additively manufactured and partly machined BLISK

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Digital process chains for networked, adaptive production

In industries such as tool and die making, components are manufactured in small quantities with high quality requirements. Various manufacturing processes such as milling, spark erosion and laser metal deposition are used. The multitude of manufacturing technologies makes the process chain susceptible to production disruption and requires considerable planning in the work preparation phase. Additive manufacturing processes increase the planning complexity, as the raw material can be formless powder or a conventional semi-finished product.

Highly flexible process chains are created when manufacturing processes as set out in Industry 4.0 are digitized by connecting machines and systems and analyzing the data obtained with the aid of intelligent algorithms. The Fraunhofer IPT has an in-depth understanding of how companies can make their machine and production data available and usable. The Aachen engineers store this machine data together with the production planning know-how in a database. The result is a helpful technology database that enables competing manufacturing technologies to be compared with one another. Such databases allow intelligent algorithms to learn to determine suitable machining scenarios for a workpiece in real time, to evaluate them taking into account the relevant target variables and to plan and adapt the process chain on the basis of the available machine capacities.

Based on extended process data the planning process can be improved in the dimensions of time, quality and costs.

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Fraunhofer IWS

Fraunhofer Institute for Material and Beam Technology IWS

The Fraunhofer Institute for Material and Beam Technology IWS stands for innovations in laser and surface technology. The Dresden scientists offer one-stop solutions ranging from the development of new processes to implementation into production up to application-oriented support. The fields of systems technology and process simulation complement the core competencies.
Researchers in the Additive Manufacturing and Printing business unit apply materials layer by layer for a wide range of applications. They fabricate complex parts from basic materials, such as powder, wire, pastes and foils. Primarily they work with metals and plastics, applying technologies including remelting, Additive Manufacturing and printing. This approach relies on profound technological and material expertise. The team covers various processes, such as laser cladding, using powder or wire, electron and laser beam melting of powder beds, and hybrid methods, which combine subtractive with additive techniques.
A highly automated process from a single-source: the researchers in the Thermal Surface Technology business unit consider the entire value chain of systems engineering and process engineering with respect to coating structures and heat treatment. The services offered include process and systems engineering for laser-supported coating and layer techniques, as well as heat treatment with a special focus on highly precise surface layer hardening. Under the buzzword »Industry 4.0«, the researchers at Fraunhofer IWS constantly strive for higher levels of automation.
Products, presented on Formnext 2019, including Laser cladding heads of the »Coaxn« series, the powder head diagnostic system »Llsec« and the laser hardening module »Lassy« underline the Fraunhofer IWS competencies in applicable system technology.

Rocket engine with aerospike manufactured by Laser Powder Bed Fusion

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coaxworks

coaxworks GmbH

Founded in 2018, coaxworks company is your new expert for systems technology and services for direction-independent, wire-based laser metal deposition. We provide both, standard and customized multi-beam laser heads with centric wire supply. As a retrofit for your laser cell, as an upgrade for your welding robot or as mounting kit for your serial machines – there are numerous options.

You are also looking for solutions about wire feeding, process monitoring or inert gas atmosphere for high-quality operations? As a Fraunhofer IWS spin-off we keep up with the latest developments in handling a multitude of wire materials. To keep you going, we offer feasibility studies, installation service and training.

Let's bring your production to the next level.

Compact laser head from coaxworks GmbH for automized additive manufacturing using wire-based laser metal deposition

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Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM

Fraunhofer IFAM offers the whole range of metal powder-based AM processes to provide thorough access to the various possibilities of additive manufacturing technologies.

- Laser Beam Melting (LBM)
- Selective Electron Beam Melting (SEBM)
- Metal Binder Jetting (MBJ)
- 3D Screen Printing
- Heat Treatment Process Control – including debinding and sintering processes
- Powder Analysis
- Fused Filament Fabrication (FFF) of Metals
- new technologies like Continuous Photopolymerization, Gelcasting or 3D Dispensing

The comprehensively equipped additive manufacturing application center at Fraunhofer IFAM in Bremen comprises the complete process chain for LBM and MBJ. At Fraunhofer IFAM in Dresden, the Innovation Center Additive Manufacturing ICAM® brings together SEBM, 3D Screen Printing and FFF under one roof.

What We Offer

- We cover the complete value chain for the additive processes, from the creation of 3D data models, through manufacturing, to final processing and inspection of the components.
- Technological benchmarking from material to component for all processes – in comparison to conventional manufacturing as well as comparison between the additive processes.
- Materials qualification & development for all described processes, together with the necessary process adaptations – the material range covers lightweight metals, such as aluminum and titanium, as well as hard metals and high-melting alloys.
- Support for process integration – execution of technology studies and market analyses.
- Comprehensive analysis from powder to component to ensure that the processing sequence is robust.
- Customer-specific training courses and workshops.

Demonstation part for additive manufacturing by 3D Metal Printing

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Metal Binder Jetting (MBJ) as an alternative for beam-based AM-processes

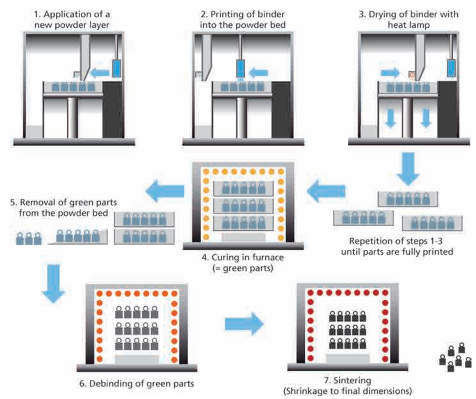
Metal Binder Jetting is a powder bed-based additive manufacturing process. Fraunhofer IFAM deals with material and process development along the entire process chain: printing - depowdering - debinding - sintering. Powder analysis is used to characterize the sintering activity and packing behavior of the starting powder, which influence the compaction and shrinkage behavior during sintering. When determining suitable sintering parameters, we draw on our analytical capabilities and many years of experience in metal powder injection moulding. Tests are carried out on ExOne Innovent systems and in commercial sintering furnaces.

Process description

In Metal Binder Jetting, a powder layer is applied into which a binder is printed using an inkjet print head. The binder is dried by a heat lamp. These process steps are repeated until the desired geometries are achieved. After the binder is cured, the resulting green part is removed from the loose metal powder and debinded and sintered in an oven. The component is compacted and shrinks to its final dimension (see figure).

Advantages:

- "Cold" printing process and consolidation by sintering without temperature gradients lead to low residual stresses.
- Components are not connected to a building platform and do not require support structures when printing, which reduces post-processing.
- The surrounding powder does not adhere to the component; this results in less roughness.
- MBJ uses a printhead bar instead of a single or multiple lasers for powder consolidation; a very high build speed is possible.



Schematic representation of the indivi-dual process steps of Metal Binder Jetting

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EBM-Turbine

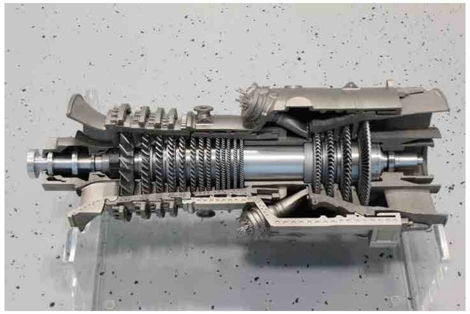
Turbine from the 3D printer

Together with the H+E-Produktentwicklung GmbH in Moritzburg, Saxony, the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Dresden has developed the technology demonstrator „Siemens SGT6-8000 H". This is a scaled model of a gas turbine for power generation on a scale of 1:25, which was completely manufactured with additive methods except for the shaft.

The component assembly consists of 68 parts made of aluminium, steel and titanium, which through component optimisation and the possibilities of Electron and Laser Beam Melting technologies replace the almost 3000 individual parts that make up the original component. The turbine is fully functional. It impressively demonstrates the current potentials and limitations of powder bed-based additive processes.

The production planning was particularly important and correspondingly complex in order to determine the right technology for each component, since, for example, accuracy and roughness of the surfaces had to be taken into account and the functionality of the demonstrator was a basic prerequisite. For example, the shaft and turbine stages must be able to rotate freely between the stator stages and the individual components of the demonstrator should be connected to each other with minimum effort - by screwing and plugging on.

Fraunhofer IFAM was involved in the manufacturing of the component as well as the data modification for the technology-adapted production. The housing components with stator stages were constructed directly on site at the Innovation Center Additive Manufacturing ICAM® in Dresden. They were manufactured by Electron Beam Melting (EBM) from Ti-6Al-4V in the Arcam Q20+ plant. The turbine stages and the other housing components were manufactured by H+E using Laser Beam Melting.



Scaled model of a gas turbine for power generation; completely manufactured with additive manufacturing technologies.

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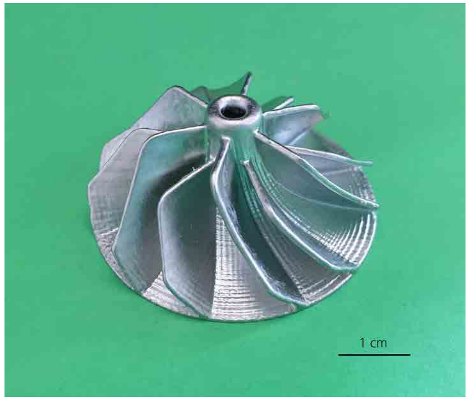
Gelcasting

Hybrid additive manufacturing process with gelcasting for metallic components

With gelcasting, the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Dresden has now redeveloped a technology for the production of components with metallic materials. Additive manufacturing processes are used to manufacture the casting moulds. The actual shaping takes place by casting these moulds with a metal powder suspension at room temperature. Due to the special properties of the suspension, there is no sedimentation of the powder. Various approaches are conceivable here. For example, simple casting, low-pressure casting, vacuum casting or injection moulding etc. can be used. Due to the high strength of the green part, any machining of the green part that may be necessary can easily be carried out using classic methods such as CNC milling or machining.

After the solidification and drying of the green part and its demoulding, it is thermally debinded and sintered in the furnace. Typical sinter densities are 99 % in perspective. The shrinkage is very homogeneous and isotropic. Depending on the shape, components with narrow walls from 1 mm up to wall thicknesses of more than 10 mm are feasible. At the same time, component sizes from a few grams to over 200 g can be realized.

The process is particularly cost-effective and is characterized by its freedom in use of materials. Different material combinations are also possible.



Propeller wheel, manufactured by AM shaping and gelcasting

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Fraunhofer-Gesellschaft

Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.

At present, the Fraunhofer-Gesellschaft maintains 72 institutes and research units. The majority of the more than 26,600 staff are qualified scientists and engineers, who work with an annual research budget of 2.6 billion euros. Of this sum, 2.2 billion euros is generated through contract research. Around 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Around 30 percent is contributed by the German federal and state governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

As researchers, entrepreneurs and visionaries, our employees see themselves as pacesetters and innovation drivers for the economy. Just as our namesake did, they strike the right balance between research and entrepreneurship, take responsibility for the future and develop solutions for tomorrow's challenges. At the Formnext 2019, they will showcase the technologies that will truly shape the future of 3D manufacturing. What's next?