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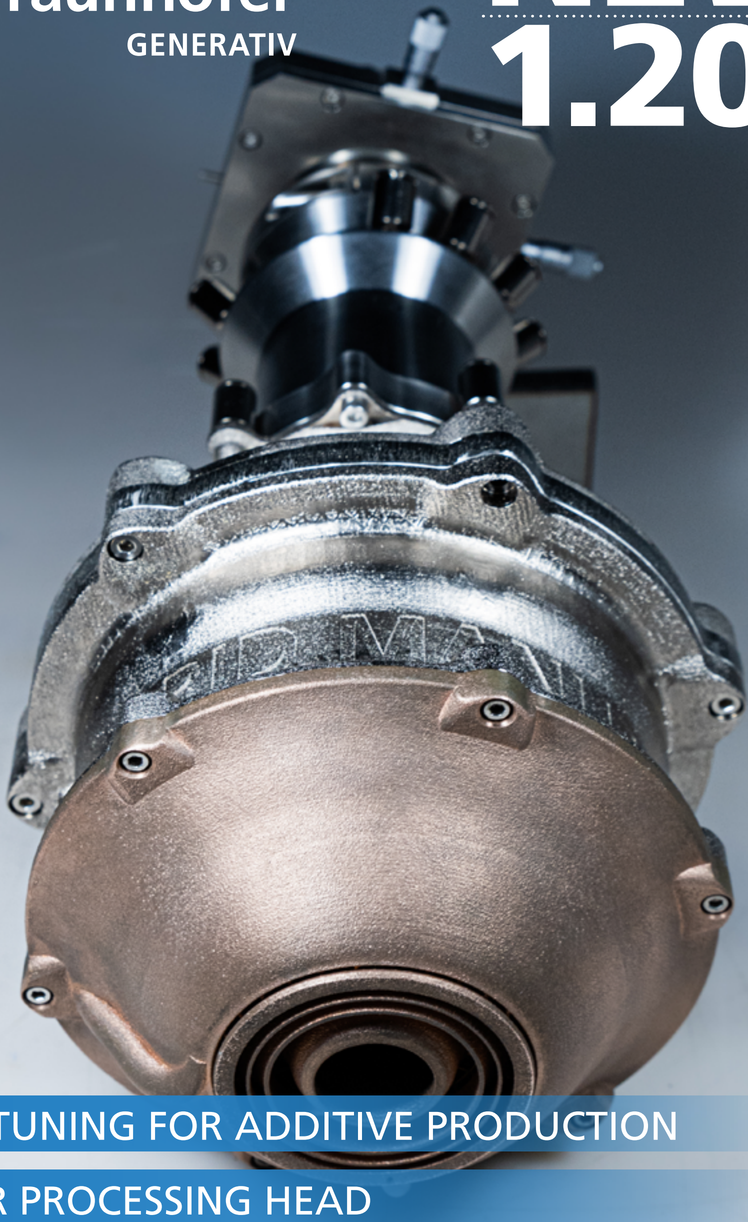
NEWS 1.20



FINE-TUNING FOR ADDITIVE PRODUCTION

LASER PROCESSING HEAD

QUALITY ASSURANCE IN LASER SINTERING

NEW FAIR CONCEPT AT RAPID.TECH

EDITORIAL

Dear Readers,

The Fraunhofer Additive Manufacturing Alliance – an association of meanwhile twenty Fraunhofer institutes, which represent the entire process chain of additive manufacturing (AM) and 3D printing – regularly publishes this newsletter to inform you about current research results.

This newsletter is published on occasion of our biennial additive manufacturing conference – the Fraunhofer Direct Digital Manufacturing Conference DDMC, hold on March 18 and 19, 2020 in Berlin, Germany. The conference brings together about 150 experts from around the world to discuss the latest trends and further developments in AM 3D Printing.

A further highlight in 2020 is our new fair trade concept, which we will present on Rapid.Tech, taking place May 5 through 7, 2020 in Erfurt, Germany. You are invited to visit our booth 2-221!

Finally, this newsletter shows 13 interesting R&D projects of our Fraunhofer AM Alliance member institutes, e.g. how it is possible to improve the laser powder bed fusion process by using high-alloyed case hardening steels, quality assurance in the laser sintering process or additive manufacturing in the production process of lightweight, robust and sustainable aircraft components.

Please find an overview of all contributions on the following page and enjoy reading.

Dr. Bernhard Mueller
Spokesman of the Fraunhofer Additive Manufacturing Alliance

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Content

Trade fair activities of the Alliance

Rapid.Tech + FabCon 3.D

Rapid.Tech 3D is one of the most important events in the field of Additive Manufacturing. It has been providing information about the status and development of Rapid Prototyping, the direct production of end products by using Additive Manufacturing as well as the way into series production. Moreover, Rapid.Tech 3D offers developers, researchers, design engineers and users the possibility to exchange innovative ideas. Please visit us at our booth with our new fair concept!

Please visit us at booth 2-221!

Rapid.Tech + FabCon 3.D
Booth 2-221
Erfurt, Germany
May 05 - 07, 2020

formnext 2020 - where ideas take shape

International exhibition and conference on the next generation of manufacturing technologies

The formnext – as the leading global exhibition and conference on additive manufacturing and the next generation of intelligent industrial production – will take place from 10 through 13 November 2020 in Frankfurt, Germany.

The fair is the leading exhibition with accompanying conference dedicated to additive manufacturing and all of its pre- and post-processes.

Please visit us on the Fraunhofer joint booth!

formnext
Fraunhofer joint booth
Frankfurt, Germany
November 10 - 13, 2020

Case hardening steels

Improvements in the laser powder bed fusion process by using high-alloyed case hardening steels
... within the framework of the AGENT3D-Project "ImProVe"

Tool and mould making is an important application area for additive manufacturing (AM) technologies, viz. laser powder bed fusion (LPBF), and has already yielded numerous application-orientated parts (quantity ≥ 1) over the last decade. Conventionally available Fe-based alloys used for mould making, especially 1.2709 (X3NiCoMoTi18-9-5), can be processed via LPBF and allow a direct manufacturing of individualized, high-performance tool geometries, which cannot be processed by conventional fabrication methods. 1.2709 tools processed via LPBF can be post-processed effortlessly in the as-built state (grinding, milling, etc.), while their final materials properties are adjusted by subsequent heat treatment (HT). The hardness of the aforementioned alloy can be increased via HT to about 52 HRC. A further increase in the hardness and with it an enhancement of the abrasive wear resistance can be achieved using chemical, thermal or for example mechanical surface treatment steps. This is, however, time consuming and leads to an overall increase in the part costs and sometimes to a design limitation – diminishing the main advantage of additive manufacturing. As a consequence, there is an increasing demand for tool steels that can be easily processed via LPBF (crack-free, low distortion, excellent machinability) and guarantee the fabrication of tools with a more pronounced wear resistance and good mechanical properties.

In contrast to 1.2709, case hardening steels, usually applied in the plastic injection moulding process (mould inserts), are interesting candidates for the qualification of new alloys and development of AM tool applications. In this case, researchers at Fraunhofer IWU in Dresden, Germany in close cooperation with the industry partner FKT Formenbau und Kunststofftechnik GmbH in Triptis, Germany have identified a promising case hardening steel (1.2764 – X19NiCrMo4) that meets the aforementioned requirements. The 1.2764 alloy can be well processed via LPBF due to a relative low carbon content and allows the fabrication of large components with a tough "core" for (damage tolerance) and a hard surface for (abrasion resistant) by subsequent case hardening of the near-net-shaped initial structure. The alloy has been qualified step by step for the LPBF process, starting with the monitoring of relevant powder properties, the optimization of process parameters and the exposure strategy as well as characterizing the materials properties of laser melted specimens (see Fig. 1(a)-1(c)). These efforts have already lead to the manufacturing of an application-orientated prototype for plastic injection moulding tests (Fig. 1(d)). The prototype has been built up by combining conventional (milled base frame) and additive manufacturing methods, viz. laser powder deposition welding (Fraunhofer IWS: functionalization of corner areas using pure copper and 1.2764) via Laser Metal Deposition (LMD) and LPBF (Fraunhofer IWU: improved temperature control via LPBF-made conformal cooling channels).

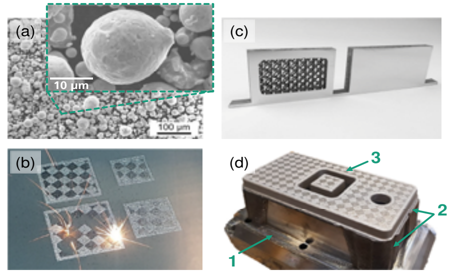

Figure 1: Insights in the qualification procedure of the high-alloyed case hardening steel X19NiCrMo4 (1.2764) at Fraunhofer IWU: (a) Characterization of powder properties regarding particle size, distribution and shape; (b) Evaluation and optimization of the exposure strategy for the processing of differently sized parts (island scanning, island size = 5 x 5 mm²); (c) Investigation of interfacial areas of parts selectively laser melted on 1.2764 base plates (part height = 20 mm); (d) macroscopic image of an application orientated prototype for plastic injection moulding showing the main parts of the tool insert (1: tool base frame – milled, 2: functionalized corner areas – laser metal deposition, 3: tool top area (8 mm in height) with LPBF-made conformal cooling channels).

With the qualification of the high-alloyed case hardening steel 1.2764, the Additive Manufacturing Department at Fraunhofer IWU has strengthened its portfolio regarding the manufacturing of individual and functionalized tools via LBPF. Currently, prototypes and tool inserts are case-hardened to 58 ± 2 HRC (CHD = 0.82 mm). A further increase in the hardness can be achieved by the adjustment of the case hardening treatment. Hence, customer needs can be considered at any time. The high hardness of additively manufactured 1.2764 together with its excellent polishability, currently tested with the prototype, offers significant advantages in contrast to steels that are commercially available (1.2709, 17-4PH, 15-5PH, further martensitic tool steels) for the LPBF process. Due to the importance of case hardening steels for numerous industry sectors, the Additive Manufacturing Department at IWU Dresden is currently investigating further alloys such as 20MnCr5 and 21NiCrMo2-2.

Financial support: Research project „ImProVe" (funding number: 03ZZ0210B), Collaborative project initiative "Zwanzig20 – Additiv-Generative Fertigung" (AGENT3D), Federal Ministry of Education and Research

GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

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Metal Binder Jetting (MBJ) is on its way into production – Fraunhofer IFAM gets an ExOne 25PRO system installed in Bremen

Being into metal powder bed based additive manufacturing processes and classical sintering for some years now, Fraunhofer IFAM has decided to support industry by investing into the next generation of metal binder jetting systems now. Therefore Fraunhofer IFAM will install and run an ExOne 25PRO metal binder jetting system in Bremen beginning of 2020. The system enables users to print with a diverse range of powders at an increased production volume. The 25PRO is a scale up from the Innovent+ of which Fraunhofer IFAM already runs two systems and it includes the latest recoating technology.

Technical Data of the new system in Bremen

- Build envelope: 400 x 250 x 250 mm (15.75 x 9.84 x 9.84 in)
- expected throughput: 3,600 cm³/h (220 in³/h)
- possible layer heights: 30 - 200 µm

Metal Binder Jetting is also on its way into production as it has some advantages compared with beam based AM processes like Laser or Electron Beam Melting:

- "Cold" printing process and consolidation by sintering without temperature gradients lead to low residual stresses
- Components - see Figure 1 - are not connected to a building platform and do not require support structures during 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

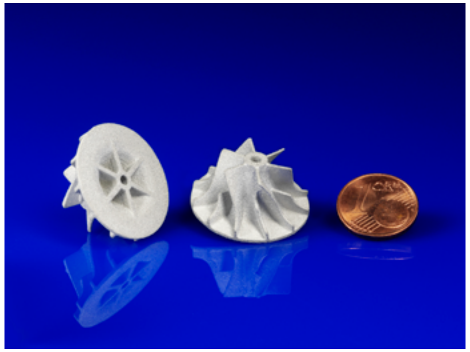

Figure 1: Study of a turbine runner, status after sintering - diameter approx. 60 mm - material 316 L

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Fatigue life assessment of additively manufactured structures based on Representative Structure Elements (RSEs)

During the proof of strength for additively manufactured structures under cyclic loading, process related influencing factors on the fatigue behaviour have to be considered in addition to the loads and environmental conditions. The heterogeneous microstructure is influenced by the exposure strategy and causes a heterogeneous distribution of local material properties, including the stress-strain relation and the fatigue behaviour, which has to be considered in the course of the fatigue assessment. In order to facilitate numerical modelling and the experimental determination of local properties, Fraunhofer LBF applies the concept of Representative Structural Elements (RSE). RSEs are Elements of finite dimensions, which represent mesoscopic integrals over microstructural entities and facilitate the numerical modelling of the fatigue problem. The mechanical behaviour comprises a stress-strain relation, which is derived by cyclic testing under variable amplitude loading with service-relevant load magnitude. The fatigue behaviour of the RSE is defined using the Fatigue Life Curve, a continuous strain-lifetime function from Low Cycle up to the Very High Cycle Fatigue regime. The experimental determination of material parameters and functions for the RSEs requires testing of small scale specimens, which on the one hand reduce the time and cost effort for the specimen manufacturing, on the other hand necessitate specialized test equipment. Therefore, new test environments, based on electromechanical and piezo-ceramic actuators have been developed. In addition to the high accuracy and repeatability, large reductions in the energy consumption of the fatigue testing are considerable benefits of those test systems.

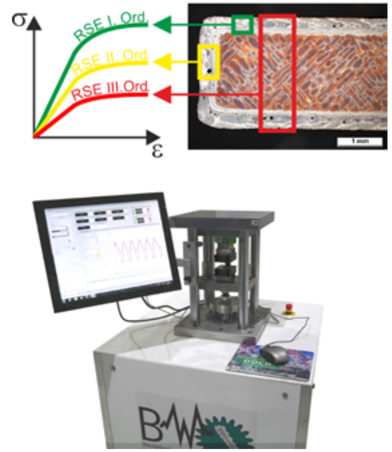

Figure 1: Determination of cyclic properties of Representative Structural Elements using specialized test environments

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Development of Process Parameters for 3D Printing of Heavy Metals and Unique Materials Development of Process Parameters for 3D Printing of Heavy Metals and Unique Materials

Due to the currently expensive parameter development for new alloys in the Laser-based 3D printing process, only a few metal alloys are used for a wide range of applications. Application fields with demand for alternative materials are momentarily only covered to a limited extent only. Specifically for dynamic applications in automobile crashes and in many areas of defense technology, no suitable materials are currently commercially available. Fraunhofer EMI is developing its own manufacturing parame-

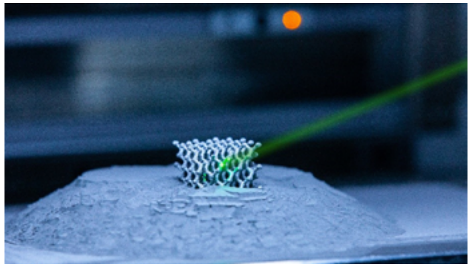

Figure 1: Complex and structured objects from the 3D printer, made out of special materials such as tungsten.

ters for the processing of special materials. An efficient in-house methodology is employed for the development of parameter sets. This allows a comparably fast, cheap and simple development of process parameters. Parameters for the production of high quality tungsten and tantalum have been developed. Both elements feature a high density and a high melting point. Fraunhofer EMI researchers were facing particular challenges during the parameter development for tungsten. Due to the high local energy yield and high cooling rates during the processing of the material with laser beams, cracking occurs in the microstructure. The work currently being conducted can successfully minimize the formation of these micro-cracks. These materials are perfectly suited for applications in the aforementioned fields, but also for other special applications such as collimators for X-ray detectors. Further fields of application are electrical engineering, medical technology, and others with high thermal requirements.

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Additive Manufacturing for lightweight, robust and sustainable aircraft components

The sustainable use of resources and consistent or even increased safety are main objectives in the eco-efficient, safe, and sustainable aviation of the future. 3D printing of light metals specifically has the potential to facilitate resource-efficient lightweight design. Only the amount of material that is really needed for the component is manufactured additively. Furthermore, this technology provides engineers with a considerably increased freedom of design, when compared to conventional manufacturing processes with their geometrical restrictions. In cooperation with partners from the aviation industry, the scientists at Fraunhofer EMI investigate the possible fields of application for 3D printing of aircraft components made from aluminum. This research is funded by the European Union in the joint undertaking Clean Sky 2.

Figure 1: CAD model of the cargo aircraft door fitting with schematic illustration of the door structure

Increased robustness and safety of optimized additively manufactured components

The freedom of design of additive manufacturing can be employed not only for lightweight design but also for attaining increased safety and robustness. At Fraunhofer EMI, researchers are working on designing topologically optimized components in a “fail safe” and structurally redundant manner. This means that components designed this way can degrade gracefully when material failure occurs. For example, in case of cracking or damage of the material, load distribution is redirected in such a way that the safe operation is ensured and the affected component can be maintained or exchanged in time. In this way, redundant components can be avoided and affective safety factors can be significantly increased, and thus, more systemsefficient can be developed.

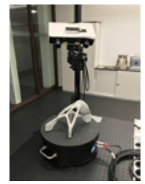

Figure 2: High-resolution 3D scan of the 3D printed cargo door fitting for quality assessment.

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Fine-tuning for additive production

Additive manufacturing systems can generate highly complex components, which could not be produced with conventional machine tools or only with great effort. Nevertheless, such industrial 3D printers are far from being standard equipment in factories. This is not just due to the purchase costs, but also to many other challenges. The Fraunhofer Institute for Material and Beam Technology IWS Dresden has presented particular solutions at the "formnext" trade fair in Frankfurt, Germany in November 2019.

Titanium, a material popular in aerospace, oxidizes in contact with air at processing temperatures above or equal to 300 degrees Celsius. As a result, the material properties change. The components become brittle and can crack. If, for example, a laser is used by a robot to manufacture a titanium workpiece additively, a large chamber must be built beforehand around the robot and the component. This chamber is then either flooded with a low-reaction noble gas such as helium or argon or a vacuum must be generated before manufacturing can start. "This kind of process shielding may be suitable for small component sizes, but it causes considerable difficulties for the production of large components in terms of process control and accessibility," explains Jakob Schneider, who focusses his research on additive manufacturing at Fraunhofer IWS. "In addition, the costs for such a chamber increase proportionally with the size of the component to be protected. These are, for example, the expanses for several cubic meters of helium or argon, which may also have to be pumped in and out due to intermediate processing steps." The same applies to workpieces made of other materials, so-called "refractory metals", such as tantalum, niobium or titanium-aluminum compounds.

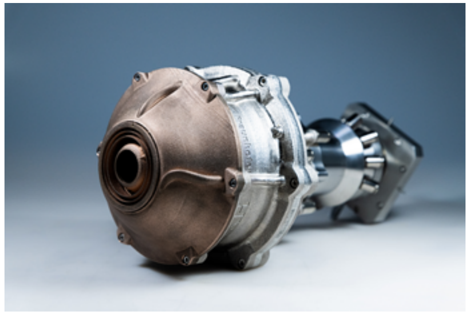

Figure 1: "COAXshield" – novel local shielding nozzle system for laser metal deposition applications with sensitive materials

"COAXshield" avoids oxidation

For this reason, Fraunhofer IWS has developed "COAXshield", an alternative protective shield designed to direct the shielding gas only to the areas where it is really needed: directly around the laser beam's processing zone, which melts the metal powder and deposits it layer by layer on to the component. The nozzle head can be mounted underneath standard processing optics. It encloses the powder nozzle and forms a protective gas cone "coaxially" around the processing zone. This cone thus only protects the hot processing zone, because just here titanium and ambient air can react with each other. "This solution saves the user a lot of time and money," emphasizes Jakob Schneider. "In addition, very large titanium components can now be additively manufactured." An example: For the X-ray space telescope "ATHENA", the European Space Agency ESA needs a satellite supporting structure made of titanium with a diameter of several meters. In cooperation with Fraunhofer IWS, ESA is developing a process and the associated system technology for additive manufacturing. The "COAXshield" has been developed in this context.

"LIsec" lights the powder stream

While in conventionally used ablative processes such as milling, the calibration of tools corresponds to the state of the art, in Laser Metal Deposition it is still a great challenge. The "LIsec" measuring device has been developed at Fraunhofer IWS to solve this challenge and push the limits to technical feasibility. The abbreviation stands for "Light Section" and reveals the principle: A measuring laser scans the powder flow after leaving the nozzle. A camera is mounted at right-angle, which records light sections through the powder and forwards them to an analysis software. "The three-dimensional distribution of the powder stream can be calculated with high precision," explains IWS engineer Rico Hemschik. "This allows significantly simplified quality control and provides conclusions about the wear degree of the powder nozzle." For example, it can be used to repair damaged or worn turbine blades on aircraft in a

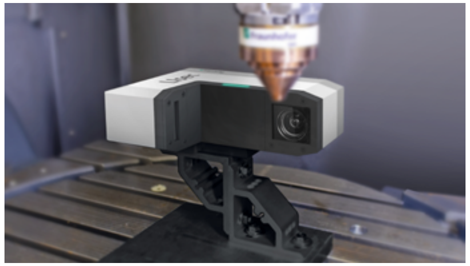

Figure 2: "LIsec" allows significantly simplified quality control and provides conclusions about the powder nozzle's wear degree.

higher quality and more reliably than before. "In this respect, our measuring device can contribute to greater safety and lower maintenance costs in aviation," says the IWS engineer. The Dresden Institute is already working on the industrial implementation of the technology with several well-known international companies and research institutes.

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Laser processing head "LMD-W-20-L": Intelligent processing module for wire-based laser metal deposition

Wire-based laser metal deposition (Laser Metal Deposition - Wire / LMD-W) is an environmentally friendly and material-efficient alternative to the better-known powder-based processes, which is particularly suitable for the manufacture of complex metallic components and for repairing or modifying larger components. In the process, a wire material is fed locally, melted with the laser and applied layer by layer to the component surface. LMD-W is characterized by almost 100 percent material efficiency. The position of the laser focus is precisely adjustable to the wire position. This means that the wire is completely melted with minimal energy input and processed close to the contour and without pores, thus enabling the production of high-quality components. A further advantage of LMD-W is the contamination-free handling of the filler material, which enables the quick and safe set up of the machine as well as the just as easy replacement of the filler material.

"LMD-W-20-L": modular design for cost-effective integration into existing systems

With the laser processing head "LMD-W-20-L", the Fraunhofer IPT in Aachen has developed an intelligent laser module that can be easily integrated into existing process chains thanks to its modular and robust design and integrated sensor technology. It can be installed in production plants or picked up by various handling systems such as gantry systems or industrial robots. Components of the processing head can be adapted to customer specifications and, if necessary, can be easily retrofitted or replaced. The two large doors that swing out to the side allow convenient operation of the optics, the wire feed motor and the positioning system, which allows the exact relative positioning of the laser spot and the wire.

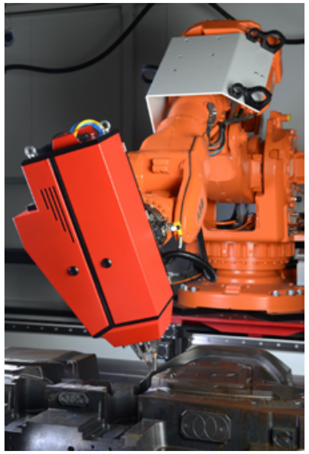

Figure 1: The "LMD-W-20-L" can be attached to a robot by means of a zero point clamping system.

Process monitoring and data recording

The "LMD-W-20-L" has a force measurement system which records process forces and stores the information obtained in a database. If a previously defined force is exceeded, the welding process is automatically stopped. The system thus offers effective collision and wire adherence detection. Component defects can thus be prevented in time. In addition to the process forces, the "LMD-W-20-L" also monitors the temperature values of the wire nozzle and the shielding gas flow and also records them in a database. By detecting the beginning and end of the process, the recorded data can be precisely assigned and evaluated.

The range of wire materials currently available includes various types of steel, nickel and titanium-based alloys, and numerous special materials. Fraunhofer IPT is currently investigating the suitability of other alloys in several projects. In addition, research is being conducted into how temperature and various forces affect the process and which interactions result from this.

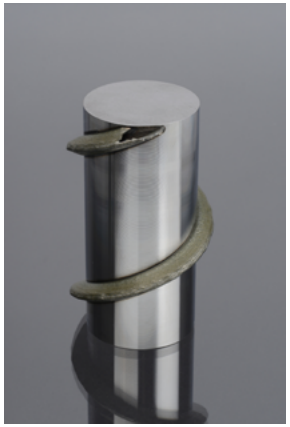

Figure 2: A cooling channel manufactured of Inconel 718, deposited onto 42CrMoV4 by the "LMD-W-20-L"

Figure 3: Welded spiral shape, Inconel 718 on 42CrMoV4, wall thickness 1.2 mm

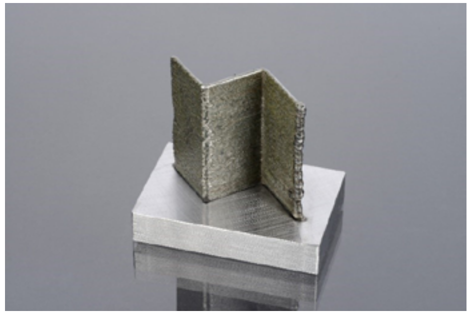

Figure 4: Structure of Inconel 718 with changing welding directions, wall thickness 1.2 mm

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New clamping and referencing system for faster further processing of additively manufactured components

Powder bed based laser melting (L-PBF) is used more and more frequently in the production of turbomachinery components or in medical technology, for example. However, the production process chain is still far from being efficient; this is especially true when the workpiece has to be conventionally post-processed. In order to simplify referencing between the individual steps of the L-PBF process chain and to improve the accuracy of the post-machining, a research team from the Fraunhofer Institute for Production Technology IPT in Aachen, Germany, has developed a clamping and referencing system in the "GenChain" project, which has now been applied for a patent.

An L-PBF workpiece is built-up on a substrate plate. With the new clamping and referencing system, L-PBF workpieces can now be further processed on conventional machine tools without having to remove them from the substrate plate by mechanical processes such as sawing or wire erosion in order to be fixed in a clamping system. Releasing them always involves the risk that the component will be deformed due to internal stresses. In addition, the more complex the geometry of a component, the more difficult it is to carry out exact referencing and clamping on conventional machine tools.

Reusable substrate plate enables faster clamping and referencing

The new system is based on a reusable, ceramic-coated substrate plate made of high-temperature steel, in which cylindrical pins are embedded. The pins serve to connect the component to the substrate plate and can be released individually. In contrast to conventional substrate plates, the ceramic coating prevents the first build-up layers of the workpiece from being applied directly to the clamping system. After completion of the layered build-up, the workpiece can simply be transported on the substrate plate to the next work step. Referencing and clamping of the substrate plate system is done automatically by a zero-point clamping system on the bottom side. After the end of the machining process, the connecting pins are simply released. The pins can be replaced cost-effectively while the substrate plate system can continue to be used.

The zero-point clamping system allows for the first time to standardize the clamping and referencing process across the entire process chain. The effort required to remove the workpiece is reduced, thus shortening non-productive times and increasing the degree of automation in production. If residual stresses appear in the component, the connecting pins can be loosened after L-PBF production in order to allow targeted component deformation and prevent cracks. Subsequent processing steps can then be carried out without residual stress.

Patented system to be used for further developments of L-PBF

The Fraunhofer IPT development team has now applied for a patent for the substrate plate technology. The scientists are already planning the next research projects in order to further improve the system and open up new fields of application: For example, the team is now analyzing the connection strength between the cylindrical pins and the L-PBF workpiece using tensile and shear tests. Experiments with different powder materials and the analysis of different bridge structures of the L-PBF basic form, as well as the integration of heating cartridges between the connecting elements, should further improve the quality of L-PBF workpieces in the future.

The Fraunhofer Institute for Production Technology IPT combines many years of knowledge and experience from all areas of production technology. In the fields of process technology, production machines, production quality and measurement technology as well as technology management, the Fraunhofer IPT offers its customers and project partners applied research and development for networked, adaptive production.

Figure 1: Clamping and referencing system for L-PBF and further processing

Figure 2: Workpiece connected to substrate system with pins and adapted supports

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Development of an SLS Process Chain Suitable for Mass Manufacturing

Although the virtually unrestricted geometric complexity of the parts they produce has made additive manufacturing technologies an efficient tool for the rapid development and manufacture of products, the parts they produce have not been satisfactorily reproducible to quality ensures that manufactured properties identical.

A quality management system, integrated throughout the additive manufacturing process chain, is being developed for selective laser sintering (SLS) in the AGENT-3D research project QualiPro. It is intended to deliver reproducible part quality and thus be suitable for mass manufacturing.

The Fraunhofer IFF's key activity in its sub-project is developing the specifications for QM data management in laser sintering of polymer powder and, based on this, the definition of QM criteria for polymer laser sintering systems. Algorithms are being developed for this, which identify causal relationships and correlations between the parameters of the base material, manufacturing process, final product and part quality. Process and part quality assessment is intended to deliver conclusions about the input parameters set, e.g. powder quality, system settings, laser output, scan rate, environmental conditions, process indicators (e.g. powder layer quality, moving axes, process radiation, temperature) and part characteristics (e.g. mechanical properties, density, porosity, dimensional tolerance, surface roughness).

The recorded data will ultimately be collected in a single part certificate and verify the complete system's process capability (reproducibility) on the demonstration part.

The measurement chains needed for data acquisition are being developed. Suitable sensor principles and other constraints relevant to data acquisition, e.g. form and dimensional tolerance, finish quality, and part position, are being identified. Real build process data ascertained in tests with simulated process disturbances (defect provocation) will be compared to develop the measurement algorithms and to evaluate critical interfaces for laser sintering.

Measurable Success Criteria

The following quantifiable success criteria will be used to verify the achievement of the project objectives on suitable test specimen geometries:

• increasing part quality (lowering the reject rate) in selective laser sintering by at least 20% based on recording data in and after the manufacturing process,

• increasing additive manufacturing process reliability for SLS by 20 up to 25 % trough integration of testing and inspection, based on 3D scan data (process monitoring), and

• cutting costs by 20 up to 30 % via improved process understanding (reproducibly linking recorded process data with part quality).

Applied Test Specimen Geometry for Quality Assurance

Current additive manufacturing technologies are so specific that a standardized test specimen geometry does not exist yet. A geometry with a shape and size (100 x 50 x 20 mm³) suited for all relevant analyses and tests (Fig. 1) was defined for the tests.

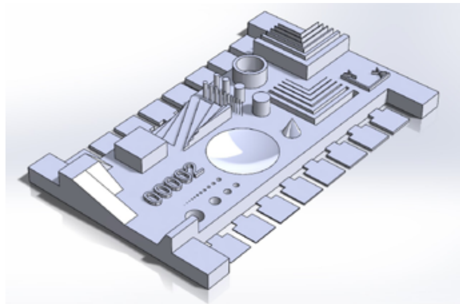

Figure 1: Selected test specimen geometry

It consists of different geometric elements positioned on different planes. Data on different geometric elements (cylinders, bores, cuboid block elements, etc.) are recorded for the QM system. Cylinders are positioned at 0°, 45° and 90° angles to the reference plane. Bores are in xy-, xz- and yz planes. This configuration makes it possible to identify process disturbances.

Cuboid block elements of varying thicknesses are used to measure achievable layer thicknesses and minimum wall thicknesses. Dimensional accuracy (deformation and horizontal displacement) is determined by measuring the outer and bore diameters in every dimension and angle variations in the XY plane and the z-direction. The tests are based on VDI Guideline 3405, Sheet 1.

Benchmark Studies for Process Parameter Optimization

Different parameters' influence on test specimen quality has been studied in extensive benchmark studies to assess quality features. Test plans were drafted following methods of Design of Experiment (D.E.) (e.g. factorial test plan based on Box-Behnken designs). Ten inspection parameters run through an inspection plan using standard-screening were defined for the tests. Afterward, an analysis of variance (including an estimation of the independent variables' effects with a Pareto chart) was performed, a regression analysis was performed, and the dependent variables were optimized.

Structuredlight 3D sensors, light section sensor, laser tracers and CMMs were the scanning systems used to benchmark automated 3D inspection. Other tests for these systems are currently in progress (Fig. 2) to ensure the desired statistical certainty (probability) and the confidence interval for the parameter values. The entire measurement process, that captures the point clouds, takes two minutes (total time to generate the scan). The tested Gocator 3D snapshot sensor has an accuracy of 0.1 mm.

Figure 2: Scanning with the Gocator 3110 3D snapshot sensor

Literature:

[1] Schmidt, M.: Selektives Lasersintern (SLS) mit Kunststoffen. Technologie, Prozesse, Werkstoffe. Munich. Hanser Verlag 2015.

[2] VDI 3405, Blatt 1: Additive manufacturing processes - Laser sintering of polymer parts - Quality control. Berlin. Beuth Verlag 2019.

[3] Kleppmann, W.: Versuchsplanung: Produkte und Prozesse optimieren. Hanser Fachbuchverlag 2016.

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Hybrid hydrogels

Personalizable regeneration of cartilage tissue

Individual biological cartilage implants for the treatment of cartilage defects offer the advantage of takint into account the patient's weight and physical activity of the and support the formation of new cartilage. In the Dyna-Implant project, Fraunhofer IGB produced gelatin-based hybrid hydrogels that mimic the natural tissue environment of cartilage cells. An additive process was developed to combine hydrogel solutions into a biomimetic zonal hydrogel.

Large demand for cartilage replacement

There is great interest in personalized therapies for the treatment of injuries or age-related degeneration of cartilage tissue. In order to realize this, innovative type of cartilage replacement materials, detailed information on the individual anatomy of patient knee joints was obtained by high-resolution magnetic resonance imaging. Person-specific force measurements from movement analyses by Fraunhofer IPA showed the dynamic forces acting at the defect location, which were subsequently simulated.

Additively formed zonal hydrogels with encapsulated cells

The cartilage tissue is composed of a network of biopolymers storing a large amount of water. Fraunhofer IGB produced gelatin-based hybrid hydrogels that simulate the natural tissue environment of cartilage cells and thus promote the biofunctionality and matrix production of the cells. The hydrogels with encapsulated cells were produced from the modified biomolecules of gelatine, hyaluronic acid and chondroitin sulfate, which supported the cell-specific expression of extracellular matrix over several weeks of cultivation. Furthermore, an additive method was developed to combine hydrogel solutions with a gradient of cartilage-specific proteoglycans to form a biomimetic zonal hydrogel (Fig. 1). The cell-containing hydrogels were produced with a mechanical strength of up to 170 kPa and subsequently cultivated under dynamic compression.

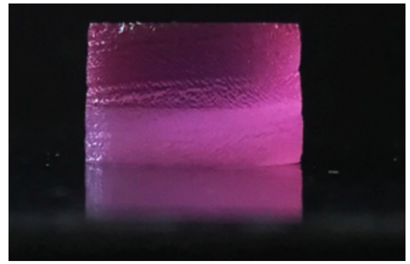

Figure 1: Zonal hydrogel for cartilage replacement.

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AM via microwave-induced plasma

Fraunhofer IPK, robot-machining GmbH, DOCERAM GmbH, IONICS SA from Belgium and the Aachen University of Applied Sciences have joined forces to develop a new additive manufacturing technology based on microwave-induced plasma beams.

The so-called PlasmaPrint technology is a further evolution of the established plasma welding process. A revolutionary new nozzle concept with coaxial material feed enables a so far unachieveable level of energy densities for precise additive build-up. In addition to metals, ceramic materials can also be processed. With this new potential, applications can be addressed in the automotive and aerospace sector as well as multi-material processes.

Figure 1: First experiments in late 2019 are showing promising results for different metal and ceramic powders.

In the PlasmaPrint process, a plasma is generated by microwaves in the GHz range from power-amplified semiconductor generators. Compared to systems based on laser or electron beams, a much cheaper, safer and more easily scalable energy source could be provided. In the PlasmaPrint concept, the deposition nozzle is moved by commercial robots. This enables a fast transfer of the technology to existing process chains in the industry.

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Qualification in Additive Manufacturing - Certified Fraunhofer Training Program "Metal Additive Manufacturing Professional"

The Certified Fraunhofer "Metal Additive Manufacturing Professional" offers comprehensive and detailed knowledge for metal-based additive manufacturing technologies in theory and practice. Certification according to ISO 17024 allows participants to achieve a qualifying degree in the field of metal-based additive manufacturing.

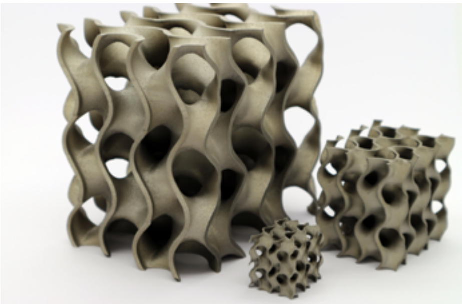

Figure 1: Gyroid structure made by laser-based powder bed fusion LPBF.

Figure 2: Training situation at the Fraunhofer IGCV.

Two specialisations are offered within the Certified Metal Additive Manufacturing Professional: "Production" and "Design". Both specializations focus on several metal-based additive technologies, including powder-bed fusion processes (laser and electron beam), directed energy deposition (powder and wire) and binder jetting. Graduates from the "Production" specialization are able to evaluate AM technologies for a specific production task. Moreover, they can manage an AM production site and a corresponding supply chain. Graduates of the "Design" specialization have comprehensive know-how in developing a part for additive manufacturing and are experienced in 3D CAD modelling and data preprocessing. The qualification courses take place as presence training at leading Fraunhofer Institutes, including Fraunhofer ILT in Aachen, Fraunhofer IWS and IFAM in Dresden, Fraunhofer IAPT in Hamburg and Fraunhofer IGCV in Augsburg. The qualification program is launched in 2020.

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Realization of functionally integrated, highly complex metal-CFRP sandwich structures

These days, a resource-saving design of component parts is more important than ever. For this reason, sandwich compounds as lightweight structures are receiving considerable attention and application in industry. Since complex surfaces can only be represented to a limited extent by the shaping core structure, the use of sandwich structures for curved surfaces has been limited so far.

In order to counteract this fact, Fraunhofer IGCV is conducting research on the realization of highly complex sandwich structures with a metallic core and CFRP cover layers in the MC-Sandwich project, which is funded by the Bavarian Research Foundation. For the successful handling of the project, material competences in the processing of CFRP and the long-standing experience in the field of additive manufacturing are bundled and the expertise of industry-partners is included.

The project goal is to enable the manufacturability of complex curved, metallic core structures with very low mass through additive manufacturing and to provide them with cover layers of thin and rigid CFRP layers in a direct and automated fiber placement (AFP) process.

The additive manufacturing of the core structures enables the integration of additional functions and thus extends the performance spectrum of sandwich structures. Functional elements can serve as connection points to other components and the choice of the processed metals is contributing to adjust the core properties. Core structures made of aluminum, titanium and copper are considered within the project. In order to manufacture complex core geometries additively with each of the three materials, a material qualification geared towards filigree structures is first carried out. Later on, the good conductivity properties of the copper cores are meant to enable electrical conduction and thus lead to a further functionalization of the cores.

The AFP technology offers great weight and cost reduction potential due to direct fiber deposition on the core structure and optimization of the laying strategies and speeds. This applies especially to complex geometries. In addition to the processing technologies, the surface pretreatment, which has a decisive influence on the property profile of the sandwich structures, is also considered. In this way, an optimal connection between core and cover layers can be guaranteed and the intended load transmission can be achieved.

By integrating the heat treatment of the additively manufactured core structures into the consolidation process of the CFRP cover layers, a further optimization of the entire process chain is aimed at.

Thus, in addition to the optimization of the individual processing technologies, a main focus of the project is on shortening the complex production chain of sandwich composites.

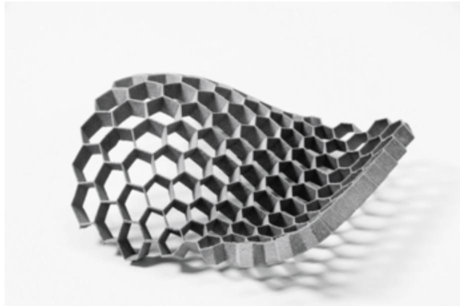

Figure 1: Additively manufactured complex shaped lightweight honeycomb structure

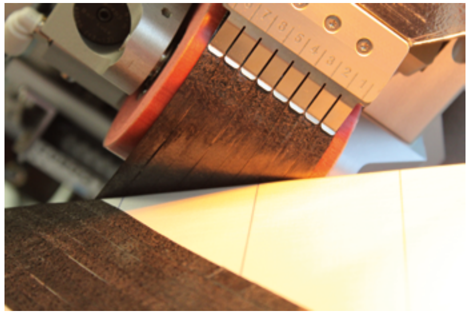

Figure 2: Automated robot-assisted deposition of CFRP cover layers

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ONE TOPIC – 20 INSTITUTES – ONE ALLIANCE

Fraunhofer-competence in Additive Manufacturing

The Fraunhofer Additive Manufacturing Alliance integrates 20 Fraunhofer institutes across Germany and represents the entire process chain of additive manufacturing.
It includes five major research areas: 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. Aim of the alliance is to advance applied developments and start trends in additive manufacturing. Many years of experience from national and international industrial assignments as well as research projects form the basis for us to develop customized concepts and to handle complex tasks. The Fraunhofer Additive Manufacturing Alliance is aimed at sectors such as automotive and aviation, but also biotechnology, medical and microsystems technology as well as mechanical and plant engineering.

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