Swiss AM Guide 2019
Exploring new applications in additive manufacturing

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Swiss Additive Manufacturing Group (SAMG)
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AM Network
Swiss AM Guide 2019

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Editorial

Dear readers,

Additive Manufacturing is developing impressively towards a serious production technology for series applications. As seen from the increasing number of economically relevant applications, the technology is finally fulfilling its promise as an innovation driver. The examples in this year's Swiss AM Guide reveal that successful implementations are not limited to changes in production technology; Additive Manufacturing is mainly driven by rethinking established value chains. For customized products, in particular, an efficient design of the components is crucial for the economic success of the application. As a result, Additive Manufacturing goes hand in hand with other technological advancements like the automation of the design process.

Of course, there are still hurdles to overcome, since the technically and economically successful implementation of the technology is not easy. The Swiss AM Guide 2019 provides insights into companies who have mastered this challenge successfully. The case studies discuss not only the final parts but also the story behind the components and the development process.

The showcases are based on interviews conducted by Daniel Omidvarkarjan, PhD student at ETH Zurich and staff of Inspire AG. His contributions highlight that solutions need to be completely rethought in order to be successfully implemented. This is still a major hurdle for many organizations.

We hope that this report gives you the impulses and inspiration for your own Additive Manufacturing development projects in your company.

Prof. Dr.-Ing. Mirko Meboldt
Professor for Product Development and Engineering Design, pd|z ETH Zurich

Dear readers,

The first 3D printer was developed about 35 years ago. Since then, many different processes have been established, the machines have been improved and, above all, modern software supports the user in process control, modelling and process simulation.

Today, we know the different processes such as vat photopolymerisation, material extrusion, material jetting, binder jetting, powder bed fusion, direct energy deposition and sheet lamination that are used with different materials for more and more applications.

The technologies are being refined and are developing very rapidly, which makes new applications possible. For example, transparent glass can now be printed, which opens up new areas of application, and a newly developed Multi Fab 3D printing technology can produce sensors with different materials and the highest resolution. Furthermore, new, faster machines reduce production costs and increase subsequently their competitiveness compared to the conventional manufacturing processes. Based on these developments, analysts forecast market growth of 30% to over EUR 7 billion for Europe by 2025.

The upstream and downstream processes for automated production remain a major challenge. Standardization, surface quality and reproducibility will continue to occupy the 3D industry into the near future. A number of development steps are still needed before production can be automated and networked in the direction of Industry 4.0.

The NTN AM-Network will continue its efforts for AM-Network members and the Swiss industry to observe current developments in the field of additive manufacturing and to make state-of-the-art as well as different technological trends and applications accessible, alongside topic-specific workshops, conferences and research projects.

Prof. Markus Baertschi
President AM Network

The AM Network is the national thematic network for additive manufacturing and 3D printing in Switzerland.

The AM Network is an initiative supported by Innosuisse, the former Commission of Technology and Innovation (CTI), in the National Thematic Networks (NTNs) program. Goal of the network is to connect companies and research institutes to foster innovation in joint research projects.

- **We enable the Swiss industry to realize the full potential of additive manufacturing through collaboration with Swiss research institutes.**
- **We organize symposiums and workshops with the goal of transferring know-how between research and industry.**
- **Our AM Guide gives an annual update on additive manufacturing and provides inspiration for the Swiss additive manufacturing community.**
- **We ensure that the additive manufacturing community has access to international networks in order to make know-how available.**

Overview Innosuisse Projects

The following list of projects was extracted from the Innosuisse database Aramis: www.aramis.admin.ch

Project No.	Applicant	Title	Partner	Start	End
17799.1 PFIW-IW	P.-A. Gay HE-Arc	Optimisation of the fabrication process of the 3D rotor in polymer and its industrial up-scaling (Rotor 3D)	Ruag Space GmbH	14.10.2015	14.5.2018
18168.1 PFIW-IW	Kaspar Löffel FHNW	Introduction of metallic 3D printing for manufacturing complex parts in the pumps industry	Sulzer	18.01.2016	18.06.2018
18060.2 PFIW-IW	Geoff Richards, AO Research Institute Davos	Personalized Ceramic Printable Ink for Patient Specific Implant Fabrication	regenHU Ltd	01.06.2016	01.06.2019
18939.1 PFNM-NM	Michel Despont, CSEM	New casting tool for textured hydrogel surfaces for 3D cell culture: TEXAS	SUN Bioscience SA	01.07.2016	01.07.2018
18527.1 PFLS-LS	Marie-Noëlle Giraud, Uni-FR	3D-printed bioresorbable polymeric coronary scaffold	Acrostak AG	01.09.2016	01.09.2018
19184.1 PFIW-IW	Frank Ehrig, HSR	3D-Printing using series plastic materials enables the reduction of development times and small-lot production	Geberit International AG	01.02.2017	01.02.2019
25701.1 PFNM-NM	Mehdi Dadras, CSEM	AMTI: Additive Manufacturing of Ti based alloy for aerospace application	ProtoShape GmbH	01.03.2017	01.03.2019
26053.1 INNO-IW	Andreas Kirchheim, ZHAW	Ventilmechanismus zum 3D Drucken mit einem Granulatextruder	3DDD GmbH	27.03.2017	27.03.2018
25195.2 PFIW-IW	Hans Wernher van de Venn, ZHAW	Additive manufacturing with FDM for small production series to complement injection moulding	Stüdli Plast AG	01.04.2017	01.06.2018
25212.1 PFIW-IW	Konrad Wegener, Inspire	ConPAM - Conditioning unit for metallic Powders used for Additive Manufacturing	Gericke AG	01.05.2017	01.05.2020
25720.1 PFLS-LS	Laura Suter-Dick, FHNW	3D human liver microtissue-based in vitro assay for predicting metabolic stability of low clearance compounds in pharmaceutical drug development	InSphero AG	01.06.2017	01.09.2018
25636.1 PFIW-IW	Ingo Mayer, BFH	Development of a material technology for wood-based 3D printing	Schilliger Holz AG	01.07.2017	01.01.2020
27436.1 PFNM-NM	Konrad Wegener, Inspire	Manufacturing of large scale components using additive manufacturing (AM)	Stellba Schweiss-technik AG	01.10.2017	01.10.2020
26239.1 PFNM-NM	Konrad Wegener, Inspire	Direct laser processing of high performance ceramic composites - DLPCC	Heberlein AG	01.10.2017	01.10.2019
26848. PFNM-NM	Johannes Renner, HEIA-FR	3D Inkjet Printing of Zirconia	Ivoclar Vivadent	16.10.2017	16.04.2019
28399.1 INNO-IW	Daniel Schwende-mann HSR	Herstellung von orthopädischen Schuh-einlagen mit Hilfe des 3D-Druck-Verfahrens	Balgrist Tec AG	29.11.2017	29.11.2018

Find the right partner for your innovation project

This National Thematic Network (NTN) promotes the introduction of additive manufacturing (AM) in Swiss industry. The technology, which is also known as professional 3D printing, allows components to be manufactured directly from digital 3D models. Because of the way it differs from traditional production processes, it opens up new applications that have not been available until now. The AM-Network's objective is to make the major innovation and differentiation potential of professional 3D printing available to Swiss businesses.

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Innosuisse – Swiss Innovation Agency

Partner AM Guide 2019

A successful duo for the future of additive manufacturing
Producing companies who want to make full use of the potential of additive manufacturing need to get to know the right project partners. AM Expo and Additively have together developed a comprehensive concept that is well established in the market to ensure that this works as well as possible.

Its purpose is to make relevant information relating to additive manufacturing accessible to wide circles in the form of events, online and in print. Developers, designers, product managers and purchasers from the processing industry thus gain understanding of how various additive manufacturing techniques can be put to profitable use.

Showcases are at the heart of the concept: interested parties can draw inspiration from numerous concrete examples that have been successfully implemented in practice. These showcases are presented and discussed at the booths of exhibitors taking part in the AM Expo. This Swiss AM Guide includes portrayals of innovative showcases on display at the AM Expo 19.

Additively: the digital meeting place for additive manufacturing
Today, the exchange between companies and solution providers takes place mainly at industry events such as the AM Expo. These were supplemented on the digital plane last year by Additively, the digital meeting place. Additively gives people searching for new technologies and solutions a place where they can find inspiration as well as answers to their specific questions. This is where discussion and exchange take place 365 days a year.

As co-initiators, partners and sponsors, we are looking forward to a successful third edition of the Swiss AM Guide and thank the authors and industry for their commitment.

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The Institute of Machine Tools and Manufacturing (Institut für Werkzeugmaschinen und Fertigung, IWF) of the Swiss Federal Institute of Technology, ETH Zurich has conducted research in the field of Additive Manufacturing since 2008.

In the three Additive Manufacturing (AM) technologies SLS, SLM and DMD the institute covers research in materials and material behavior, research on the process and process chains for and with AM, research in machines and special applications as for instance lightweight parts and functionalized parts.

The research activities in the field of SLS (Selective Laser Sintering), SLM (Selective Laser Melting) and DMD (Direct Material Deposition) are described in detail in the research institute section of this AM Guide. In general, the research covers the whole spectrum around AM technologies: It encompasses material / powder development and qualification, simulation of laser-powder interaction, simulation of the solidification of molten material and the resulting microstructure, the increase of the build-up rate, the development of improved material quality with minimum warpage and thermal stress in the workpiece as well as quality management and process monitoring.

In addition to the research in additive manufacturing, also successive processes are investigated in order to achieve the desired form and surface properties or to improve the workpiece quality. For these additional process steps, broad knowledge of other IWF groups is available.

The AM group of IWF collaborates closely with with inspire icams group in St. Gallen whereas the IWF groups focus on basic research aspects, and the inspire groups focus on on feasibility of new approaches in industrial applications. Both the IWF and the inspire groups are under the scientific supervision of Prof. K. Wegener, IWF ETH Zurich.

Prof. Dr. Konrad Wegener

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Showcases: Investigating the Value Adding Adoption of Additive Manufacturing in Industry

Even though Additive Manufacturing (AM) has been around for multiple decades, entering into this new technology still represents a key challenge for many organizations. From our perspective as a research institute in the field of product development with AM, this challenge mainly results from two major hurdles: First, the identification of technologically feasible and economically viable applications within a company’s value chain and second, the development of necessary expertise to implement them. In addition, cultural factors also play a significant role, as the adoption of new technologies always has an impact on the people who employ them.

In our research projects, we aim to develop methodologies and tools, which enable organizations to overcome these challenges. One of our approaches includes the presentation and analysis of success stories of AM serial applications in Switzerland and neighboring countries. In what is now the third edition of this report, we would like to present you twelve successful AM implementation projects from various industries. During the selection of the showcases, we attempted to include a diverse mix of different AM technologies, materials and applications. The showcases not only discuss the results, but also challenges, misconceptions and learnings, which were faced throughout the process. We hope that with the help of the showcases you will get an insight into how implementation of AM in organizations can be approached. Having said that, I hope you enjoy reading the showcases and that they will spark your curiosity for AM implementation.

Daniel Omidvarkarjan
Research Associate, Inspire AG / Product Development Group Zurich (pd|z)

Automated design process for additively manufactured jigs and fixtures

Innovation

Engineering

Business

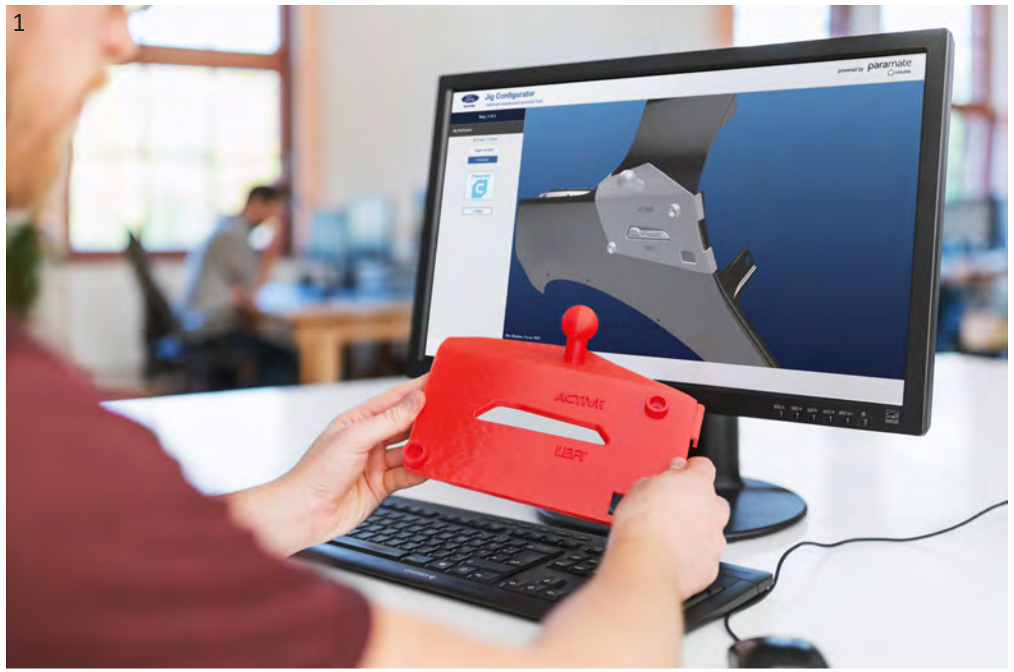
End-to-End Integration

trinckle offers a parametric platform for additively manufactured parts and products. In a project with Ford, a configurator for customizable positioning jigs was developed.

Leveraging Additive Manufacturing for the fabrication of jigs and fixtures is one of the more widespread value adding applications of AM. As examples in different industries (e.g. automotive) have shown, firms can reduce costs in operations by means of additively manufactured tools. The resulting parts do not necessarily require sophisticated materials or manufacturing processes, meaning that often times Fused Deposition Modeling together with regular PLA or ABS is sufficient. Still, scalability of this application is hindered due to the time-consuming process of manually designing jigs and fixtures. trinckle has developed an automated design solution in collaboration with car manufacturer Ford. Their configuration tool shall be discussed in this showcase.

Customer	**Internal use at Ford**
Manufacturer	**n.A.**
Technology	**FDM**
Material	**PLA**
Machine	**Ultimaker S5**
Produced quantity	**n.A.**

1



At Ford, additively manufactured tools have already been utilized in more than 50 cases. For example, jigs are used to position vehicle type and model badges in order to glue them precisely on the car body. The benefits of AM within this value adding application are the following: lower part costs in small quantities when compared to conventional processes, lower weight than their metal counterparts and faster availability in the event of unplanned demand.

2

Still, one major challenge remained regarding the scalability of this application: the manual design effort of the part accounts for up to 50% of total costs per tool. For each new car series and each special edition, jigs need to be individually configured to position the corresponding badges accurately. As the tools have to adapt exactly to the surfaces of the sheet body, the final shape is rather complex including free-form surfaces. When done manually, this process easily took between two and four hours. In order to shorten the design process and therefore enable scalability, Ford teamed up with trinckle to develop an internal software application for the efficient creation of these jigs.

The Berlin-based startup offers specialized solutions for design automation and product configuration in the domain of Additive Manufacturing. Its main product, the cloud software solution paramate, enables automated creation of AM designs that can incorporate the respective user into the design process. Product configurators enabled by paramate include highly individualized industrial components such as copper inductors and vacuum grippers, or lifestyle and consumer products such as jewelry and surfboard fins.

In the case of Ford, the workflow of designing a new jig starts with an upload of the car model data and letterings to be placed. Afterwards, the user can add preconfigured standard

1 Configurator for the automated design of positioning jigs

2 FDM printed jigs are used for the positioning of badges

elements, as for example handles, magnetic holders for attaching the jig onto the car body, mechanical stops and custom labelling. All of these features can be accessed with a few mouse clicks within an intuitive user interface. Afterwards, the application automatically creates the geometry of the tool using the algorithms of the paramate platform. The resulting jig precisely fits the contour of the car and is individualized according to user needs.

3

3 The intuitive user interface lowers the barrier for design for AM

Leveraging the capabilities of the paramate platform, trinckle's configurator reduced the duration of the design process from 2-4 hours down to 10 minutes. Furthermore, the application does not require any know-how in CAD or design for Additive Manufacturing, enabling regular assembly employees to use the configurator. Since the later users are now able to design the jigs themselves, time consuming feedback loops between designers and tool users can be eliminated. Therefore, the overall process is streamlined since designers are relieved from this activity and shop floor employees are empowered to shape their tools to their respective needs.

Compared to the former design process, this approach offers even more potential for the future: by analyzing historical user configurations, the jig and the software tool itself can be optimized over time. In the case of Ford, the software tool could for instance automatically propose an initial draft which is optimized using the most common configurations. As seen in this example, automated design configurators offer a direct way of acquiring and handling customer / user insight.

All in all, the showcase of trinckle and Ford demonstrates that value adding applications of Additive Manufacturing require an holistic consideration of all process steps involved. Only by improving the design process through design automation has the feasibility of the business case been ensured.

Copyright images:
steve_bergmann - trinckle

PeakBoil – An additively manufactured and gas-driven burner-unit for outdoor applications

Innovation | Engineering | Business | End-to-End Integration

When it comes to cooking during a camping trip, there is a common problem known to most outdoor enthusiasts. Regular camping stoves are prone to be blown out by wind gusts while also being rather inefficient. This is due to the fact that most of the generated heat is not transferred into cooking your camping meal, rather dissipates uselessly into the environment. Due to limited functional integration, state-of-the-art systems are also rather material inefficient. This is an issue especially for professional mountaineers, since for them every additional gram of weight counts. Therefore, the interdisciplinary team of the product design student Tobias Pestalozzi (Zurich University of the Arts, ZHdK) and the mechanical engineer student Patrick Beutler (ETH Zürich) made it their task to rethink the camping stove by means of Additive Manufacturing within their Bachelor thesis. The project was supervised by the ETH Zürich by the PhD candidate Julian Ferchow (Inspire AG) and the pd|z of Prof. Meboldt. The result is called "PeakBoil", a novel stove bringing the flame into your kettle.

PeakBoil is an award winning camping stove with a complex SLM printed burner. By bringing the flame into the kettle, the stove is more efficient than conventional ones.

Customer	**Consumer**
Manufacturer	**Inspire AG, pd|z - ETH Zürich**
Technology	**Selective Laser Melting**
Material	**Stainless Steel 316 L**
Machine	**Concept Laser M2 Cusing**
Produced quantity	**< 10**

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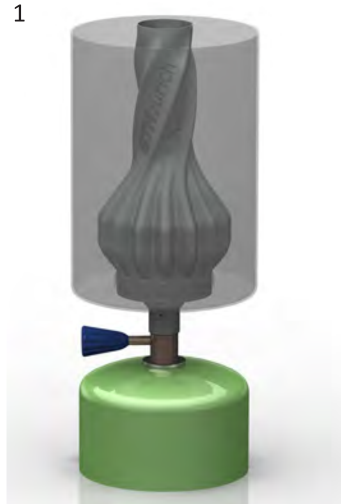

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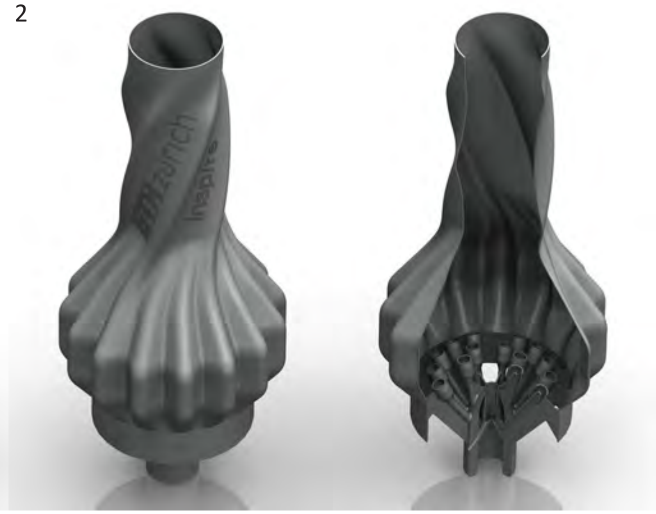

Page 15:
1 Additively manufactured camping stove

2 Complex burner structure within the kettle

In order to overcome the major flaws of regular camping stoves, the main goal of the joint development was to make the kettle as energy efficient as possible while keeping the weight to a minimum. Making use of the design freedom of Additive Manufacturing, the outer shape of the gas burner is rippled, similar to a citrus juicer, in order to vastly increase the surface area of the part. Using very thin wall thicknesses of 0.4 mm, an optimal heat transfer is ensured. Furthermore, Venturi nozzles with opening diameters of merely 0.2 mm were applied, causing a localized drop in pressure and therefore overall increasing the airflow through the burner. This feature improves the quality of the flame and boosts efficiency. Throughout the whole design process, it was attempted to keep post-processing efforts to a minimum (e.g. by avoiding support structures). Apart from separating the part from the substrate plate and removing powder from the burner chamber, no other post-processing steps are required. The stove is manufactured by Selective Laser Melting using a stainless steel alloy as build material.

3

3 PeakBoil during operation

Apart from creating a more efficient camping stove, the motivation of the project was also to demonstrate what is possible regarding additive manufactured designs using state-of-the-art materials and machines. In order to do so, the part has been optimized persistently. Employing a prototype-driven approach, a total of four iterations were developed over the course of one year. Starting with paper prototypes and simple field tests, the team was able to overcome major design flaws from very early on and subsequently finalize the product faster. Yet again, only by means of Rapid Prototyping, a key value adding cluster of Additive Manufacturing, would such a development approach have been possible. The innovative design has also been honored by an international jury of design experts and engineers. Recently, PeakBoil has been awarded a prize in the 3D Pioneers Challenge competition in the Design category.

Now that a proof-of-concept has been delivered, the team looks forward to further optimizing the product, especially regarding manufacturing costs. Next steps include the optimization of material and machine parameters to enable faster and cheaper manufacturing. It is also intended to translate the knowledge regarding additively manufactured burners to functionally similar but much bigger systems as for example gas turbines. The team is open for collaboration with industrial partners to further develop the product and to make sure that cooking outdoors becomes as pleasurable as it should be.

4

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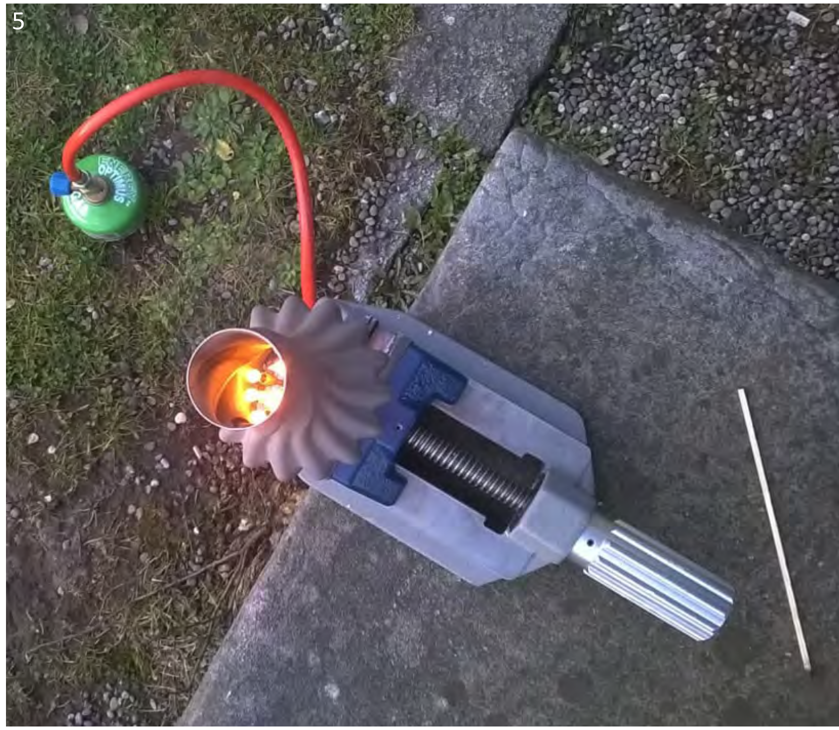

4 SLM burner within kettle

5 Setup for testing early prototypes

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ETH Zurich

Additively manufactured reinforcing sleeves for geothermal probes

Innovation

Engineering

Business

End-to-End Integration

Jansen AG and BSF Bünter AG have developed SLM printed reinforcing sleeves for geothermal probes. By switching to Additive Manufacturing, substantial cost reductions were achieved.

In order to satisfy rising energy demands in an environment-friendly way, geothermal probes are used to gain access to the vast energy reservoirs of our planet. With increasing depths, higher temperatures and therefore higher efficiencies can be obtained. Depending on the respective location of the probe, the temperature rises by around 1 Kelvin with every 30 metres of depth. Still, increasing depths also demand higher requirements regarding material and machine. In order to cope with these forces at the lowest point over decades, Jansen AG uses additively manufactured reinforcing sleeves. Their product, which was developed together with BSF Bünter AG, shall be discussed within this showcase.

Customer	**Jansen AG**
Manufacturer	**BSF Bünter AG**
Technology	**SLM**
Material	**Stainless steel 1.4404**
Machine	**Concept Laser M2**
Produced quantity	**Less than 100 in the first year**

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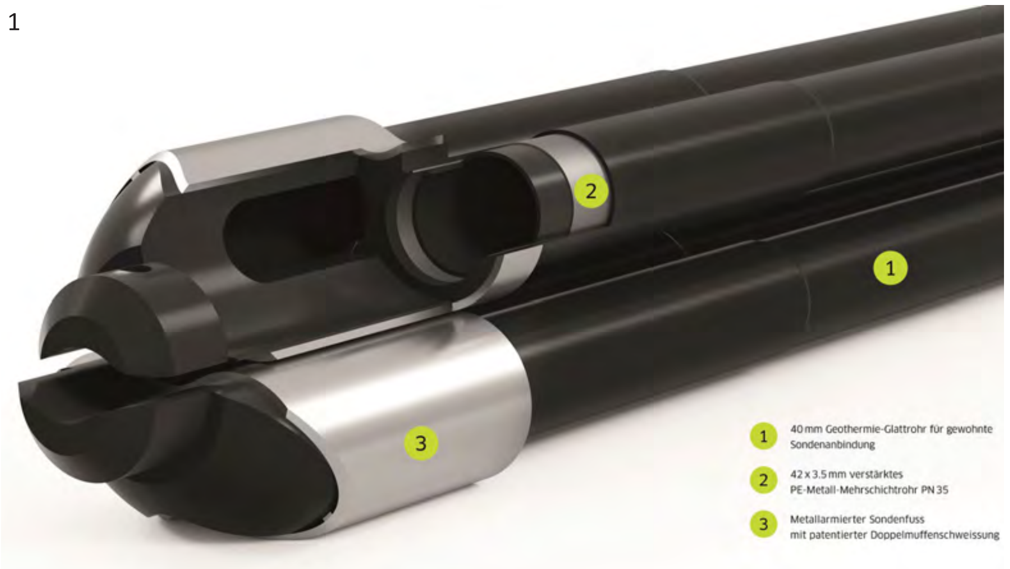
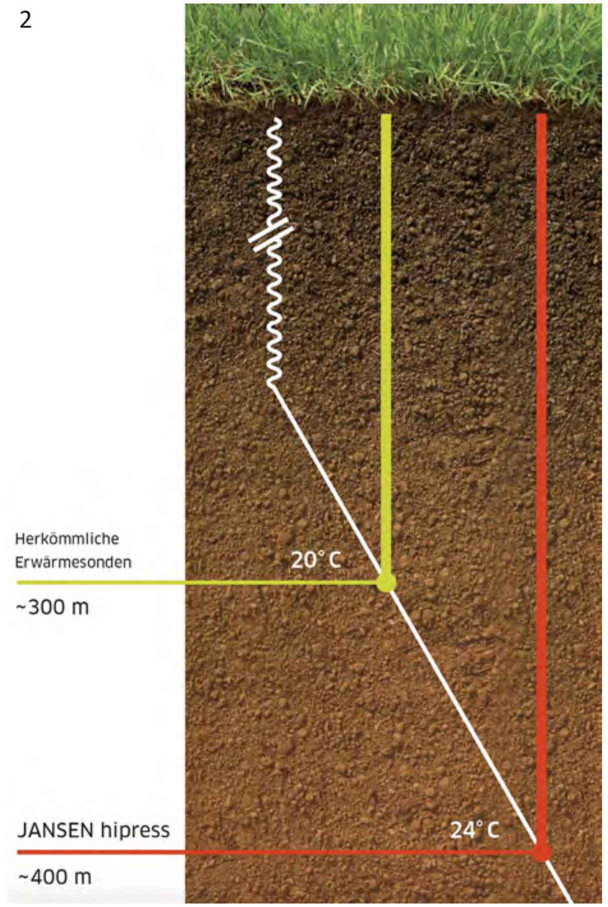


Geothermal pipes are deflected at the lowest end of the probe, the so-called probe foot. In order to protect the tubes against surrounding and internal pressures (up to 35 bars), a reinforcing sleeve is attached and embedded into concrete. Since the part is required in only small quantities per year, series production on a meter basis is not profitable. Milling can also not be applied due to the thin wall thicknesses involved. Therefore, Jansen AG formerly chose the wire erosion process to manufacture the parts. For its newest geothermal probe, the Jansen hipress, Additive Manufacturing was used in order to avoid high costs per quantity and long lead times of wire eroded parts.

2



1 Jansen's geothermal probe with SLM printed sleeve

2 Jansen's probes are positioned much deeper compared to conventional ones

The development of the part took place in an iterative manner with the help of BSF Bünter AG. Using the existing design for wire erosion, an additively manufactured prototype was produced by means of Selective Laser Melting. By physically testing the prototype, several design adaptations for the additively manufactured version were identified: Easiness of assembly was increased through a tapered, free form shape, which ideally secures the pipes. The wire eroded design could not provide this feature due to the limitations of the manufacturing process. Furthermore, warping of the reinforcing sleeve was reduced through several design adaptations. In this context, BSF Bünter's experience in Design for SLM proved to be greatly beneficial. The final part is made out of a stainless steel alloy (1.4404). Post processing includes blasting operations.

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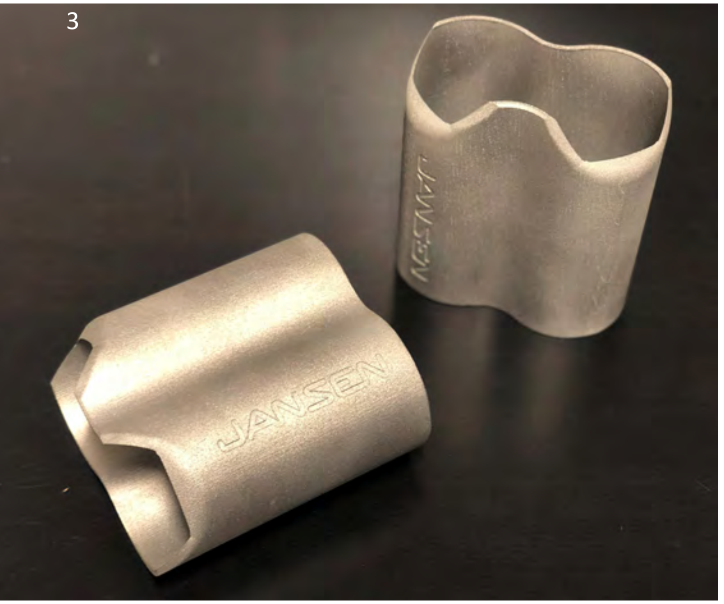

4


3 SLM printed sleeves

4 Sleeves mounted on probe pipe

By switching from wire erosion to Selective Laser Melting, multiple benefits were achieved. First, costs per part were reduced by 70%. As seen in this and other showcases, AM excels especially when it comes to producing small quantities due to its "Lot size one" property. Furthermore, a more flexible and faster availability of parts was enabled by the means of AM. If needed, additional quantities can be manufactured and delivered in shorter periods compared to the wire erosion process. Delivery times of down to one week are possible in the event that additional reinforced sleeves are required. As a consequence, the need for warehousing is significantly reduced. In addition, waste of material is also reduced. In the case of wire erosion, steel slabs act as raw material for the manufacturing of the reinforcing sleeves. A considerable amount of the raw material is therefore wasted. Since SLM is a powder-based process, no chips are generated and a major portion of the powder can be recycled.

To sum up, this showcase illustrates how a change of a product's manufacturing technology to AM can result in multiple benefits: including both functional benefits such as improved assembly and economical aspects like cost reduction and better availability.

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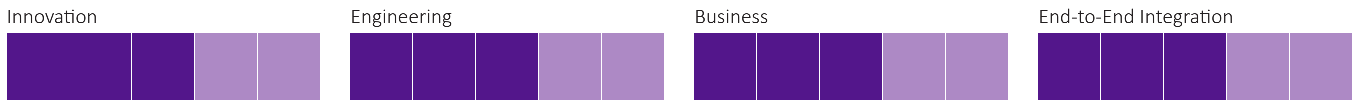
Jansen AG, BSF Bünter AG

Optimizing cooling lubricant supply in industrial grinding solutions through SLM nozzles



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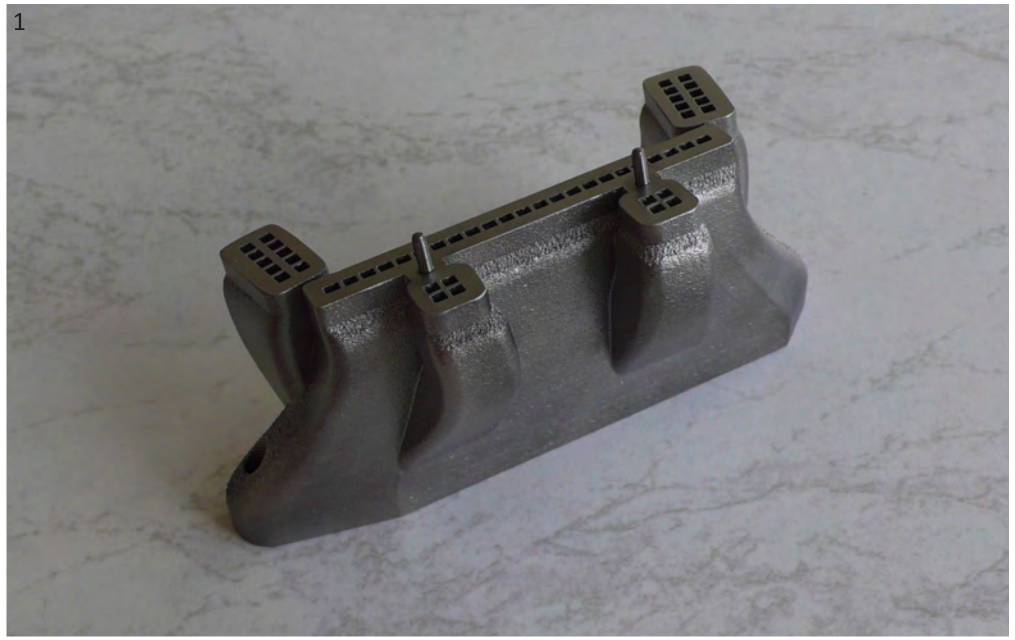


JCM Tooltec GmbH and Ecoparts AG have developed specialized, complexly shaped cooling nozzles for grinding machines. Their individualized parts are manufactured with SLM.

1 SLM printed nozzle head

Customer	**JCM Tooltec GmbH**
Manufacturer	**Ecoparts AG**
Technology	**SLM**
Material	**Stainless Steel CX / Corrax**
Machine	**EOS M 290**
Produced quantity	**Individual Solutions from 2 to 16 Sets**

Beside milling and turning, grinding is one of the major machining processes in today's manufacturing industry. When it comes to grinding product components or tooling, an optimal cooling of the process is of high concern. JCM Tooltec GmbH has developed specialized, complexly shaped cooling nozzles, which are manufactured with Selective Laser Melting. The following showcase discusses their product, which was developed and manufactured together with Ecoparts.

The main purpose of cutting fluid is to cool and lubricate parts and tooling during the operation. Furthermore, the steady stream of liquid transports chips away from the interaction zone. Optimizing the coolant supply has been increasingly focused on in the recent past: first, handling big volumes of cooling liquids is a very energy intensive process, since pumps, coolers and filters have to be powered. Second, from an industry 4.0 perspective, grinding operations act as a parameter for the whole manufacturing process chain. Therefore, high repeatability and robustness are required, which is supported by better cooling of the process. State-of-the-art products only partly fulfil these criteria. Regular solutions encompass bended INOX tubes or plastic systems, which are individually equipped and adjusted raccording to the particular application. Often, these products fail to distribute coolants optimally and lack repeatability, when nozzles have to be changed (e.g. after a crash).

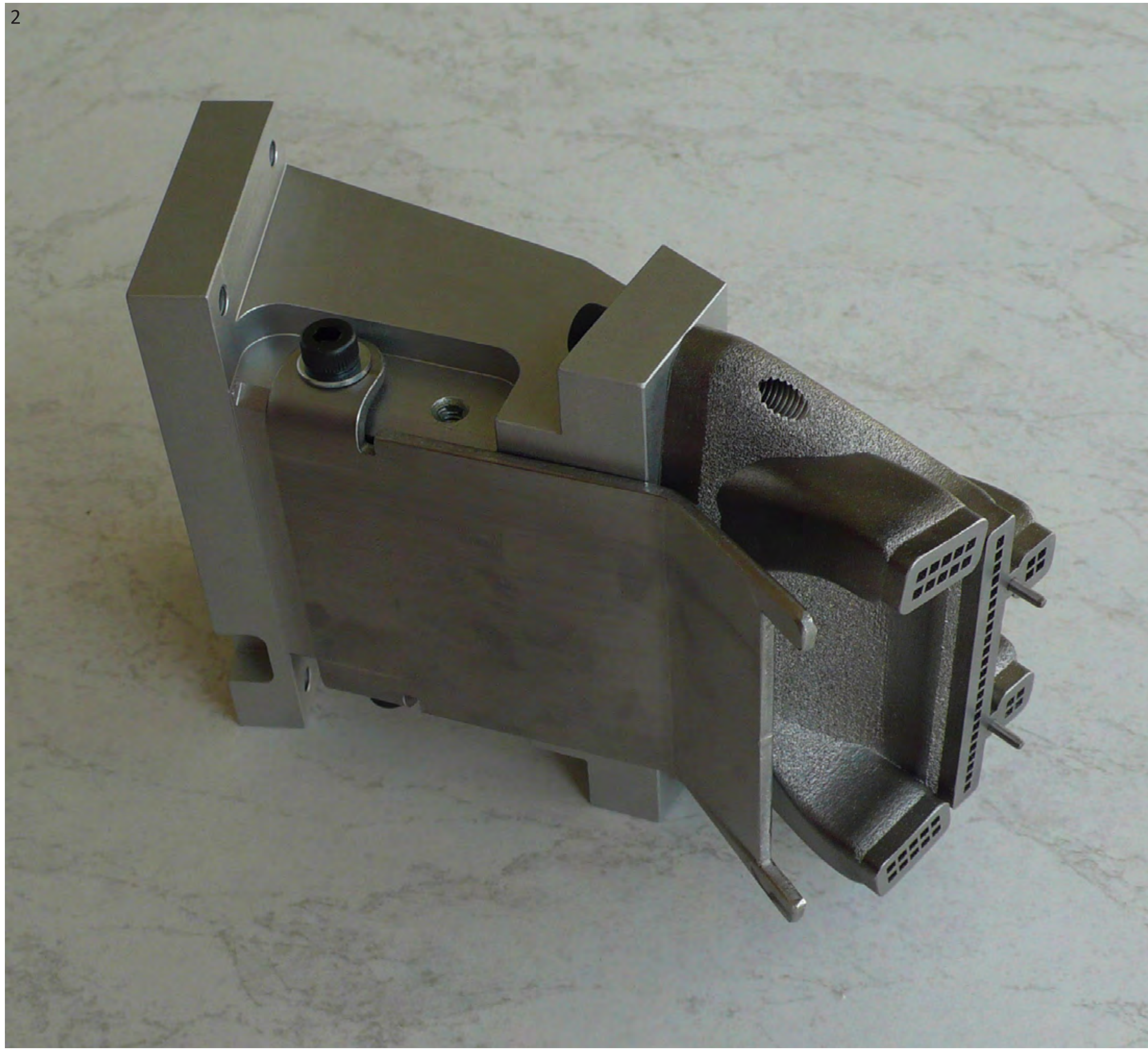
An optimal cutting fluid nozzle therefore should guide just as much coolant as needed to the right spot and should allow for a fixed position nozzle change. Since the resulting shape is rather complex, JCM Tooltec GmbH decided to leverage the unique geometrical freedom of AM for this application. The firm is a provider of specialized grinding solutions and has been working with AM for several years already. First products included plastic nozzles manufactured through SLA, which were then optionally metal coated during post processing. In order to ensure higher robustness and reliability in industrial applications, JCM Tooltec GmbH expanded its portfolio to include SLM manufactured nozzles.

The function driven design approach can generally be divided into the following steps: Fluid dynamic parameters act as a starting point for the design process. These indicators include for example volumetric flow, in- & outflow velocities and flow directions. Using different simulation tools, an ideal shape is derived which enables optimal flow through the nozzle. Afterwards, the actual nozzle geometry is "built around" the ideal shape within a confined design space in order to prevent collisions with surroundings. This step includes considerations of manufacturability, which is why a close collaboration with the supplier Ecoparts proved to be beneficial. Experience from former projects further simplifies this process step. As a result, a highly optimized nozzle design can be achieved.

During the development of the SLM printed nozzles, JCM Tooltec GmbH faced two challenges and found ways to overcome them: First, in order to minimize the engineering effort, JCM Tooltec GmbH introduced modularization and standardization to its products. By combining conventionally manufactured base nozzles and connectors with individualized SLM nozzle extensions, costs can be kept to a minimum. This is of high importance, since cutting fluid nozzles are rather cost-sensitive products. Mechanical interfaces, as for example fast swapping mechanisms, ensure compatibility between the components. The second challenge refers to the finishing procedure of the parts. Since surface roughness is highly dependent on orientation, there is a need for surface treatment. Inner surfaces of the nozzles are finished with a combination of abrasive flow machining and a proprietary process. This ensures an optimal flow of the cooling fluid through the SLM printed parts.

The showcase of JCM Tooltec GmbH and Ecoparts strikingly demonstrates how Additive Manufacturing can be leveraged to translate functionally optimized designs into physical products with minimum compromises. JCM Tooltec GmbH is is expecting that the rapid development of AM technology will facilitate even more possibilities and process simplifications in the future.

2



2 Modular structure of nozzle

Copyright images:
Ecoparts AG

New applications for AM enabled by wear resistant materials and digital configurators

Innovation

Engineering

Business

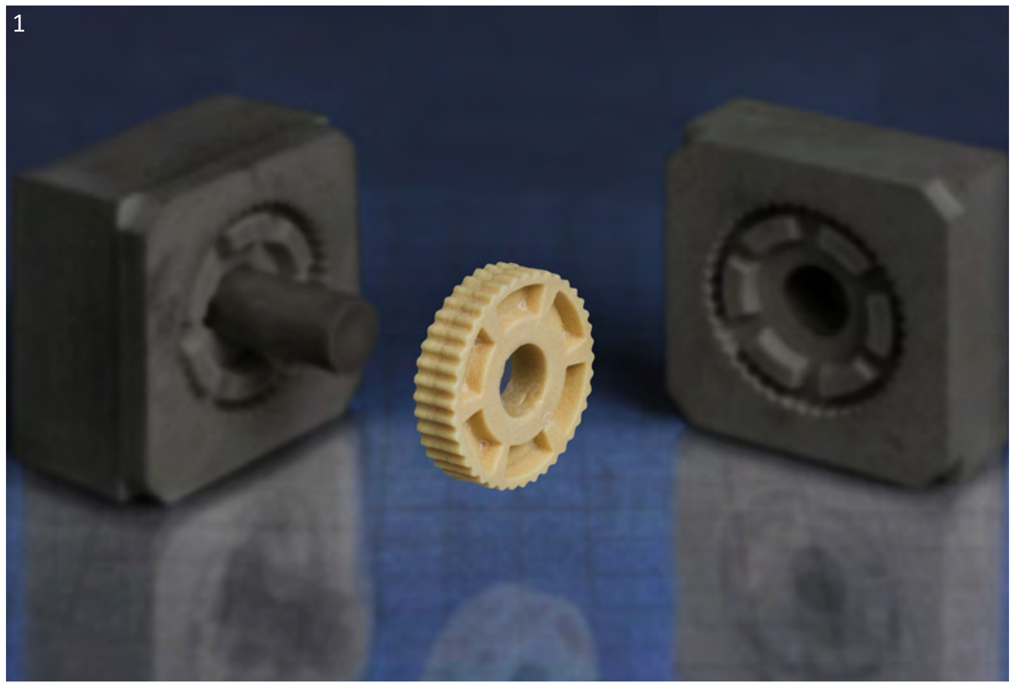
End-to-End Integration

igus offers highly wear resistant materials for SLS and FDM printing. Customers can order e.g. custom gears through an inhouse configuration and printing service.

Customer	**Consumer & Professionals**
Manufacturer	**Inhouse**
Technology	**FDM, SLS**
Material	**Iglidur**
Machine	**EOS Formiga P110**
Produced quantity	**96000 pieces per year**

Among the powder based Additive Manufacturing processes in plastics, Selective Laser Sintering (SLS) appears to be the most prevalent one when it comes to series applications. This is mainly due to its high geometrical accuracy, good mechanical properties and wide range of different materials. As seen from examples in this AM Report, SLS offers the opportunity to manufacture parts ready for operation, for example machine components like gears. Still, SLS components printed with regular materials such as PA12 are oftentimes susceptible to wear and therefore offer only limited service life. Germany-based igus has recognized this issue and therefore offers highly wear resistant plastics for the FDM and SLS process. In this article, applications made possible by igus' material innovation are discussed.

1



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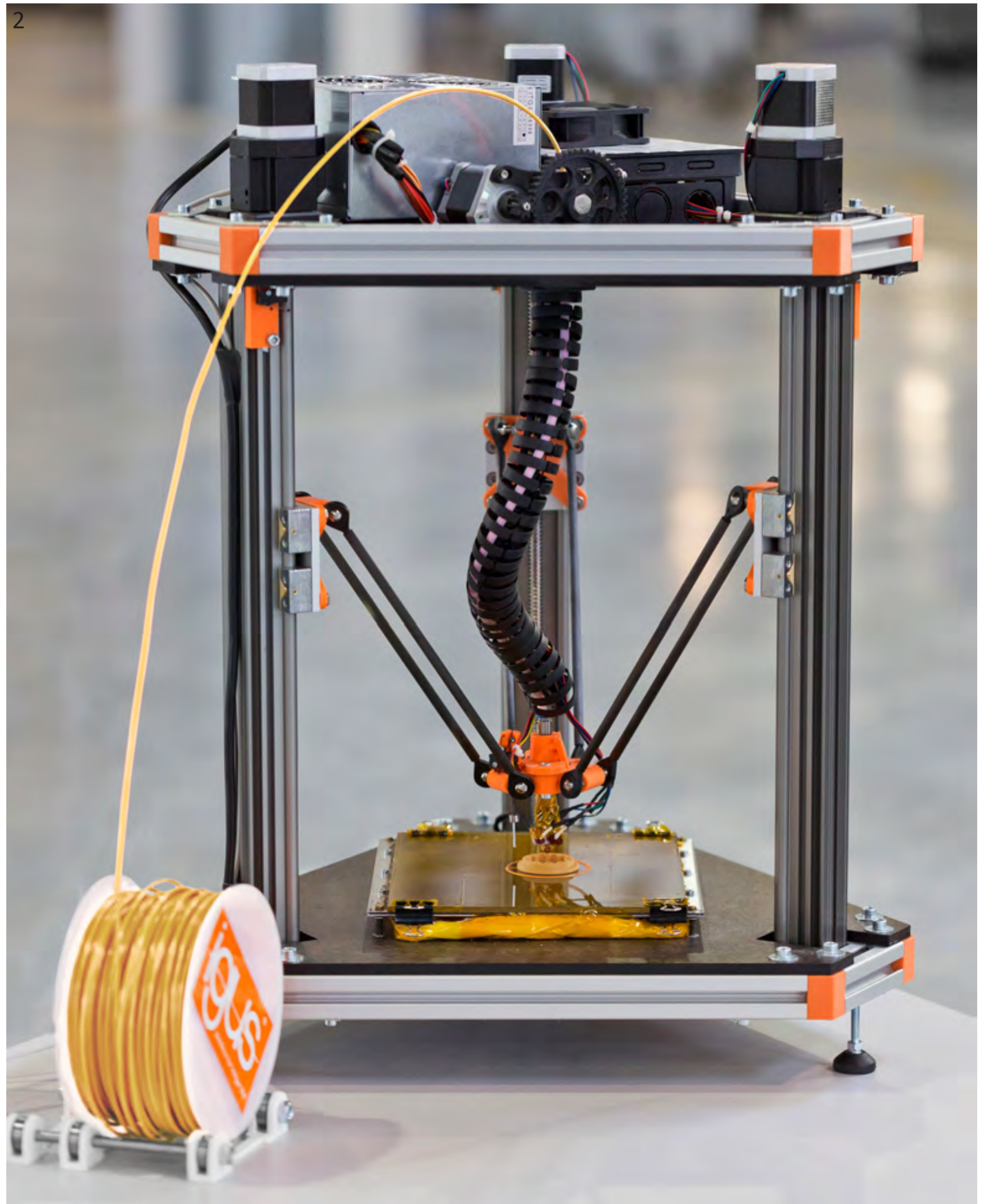
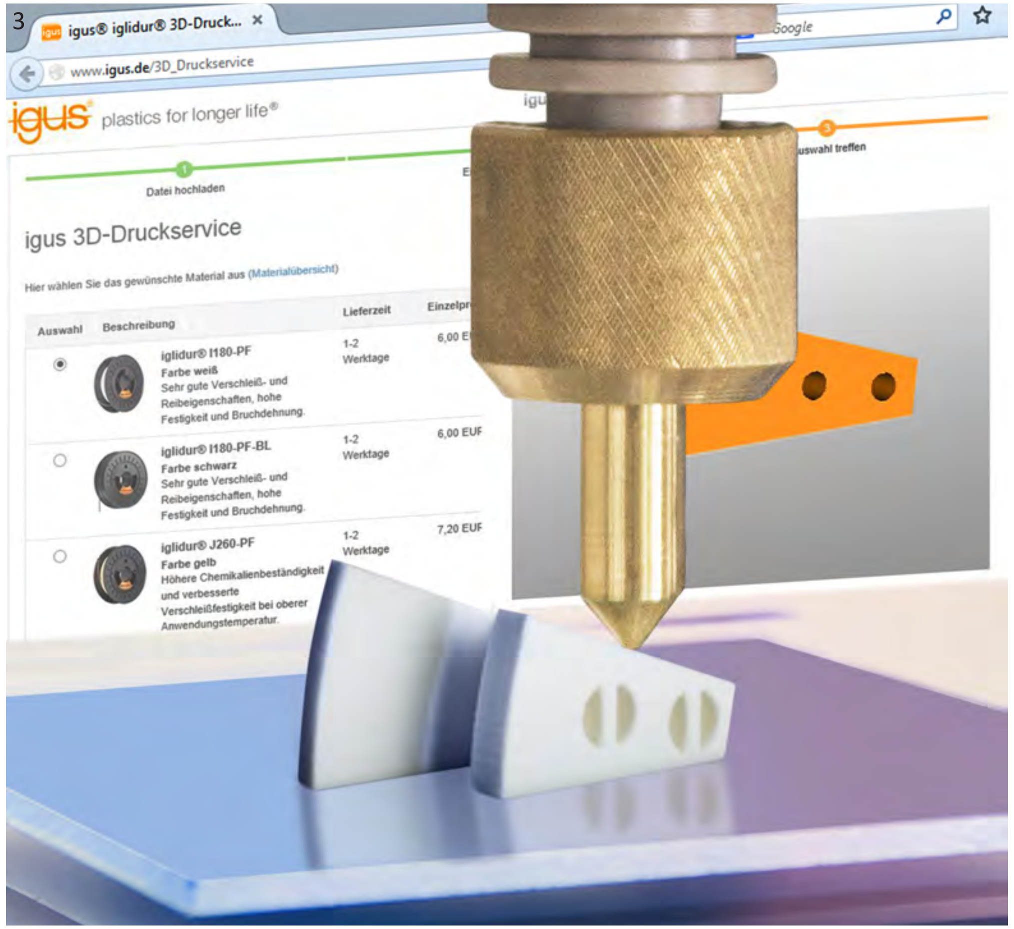


1 Wear resistant moulds for casting made with igus' material

2 Highly wear resistant material for FDM printing by igus

Based in Cologne, Germany, igus originated as a manufacturer of highly wear-resistant plastics, which are mostly injection molded. Its products include bearings, guides and cable carriers. Since 2015, igus has been offering tribologically optimized filaments for FDM and powder based materials for SLS. Igus' materials, labeled under the name iglidur, enable lubrication- and maintenance-free operation compared to standard polyamide materials, since they are optimized for friction and wear. In part, iglidur materials were specifically designed for AM processes, while others were transferred from injection molding applications. Experimental assessments at igus have shown that wear resistance can be improved by a factor of 50 for FDM printed parts and up to three times for the SLS process compared to regular materials.



3 igus' configuration service includes a printing service

4 igus' manufacturing facilities with Tom Krause, Head of Business Unit Additive Manufacturing

First applications of iglidur materials include light weight grippers for the packaging industry. Igus' customer required grippers for screwing lids onto cans, which needed to be changed whenever a new format is used. By leveraging Additive Manufacturing with igus tribo-filaments, cost reductions of up 85 percent were realized compared to former metal grippers. Lead times reductions of 70 percent were achieved through the rapid availability of additive manufactured parts. On top of that, the FDM printed plastic grippers are seven times lighter compared to their metal counterparts, leaving potential for increased productivity through higher processing speeds.

Apart from materials for AM, igus has also established a 3D printing service in combination with an online configurator for gears, bearings and pulleys. In particular, gears are suitable for AM due to their high shape complexity (involuted shape) and costly and time consuming manufacturing process when made conventionally (e.g. milling out of polyoxymethylene, known as POM). Using igus' configurator, customers can generate gear designs with few parameters. The configurator requires almost no CAD knowledge, which ensures high accessibility. Users can choose between different configurations, for example single or double straight toothed gears and different shapes for torque transfer (rounded or flattened hole, keyway or square bore). Customers without any design knowledge can even send in reference parts which are then scanned to obtain the right parameters. Through design automation, an ideally modelled involute gearing is generated, which ensures a low-noise operation and long service life. After a design has been created, the model can be downloaded in different formats. In the future, igus intends to offer more complex designs, for instance regarding lightweight structures or other gear configurations.

The 3D printing service by igus offers customers the opportunity to order customized gears after the configuration. The manufacturing of ordered parts is done in-house in order to ensure minimal lead times. Generally, orders can be processed within three working days, sometimes even within 24 hours. At the moment, igus uses three EOS Formiga P110 machines, which provide the demanded geometrical accuracy.

The case of igus strikingly demonstrates how innovations in materials in combination with an integrated, digital process chain enable new applications for AM. In the future, igus looks forward to introduce more new materials for AM, especially with regard to special requirements such as heat resistant or FDA approved parts. Furthermore, the application of AM for indirect processes (e.g. injection molding tools) is being considered.

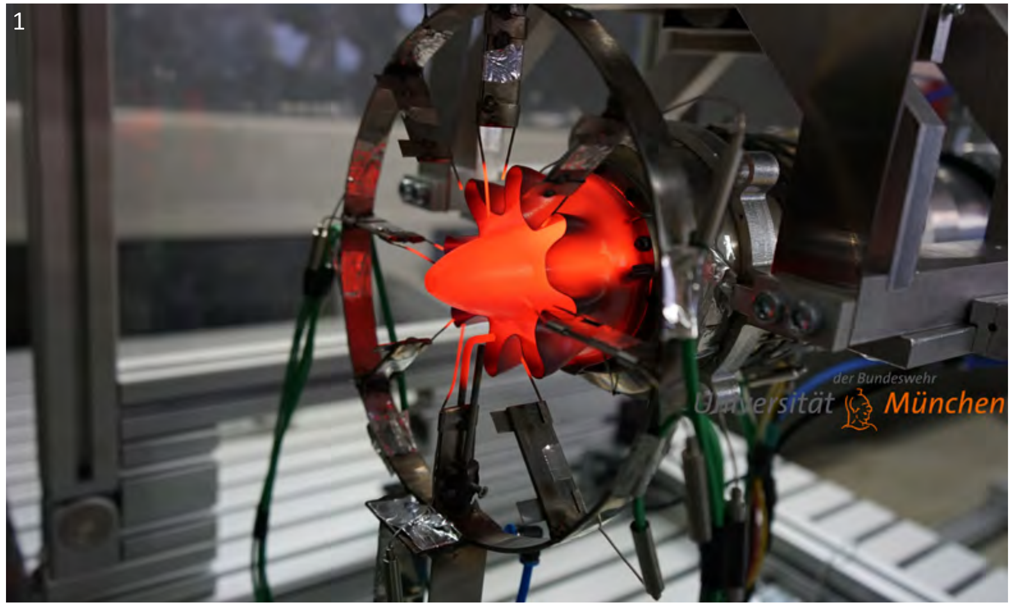
Copyright images: igus GmbH

Instrumented lobed nozzle for micro gas turbines

Innovation | Engineering | Business | End-to-End Integration

Vectoflow GmbH has developed an instrumented lobed nozzle for micro gas turbines. The complex DMLS part is equipped with integrated measurement ports for various sensor types.

Customer	**Universität der Bundeswehr München**
Manufacturer	**Vectoflow, 3T RPD Ltd.**
Technology	**Direct Metal Laser Sintering**
Material	**In718**
Machine	**EOS M290**
Produced quantity	**1**



In hindsight, aerospace was one of the first major industries to adopt Additive Manufacturing for series applications. As seen from many examples of firms like General Electric and others, AM has been leveraged to manufacture complexly shaped parts like nozzle and turbine components. In the majority of the cases, the opportunity for complex geometries and functional integration was exploited by the designers. The following showcase by Vectoflow GmbH discusses a novel design of an instrumented lobed nozzle for micro gas turbines, which is built using the Direct Metal Laser Sintering (DMLS) process. The joint development of Vectoflow with the other AM Venture firms Additive Works and 3T RPD Ltd. demonstrates how a collaborative development can be undertaken by combining complementary competences in a common part design.

Vectoflow is a Munich-based firm which offers fluid dynamic measurement solutions to customers from various industries. Many of its flow measurement probes are tailored to a respective user's need. Depending on the application, the probe design is adjusted according to probe shape, head types, number of measuring holes etc. The highly individualized probes are manufactured through Laser Sintering or Laser Melting. A broad range of material is offered by Vectoflow, including stainless steel, titanium, ceramics and different plastics. The flow measurement probes have already been discussed in detail in the last edition of the AM Report.

In its most recent project, Vectoflow has developed an instrumented lobed nozzle for micro gas turbines in collaboration with Additive Works and 3T RPD Ltd. Small sized gas turbines have been of high interest in the recent past, especially in China. Thanks to the geometrical freedom of AM, there is a high potential for improved turbine performance due to optimized flow structures. Furthermore, functional integration allows to incorporate flow measurement probes and therefore achieves a reduction of components. Both aspects can also be found in Vectoflow's lobed nozzle. The part is equipped with multiple integrated measurement ports, which enable

1 Lobed SLM nozzle on micro gas turbine testbench

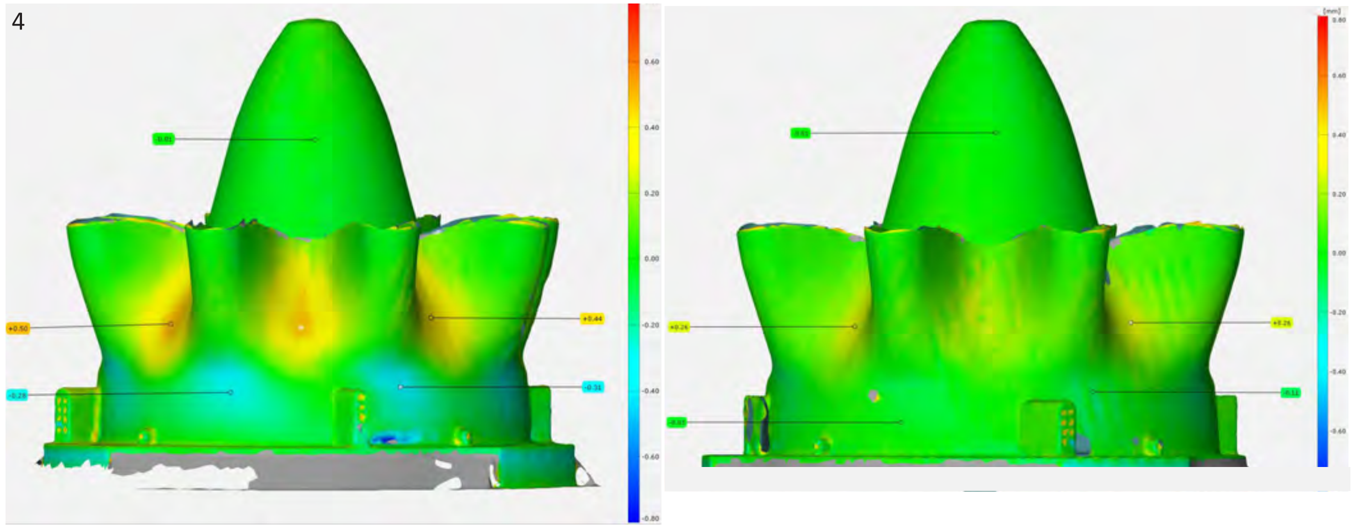
2 Finished SLM nozzle with integrated instrumentation

3 Physical validation of part accuracy

the investigation of flow conditions in the exhaust of a small gas turbine. Thermocouples can be inserted into four ports to measure exhaust gas temperature. Further measurement ports include two rows of static pressure connectors on the center cone that evaluate flow separation and static pressure within the nozzle. The airfoil shaped trusses connecting the cone with the nozzle are instrumented as well. Two of them are equipped with pressure kiel heads and three-hole probe heads to determine axial and circumferential flow.

Apart from functional integration, special interest was set to ensure a stable building process while minimizing post processing efforts. Using the Amphyon software solution by Additive Works, the amount of support structures was consistently reduced. Furthermore, the part's deformation induced by the Laser Melting process was simulated in pre-processing and compensated in the STL file. The part design itself was also adjusted to minimize distortions due to thermal deformation. As an example, the four tangential trusses leading to the center cone were positioned in a symmetrical manner, in order to cancel out torsional stresses due to thermal deformation cancel out. Using the Amphyon environment, an experimental validation was conducted by measuring and comparing surface deviations of an optimized part with a non-optimized reference version. In comparison, a 50-90% increase in accuracy was achieved.

4



4 Comparison of geometrical deviation without (left) and with pre-deformation (right)

By relying on a simulation driven approach, time-consuming trial-and-error design iterations were avoided. The final part was built in In718 using an EOS M290 machine. As a long-term manufacturing service provider, 3T was able to offer extensive experience regarding data preparation, build setup and post processing. In the future, Vectoflow looks forward to validating the design of the lobed nozzle on an experimental test bench at their customer's facility.

To sum up, the showcase of Vectoflow demonstrates that for the development of additively manufactured products a variety of fundamentally different competences might be necessary. Application specific knowledge, simulation capabilities and manufacturing & material related know-how were required during the development process of the lobed nozzle. Firms have the choice of either acquiring the portfolio of different competences on their own or, like in Vectoflow's case, to collaborate with specialized providers.

Copyright images:
Ralf Schmidt, Universität der Bundeswehr München, 3T RPD Ltd., Additive Works

Cutting manufacturing costs by half by optimizing part design

Innovation

Engineering

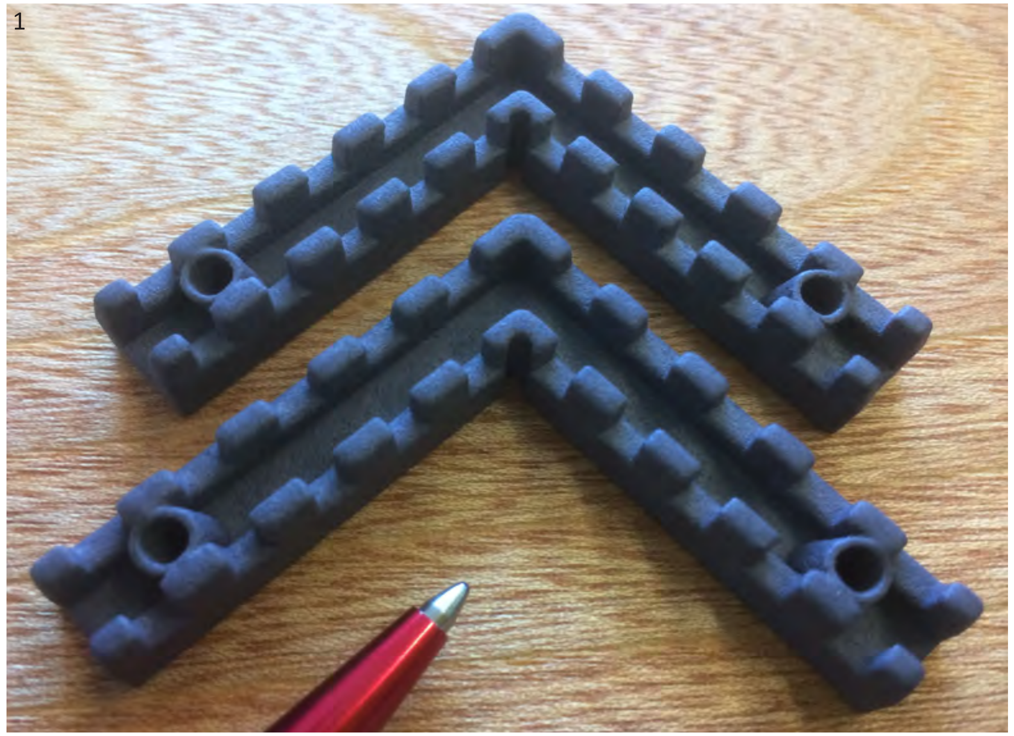
Business

End-to-End Integration

In order to pre-assemble wooden frames in window construction, corner brackets are used as assembly aids. These jigs allow easy positioning and gluing of the wooden frames that are used for wooden or metal windows. With an estimated quantity of 1,000 to 4,000, corner brackets are at the lower limit for an economical injection molding solution. Still, long delivery times remain for the manufacturing of an injection mold, which is why Jansen AG decided to pursue an additively manufactured alternative with prodartis AG. This showcase discusses their iterative design approach, which allowed cost reductions through design optimization loops.

prodartis AG and Jansen AG have developed an additively manufactured positioning jig for window assemblies. By combining design optimizations with the right manufacturing process, the unit cost was reduced by about 50%.

1



Customer	**Jansen AG**
Manufacturer	**prodartis AG**
Technology	**Multi Jet Fusion**
Material	**PA 12**
Machine	**HP JET Fusion 3D 4200 Printer**
Produced quantity	**1300**

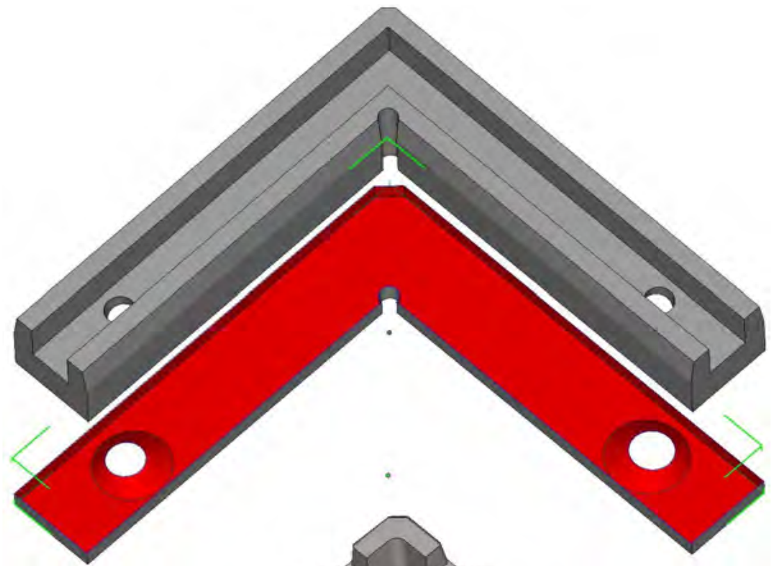
The mechanical requirements for the component are not critical and can be easily met by an additively manufactured part. Being a single-use part, the component is still very price-sensitive. A first design version from Jansen AG was therefore too costly due to a high material volume of 5 cm^3. Since the height and volume of the component have a direct impact on manufacturing costs, a redesign was conducted. During several personal discussions and optimization rounds with the supplier, it was determined where and how much material could be saved. By integrating crenellated structures on the outer edge of the component, the material volume was reduced by 1.7 cm^3. Further optimizations included the integration of honeycomb lattice structures, which increased the stiffness of the bracket. Inclined screw channels were applied to ensure a guided, easier and more precise fastening of the brackets. By shortening the bracket length by about 5 mm, the material volume was finally reduced to 2.87 cm^3, which corresponds to a total reduction of about 43 %.

Page 51:
1 Corner brackets made out of PA12 through MJF

2 Primary design of corner bracket

3 Optimized design including internal honeycomb structure

2



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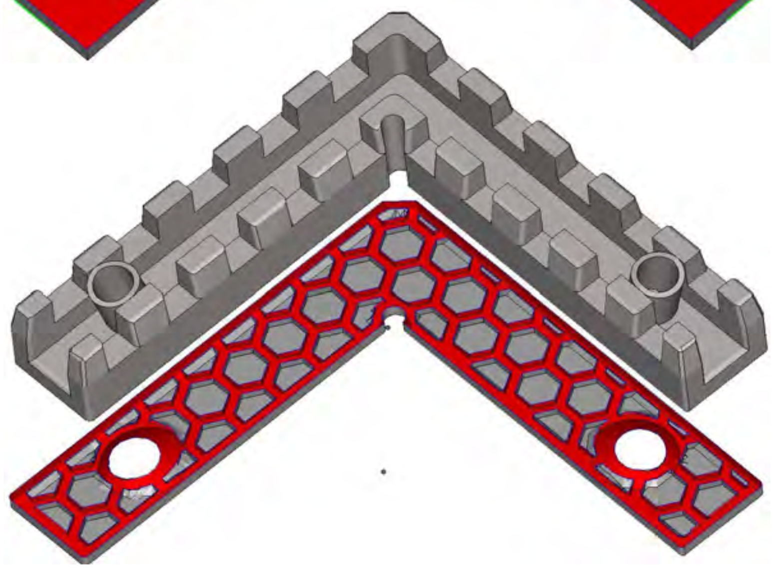
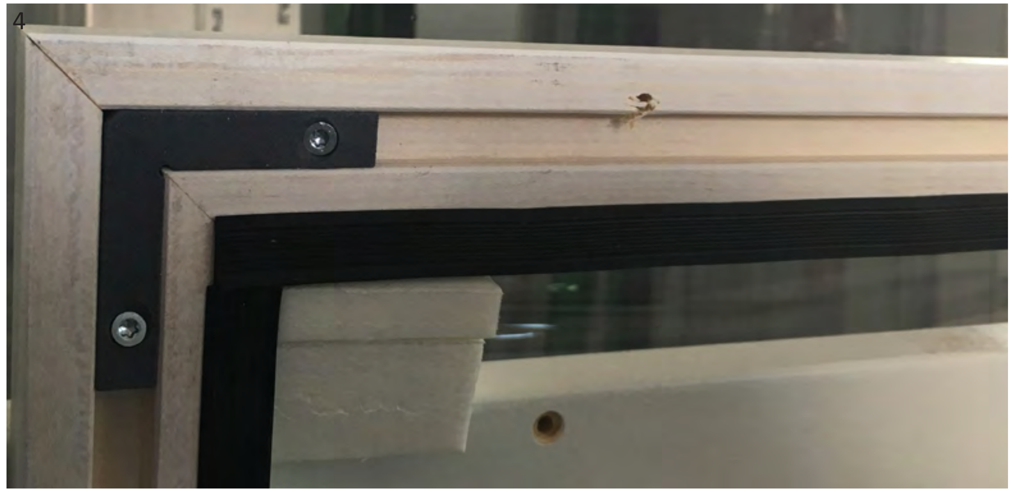


For this component with its rather complex geometry, HP's Multi Jet Fusion technology (MJF) turned out to be ideally suited. While in MJF the application of the agent and the heating process of each individual layer take the same time regardless of the area to be fused, the layer processing time in Selective Laser Sintering (SLS) is strongly dependent on the section geometry. In the case of corner brackets, the cost reduction in material savings would have been cancelled out by the longer scanning time of the SLS laser.

The overall project was completed within just a month, including the first touchpoint between client and supplier, several design optimization rounds and manufacturing of prototypes. prodartis' experiences from former AM projects proved to be essential for keeping the project duration to a minimum. As a long-standing manufacturer of plastic AM parts, the firm has a vast pool of design optimization ideas to choose from. In order to develop tailor-made solutions for the respective customer, a close cooperation with the client within the context of a consulting service was carried out.

4



4 Corner bracket fixed with two screws in window assembly

To sum up, this showcase strikingly demonstrates how product design, manufacturing process and material selection have to be consistently aligned to each other to enable viable applications of AM. Only by combining design optimizations and the selection of an appropriate manufacturing process, were material and machine time saved in the case of the corner brackets, which led to a halving of unit costs. As a positive side effect, the bending stiffness was increased due to the honeycomb structure.

Copyright images:
prodartis AG

Taking orthoses and prostheses to the digital age through AM and a digital solution platform

Mecuris offers highly individualized prostheses and ortheses, which are manufactured with SLS. Customers can configure the parts regarding functionality and esthetics through a digital solution platform.

Customer	**Certified prosthetists and orthotists**
Manufacturer	**Mecuris via certified supplier**
Technology	**SLS**
Material	**PA12, TPU**
Machine	**EOS P series**
Produced quantity	**2-digit number of products per month**

1

When it comes to prosthetics and orthotics, patients face the following dilemma: They can either choose off-the-shelf products, which are instantly available but only provide suboptimal fit or go for individualized aids, which provide better functionality but require long lead times. Neither of them provide the opportunity for patients to properly customize esthetics and looks, even though there has been a change of mind for displaying instead of hiding personal aids. Mecuris made it their task to overcome this dilemma by taking orthoses and prostheses to the digital age with the means of Additive Manufacturing and their digital Mecuris Solution Platform.

The company is a Munich based startup, which was established in 2016 as a spin-off from Munich University Hospital (LMU). Currently, the team of Mecuris encompasses 30 members of staff with various backgrounds: doctors, engineers, IT specialists, business economists and designers as well. Mecuris' core product is its digital solution platform, which enables certified prosthetists and orthotists (CPOs) to co-create unique orthotics & prosthetics (O&P) products with their patients. As a result, patients are provided with highly individualized, additively manufactured parts, which are optimized to meet both functional and esthetic needs of the customers. This also means that gaps can be finally closed for the treatment of small patient groups, such as children, where off-the-shelf products often don´t even exist.

2

1 Individualized prostheses made with AM

2 Mecuris' products also include custom solutions for children

The digital toolbox of the Mecuris Solution Platform covers a broad portion of the process chain that leads to a truly individual orthopedic aid. Scans and measurements made by certified prosthetists and orthotists act as an input for the automated design generator. By law, this has to be done by specialists, since orthoses and prostheses are regarded as medical products. Apart from functional parameters, patients can define individual preferences regarding esthetics and looks. In only a few klicks on the web-based platform, patients can choose between different colors, textures and designs. With both functional and esthetical inputs defined, the Mecuris Solution Platform automatically generates a design, which is digitally validated through finite element simulations. Once a feasible structure has been obtained, the design is then sent to certified suppliers for manufacturing. Most of the parts are built through Selective Laser Sintering with PA12. Post processing includes regular operations such as grinding, blasting and dying. On customer request, waterproof components are used in the assembly process making the end-product fully waterproof. Through the establishment of quality agreements with its production partners, Mecuris was the first manufacturer worldwide to receive the CE marking for additively manufactured prostheses feet. Thanks to the rapid availability of additively manufactured parts, lead times can generally be kept to less than ten workdays . This is a huge improvement compared to competing products, where lead times of up to 2-3 months are common. Throughout the process, prosthetists and orthotists are provided with information and functionalities regarding order management. This includes invoice processing capabilities as well.

3

3 The SLS manufactured covers can be customized regarding functionality and aesthetics

Beyond individualization and rapid availability, the opportunity for functional design is also exploited. Mecuris' additively manufactured parts incorporate standard metal adapters to ensure compatibility to industry standards. Furthermore, carbon fiber reinforced plastics are integrated whenever a higher stiffness is needed. Some products also include multi material assemblies with e.g. laser sintered TPU parts to provide dampening properties.

To sum up, this showcase demonstrates how the unique properties of AM can be exploited in the field of orthoses and prostheses through the establishment of a digital process chain. In the future, Mecuris looks forward to expanding its product portfolio through the introduction of other additively manufactured orthoses and prostheses. Furthermore, the company intends to improve its digital platform by further refining and automating the process chain. New functionalities can be expected, especially regarding scan data processing and design generation. Other Additive Manufacturing processes besides Selective Laser Sintering are being considered as well.

4

5

4 Integrated CFRP sheets increase the stiffness of the part

5 The highly individualized parts are optimally configured regarding functionality and esthetics

Copyright images: Mecuris GmbH

Leveraging Agile and Additive Manufacturing in New Product Development – The ALPA Case

Innovation

Engineering

Business

End-to-End Integration

ALPA has extensively adopted AM for the development of series products. This showcase discusses the implications of applying Agile in combination with AM in new product development.

Customer	**Professionals from photography and videography**
Manufacturer	**ALPA Capaul & Weber AG**
Technology	**SLS**
Material	**PA**
Machine	**n.A.**
Produced quantity	**Less than 50 pieces**

As many examples have shown, Additive Manufacturing enables a large variety of new engineering products due to its distinctive technological properties. The exploitation of both Complexity-for-free and Lot-size-one has been demonstrated in several showcases, as seen in this report. Besides, AM also has a major impact on how we actually develop products, since the technology enables the deployment of new development approaches, most prominently Agile. The uninterrupted application of AM for both prototypes and end user products simplifies the introduction of new products. By analyzing the development of the ALPA Platon videography camera, this showcase intends to illustrate on how this development practice can be implemented for developing a series product and what implications result on the AM process chain as a whole.

1

ALPA Capaul and Weber Ltd. is a Zurich based small-sized company, which specializes in the field of medium format cameras. Their modular cameras are mostly used in the field of professional photography, especially in the context of landscape and architecture. ALPA's products are characterized by low quantities, focus on conventional manufacturing (like milling) and high reliance on third party products and manufacturers. Recently, ALPA has identified new markets (i.e. convergence of photography and videography), where user requirements are unknown or have not consolidated yet. This creates a challenge for the development of new products, since new exploratory concepts are only hardly pursuable in an economical manner.

2

In order to overcome this challenge, ALPA has from very early on leveraged the benefits of AM. Through several development projects (as seen in the AM Report of 2016 and 2018), the company was able to gather extensive experience regarding the implementation of AM. In its newest project, the development of the videography camera Platon, ALPA applied Agile principles through the introduction of short and iterative development cycles. This enabled the company to rapidly provide viable product increments to lead users and increase product-to-customer fit through feedback loops. To sum up, the implementation of Agile led to a vastly accelerated validation of product increments (after six months), reducing initial costs and risks through early monetarization. Furthermore, a higher flexibility regarding later design changes was achieved.

1 ALPA's newest videography system Platon

2 Several components of the system are manufactured with SLS

Apart from the described benefits, several challenges occurred through the implementation of Agile as well. In order to maintain short iterative cycles, it is crucial to have a fast and steady supply chain of AM prototyping parts. This was an issue to ALPA since the order systems and processes in place were largely optimized for conventional machining technologies. To be more precise, the existing process lacked the required speed, transparency, portability and ease of use to allow to fully leverage the speed potential offered by AM. The goal was therefore to rethink the supply chain from the perspective of Additive Manufacturing. The optimized supply chain should cover the whole process chain and therefore include order generation in CAD to cost center, allocation and invoice processing.

3

3 The development of the AM parts was done in an Agile process

In order to overcome these challenges, student theses were conducted in collaboration with the Product Development Group Zurich of ETH Zurich. As a result, a novel supply chain for AM prototypes was conceptualized and implemented. With the new system in place, it is possible to order prototypes directly from the CAD environment (in ALPA's case Fusion 360). Rough estimations of cost and lead times are already provided in Fusion 360, enabling designers to better plan their development activities. To be manufactured parts are added to an order backlog, which is located within the commercial work management platform Smartsheet. Here lies the fundamental distinction of the novel system compared to its predecessor: formal orders are replaced by a backlog, containing all of the parts which need to be manufactured including both 3D models and specifications. This enables the supplier to independently manage in which order to process the backlog entries and therefore optimize for maximum machine utilization. As a side effect, delivery delays are avoided and manufacturing errors are minimized as well. Furthermore, subsequent process steps such as order confirmation, receiving inspection and invoice processing were also integrated within the Smartsheet prototype and automated whenever possible. Dashboards for ALPA and the supplier give an overview of the most relevant key performance indicators (e.g. outstanding orders, expenses) at any time.

4

To sum up, following benefits were achieved through the introduction of the new order system: increased predictability through cost and lead time estimations, higher transparency through continuous order tracking and dashboard functionalities and lower order effort through optimized process integration and automation. In the bigger picture, this example demonstrates that the implementation of AM in organizations results in implications on the whole process chain: starting from new product development, where Agile development approaches suddenly become viable thanks to the rapid availability of additive manufactured prototypes; in operations, where supply chains and order processes have to be adapted to the needs of AM and in marketing & sales as well, where customer relationships are altered due to the opportunity of early validation of product increments through user feedback. Only by progressing in all functional clusters, did a holistic exploitation of AM for series products prove to be manageable for ALPA.

4 The AM camera cage includes a cooling fan and plugs for power supply

5 ALPA can quickly react to changing customer needs thanks to AM and Agile

5

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ALPA Capaul & Weber AG

Additively manufactured brake calipers for Formula Student racing car

Innovation | Engineering | Business | End-to-End Integration

AMZ, the Formula Student team of ETH Zurich and HS Luzern, has developed SLM brake calipers for the most recent edition of their racing car. By employing Additive Design, the weight of the part was reduced by 26%.

Weight is one of the major optimization criteria for racing cars. As a rule of thumb, one percent of weight reduction approximately corresponds to 0.2 percent shorter lap times. As seen in many examples, Additive Manufacturing offers the opportunity to improve lightweight design through load optimized, complex structures. Therefore, the Academic Motorsports Association of Zurich (AMZ), the Formula Student team of ETH Zurich and Hochschule Luzern, relied on SLM printed braking calipers for the latest edition of their electric racing car. The lightweight part was developed in collaboration with AM Kyburz and was manufactured at their premises. In total, more than 100 grams were saved thanks to the load optimized, additive design. Their braking calipers shall be discussed within this showcase.

Customer	**Academic Motorsports Association of Zurich (AMZ)**
Manufacturer	**AM Kyburz**
Technology	**SLM**
Material	**AlSi10Mg (CL31 from Concept Laser)**
Machine	**M2 Duallaser (Concept Laser)**
Produced quantity	**8**

1

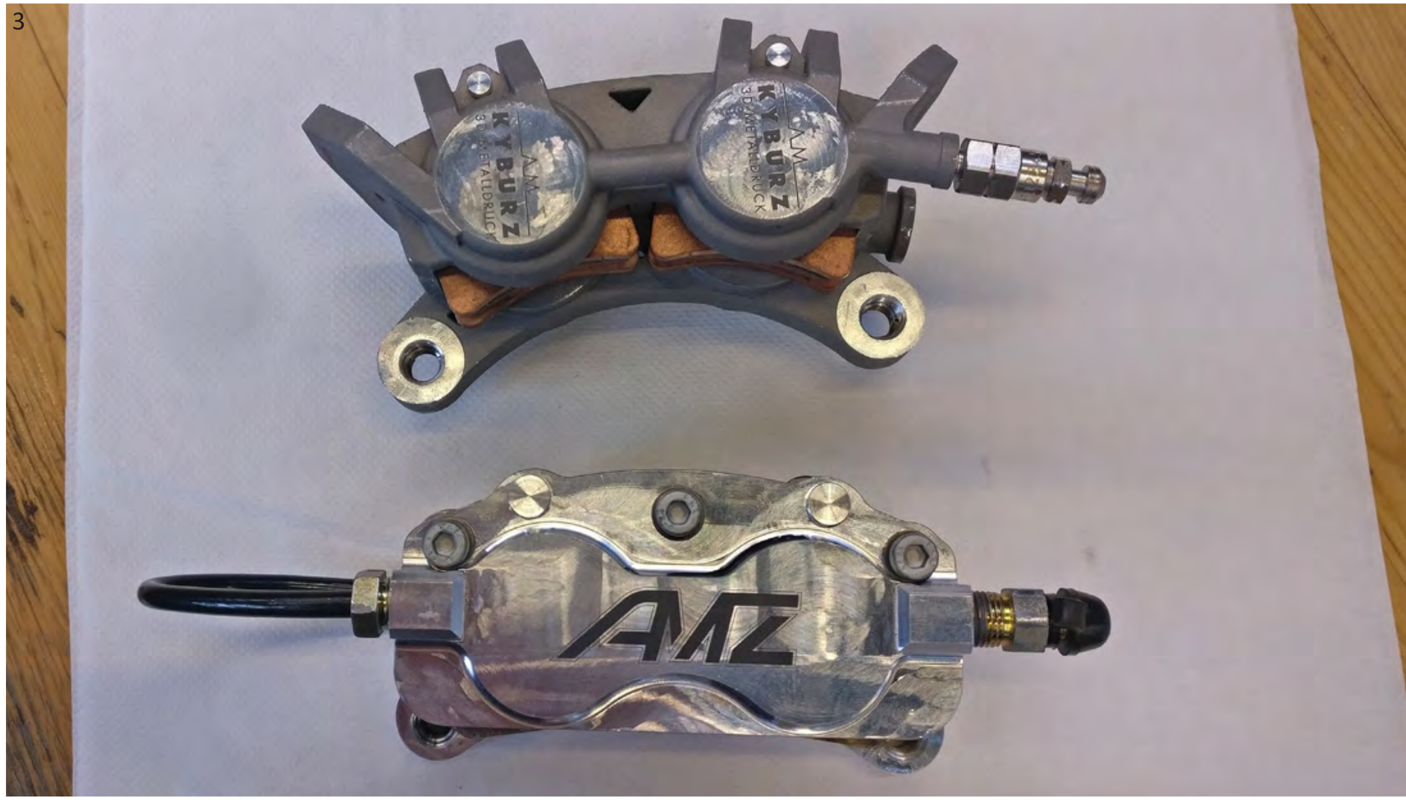

2


To briefly explain, Formula Student is the world's biggest competition for engineering students. Every year, university students from all over the world develop, build and compete with their racing cars in different classes. These include electric and even self-driving vehicles. The competitions take place at actual race tracks like Hockenheim, Germany or Silverstone, England. The team of ETH Zurich and Hochschule Luzern (AMZ) has successfully participated in these contests for over 10 years with frequent top-tier results.

Raphael Huber was responsible for the design of the braking calipers of AMZ's latest racing car "eiger". These calipers are used in the front & the rear braking system and rely on a hydraulic mechanism: brake fluid transfers pressure on an aluminum piston, which is connected to brake pads. The structural component carrying the brake fluid was manufactured with Selective Laser Melting using an aluminum alloy. Making use of the geometrical freedom of Additive Manufacturing, internal channels were applied to efficiently distribute the brake fluid in the system. Multiple cutouts were used to reduce material whenever possible. The final weight was 485.5 grams, which corresponded to a reduction of 26 percent compared to the formerly milled predecessor.

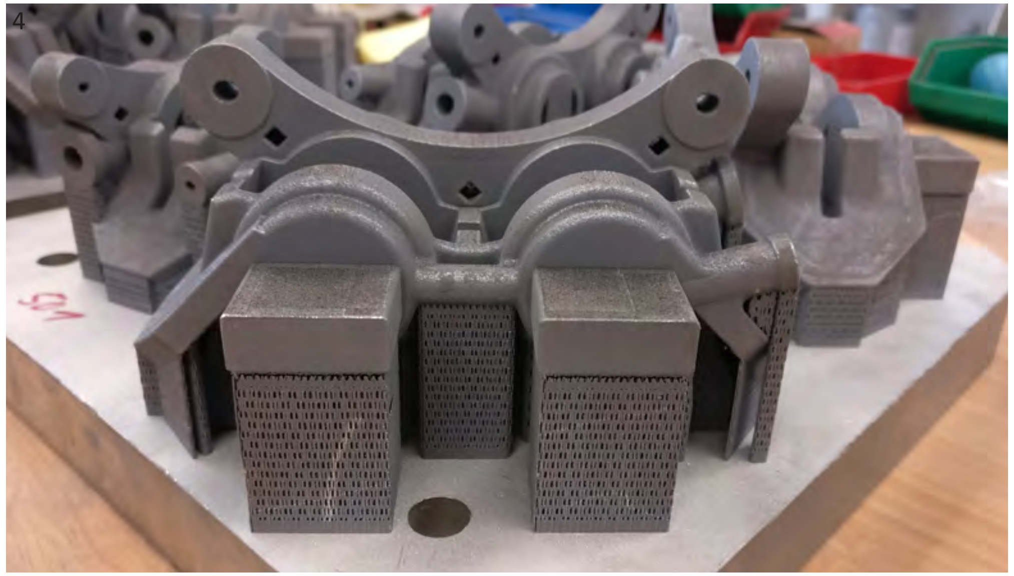
1 and 2 Lightweight SLM brake calipers

3 Compared to the milled counterpart the weight was reduced by 26 %

3


Apart from weight optimization, it was attempted to reduce mechanical post processing effort to an absolute minimum, for example rectangular clamping structures were integrated into the design. As a result, the parts were easily clamped into the milling machine for mechanical finishing. Furthermore, the cylinder for the piston was designed in a way that the pressure interlocks the pin with a form-fit. Therefore, no additional threads are needed.

4



4 Clamping structures were integrated into the design to reduce post processing effort

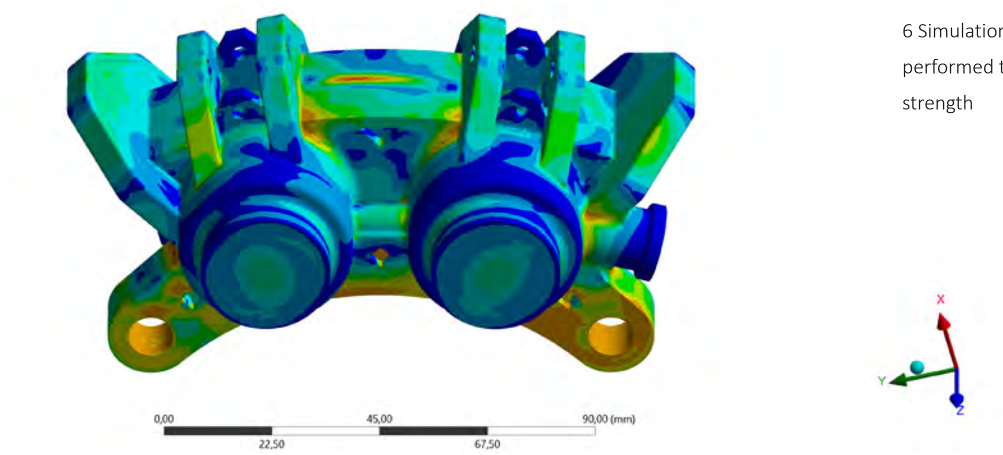
Choosing an Aluminum alloy resulted in the following challenge: the strength of the material proved to be insufficient during the development process. In order to increase tensile strength, the T6 heat treatment was applied. The three phase process ensured that the part sustains the loads during operation. As a specialist for SLM, AM Kyburz was able to conduct the heat treatment in-house. Further post processing included machining operations like threading and insertion of helicoils. Due to the close vicinity of Kyburz Feinmechanik AG's machining experts, it was possible to deliver the finished parts in a short time.

5

5 Specimens for tensile testing were manufactured as well

In general, the development process heavily relied on frequent simulations. These were conducted to investigate stress distributions within the part. Furthermore, physical specimens were used for experimental testing of tensile strength. In total, only one manufacturing trial was required to build the part successfully. AM Kyburz' extensive experience in the field of SLM proved to be greatly beneficial to ensure first-time-right-design.

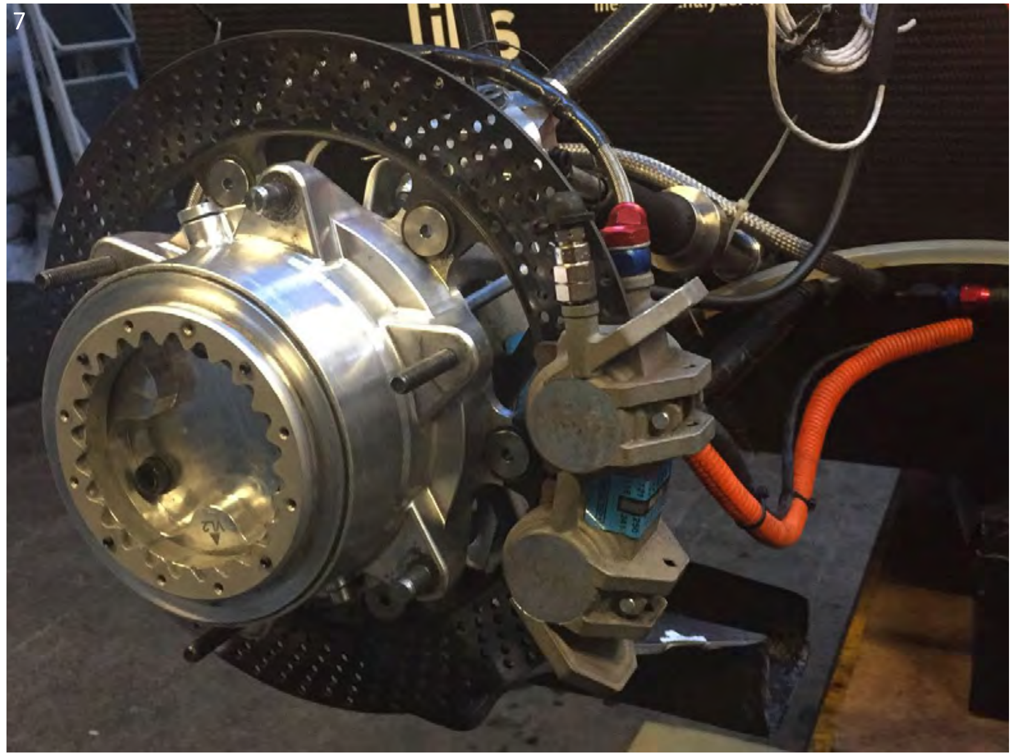
6



6 Simulations were frequently performed to evaluate the part's strength

To conclude, the showcase by AM Kyburz and AMZ demonstrates that know-how regarding design, material, machine and post processing have to be aggregated to successfully develop high-performing parts. The racing car equipped with the SLM braking calipers performed successfully in the Formula Student competitions. In the most prestigious race of Hockenheim (Germany), "eiger" took first place in the overall standings.

7



7 Calipers mounted on the AMZ racing car "eiger"

Copyright images:
Raphael Huber

Development and Series Implementation of Indoor Home Ventilation System Supported by Vacuum Casting Technology

Innovation | Engineering | Business | End-to-End Integration

Protoech FL AG provided Hoval AG with several sets of vacuum casted parts for field testing. This enabled Hoval to optimize its home ventilation system within short development loops.

Fresh air awakens the spirit of life and activates the immune system. Disease inducing particles such as viruses, bacteria or mold have to be minimized - a challenge for today's new buildings, which are more or less "airtight". Hoval AG has developed a home ventilation system, which guides and distributes filtered outside air optimally and completely without draught to the inside. Noise, dust and dirt particles remain outside, while odors and moisture are discharged to the outside in a controlled manner. The newest iteration of the air outlet was thoroughly engineered to improve assembly and installation. The joint development with Prototech FL AG heavily relied on field testing with vacuum casted parts. Therefore, this showcase discusses their approach of combining Additive Manufacturing with vacuum casting for the early validation of series parts.

Customer	**Hoval AG**
Manufacturer	**Prototech FL AG**
Technology	**Vacuum Casting (also known as Silicone Casting)**
Material	**PR 700 (hard components), rubber (soft components)**
Machine	**n.A.**
Produced quantity	**Several sets for field testing and functional part optimization**

1

While re-engineering the air outlet of the home ventilation system for improved assembly and installation, Hoval faced several uncertainties. These included the functional design of the break-outs (especially for the nails), the adjustability of the two-component grid supports, as well as the behavior of the frictional locking. To ensure that the product requirements of the individual components were met, it was necessary to validate the design solutions envisaged by Hoval in practical field tests. These were performed in close cooperation with Prototech FL AG. In an initial requirements evaluation, the vacuum casting process was chosen, as it is suitable for such a pilot series. Strengths of this process include high repeatability, short implementation times, high flexibility and a broad range of materials including multi material solutions. In comparison to "linear" price scaling of AM, output ratios of 40-80 components per silicone mold enable a high cost-benefit factor for prototype series, especially for complex or voluminous components with an edge length of up to 1.20m.

2

3

1 Vacuum casted cover of the Hoval housing system

2 Hoval "Quick" connection housing system, design draft

3 Several field tests were performed throughout the process

Vacuum casting is a proven reproduction technology starting from a so-called master pattern which is additively manufactured (stereolithography) based on a CAD data set. Compared to conventional AM process chains, the final surface structure is already applied to the 3D-printed master pattern. Therefore, it is reproduced during the casting process instead of being "finished" onto the later vacuum casted parts.

The prepared master pattern is cast in silicone and de-gassed in the vacuum chamber. The cured silicone mold is appropriately cut off the master pattern. Additional insert components like threads or other prefabricated parts can be easily integrated with interlocking connections. For complex parts the silicone mold is divided into several components. Furthermore, multiple cavities can be integrated to improve both cycle time per part and application rate per silicone mold.

The reassembled silicone mold is then placed in the bottom compartment of the vacuum casting machine. The casting machine is closed, and the two components of polyurethane based casting resins are mixed in the top compartment semi-automatically under vacuum conditions. Once the pre-defined mixing time has elapsed, the resin is cast into the silicone mold. After completing the casting, the mold is placed in an oven to cure. Post curing the vacuum cast parts are removed from the mold, which can then be reused for the next production cycle. Runner and risers are then removed from the cast parts (finishing) followed by an outgoing inspection and packaging.

4 Removing the protective cover of the mounting plate

5 First result without predetermined breaking point

In cooperation with the Hoval development team, Prototech first discussed the initial design, pre-optimized it and manufactured it using the vacuum casting process described above. In the course of the field tests, various design details were further adapted on the basis of empirical findings. The revised components were then cast by Prototech FL AG within a few days and re-tested by Hoval.

These revised components include for example the friction-locked fasteners. The optimum thickness, number of fins and Shore hardness were quickly determined by means of vacuum casting. The same procedure has proven effective for optimizing the snap-in hook of the clamping strip. The geometries of the snap-fit and the clamping band fastener were adapted and simplified on the basis of the practical tests.

6 Attaching and positioning the ventilation lattice

The functional validation of the breakable housing cover was unproblematic, unlike the nail breakouts. The challenge here was that they were required to withstand the impact of the nails during installation and to break out reliably when the casing is removed. In the course of the field tests, it was revealed that the original design did not sufficiently meet the requirements. With the subsequent design modification, the functionality could be proven without significant loss of time.

To sum up, thanks to the close collaboration between the Hoval development team and Prototech, the new product was significantly improved within a few optimization loops. The process merely spanned a few weeks, ranging from the first concept drafts to series readiness through pre-tests on an actual construction site. This showcase strikingly demonstrates how AM in combination with other processes such as vacuum casting can substantially minimize risks and therefore time and costs during the late phases of a product development project.

7 Initial design of the flexible clamping band (left) versus the final design version after testing (right)

8 Initial design of the grid holder (red) versus the final design version after testing (white)

Copyright images:
Images 1,6,7: Prototech FL AG
Images 2-5: Hoval AG

SLM valve body for an intelligent solenoid valve for hydrogen gas filling stations

Innovation | Engineering | Business | End-to-End Integration

Nova Werke AG has developed an intelligent solenoid valve for hydrogen gas filling stations. The main valve body is optimally designed for the SLM process and integrates various sensors.

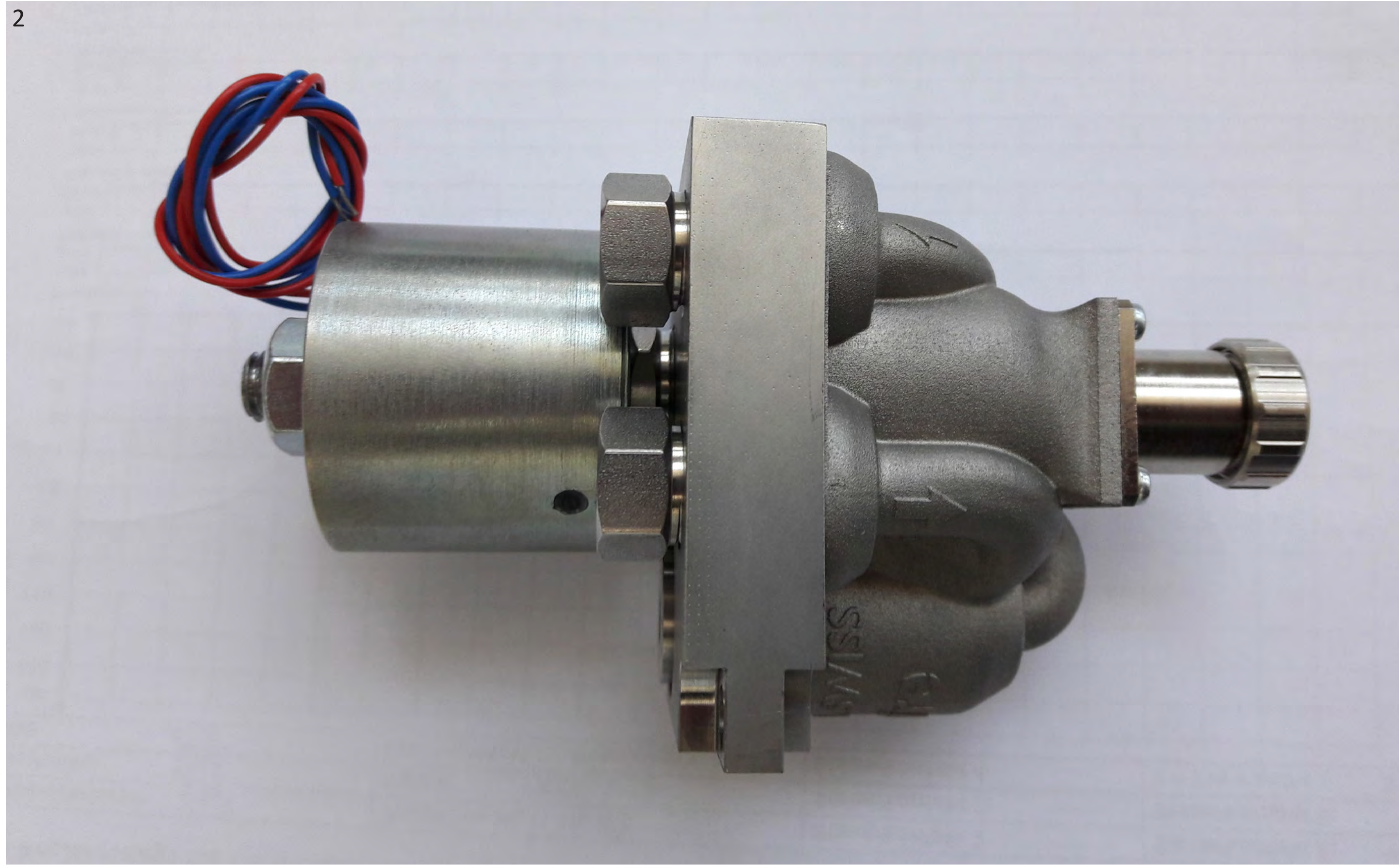
Customer	**Manufacturer of hydrogen gas stations**
Manufacturer	**Nova Werke AG**
Technology	**Selective Laser Melting**
Material	**Stainless steel (1.4404)**
Machine	**Concept Laser**
Produced quantity	**> 10 Prototypes**

Fuel cells play an important role when it comes to promoting the adoption of environmental friendly energy resources for mobility. Briefly explained, hydrogen gas is used to chemically react to water while generating an electric current, which can be used to power a vehicle. Compared to conventional electric cars with batteries, fuel cell powered vehicles tend to have a greater range and can be refueled substantially faster. If the hydrogen gas is generated with green energy resources (e.g. wind or water), the environmental footprint is much better compared to lithium based batteries. Still, fuel cell cars have not made their breakthrough yet, mostly due to a sparse hydrogen refueling network. Nova Werke AG, a Swiss technology company based in Effretikon, has developed a solenoid valve for hydrogen gas stations. The valve body is specifically designed for the Selective Laser Melting process. The joint development project with Inspire shall be discussed within this showcase.

1

As depicted in Figure 1, the presented part is a solenoid actuated valve, which controls the flow of hydrogen gas in a filling station. Since pressures can reach up to 1000 bar, the design is based on a pilot valve to reduce the required actuation force. Special focus was set on minimizing the size of the valve. As a result, the four closely positioned outlets are connected by complexly shaped, high-pressure gas-carrying pipe structures.

2



The overall design was consistently optimized in order to reduce post processing efforts to a minimum. Finishing encompasses mechanical machining of all valve connectors to satisfy requirements regarding accuracy or surface quality. For example, all in- and outlets were arranged vertically and at the same height to make mechanical finishing as easy as possible. Furthermore, drop-shaped pipe sections were applied to avoid support structures whenever possible.

Further innovativeness of the part lies in its integration of sensors into the SLM structure. The goal was to enable intelligent features, as for example report of valve status. As a result, two temperature and one Hall sensor are introduced into the assembly. In order to integrate the sensors, the build job is interrupted and the sensors are positioned in pre-built cavities. Afterwards, the build process can be continued. The vertical positioning of all three sensors was arranged as such that only one built job interruption is required. Cable guiding was also integrated into the SLM part. Two patent applications have been filed for all of these features.

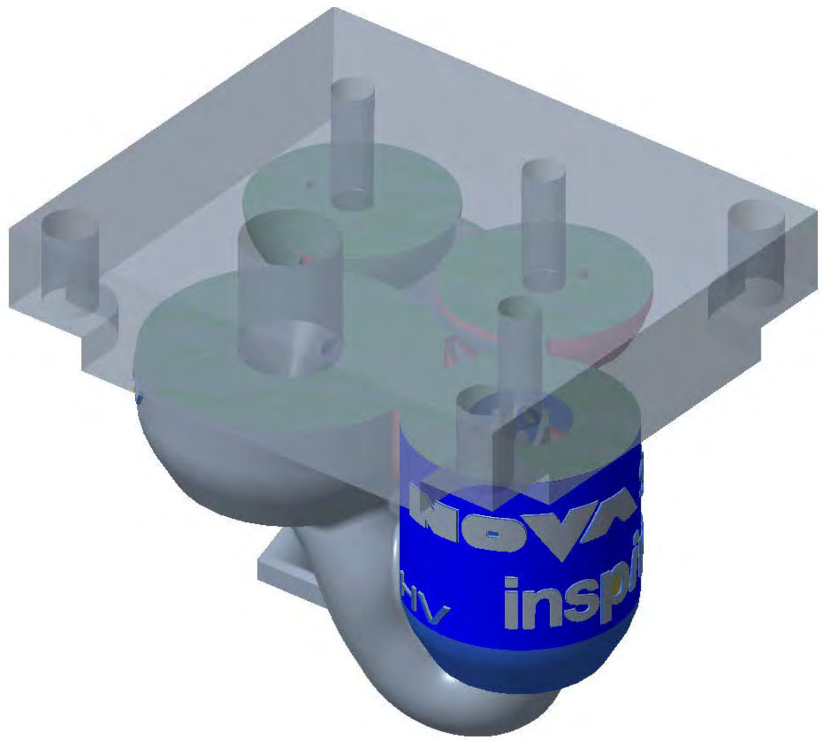
1 SLM valve body

2 Solenoid valve mounted on SLM valve body

The joint development project between Nova and Inspire was conducted in an iterative manner. Starting with a design thinking driven workshop, user personas and first concepts of the valve were created. Afterwards, multiple iterations of the part were designed. Even late in the project, conceptual changes were allowed to improve the overall performance of the product. For instance, the part orientation was flipped up side down very late in the project in order to allow hybrid manufacturing on top of a conventionally manufactured plate. Even though the CAD model had to be substantially remodeled, the benefits were much bigger since the part volume was reduced by 40%. In order to precisely position the print job on the build plate, positioning guides were introduced as well.

3 Hybrid structure with conventional plate

3



Throughout the whole project, physical testing of the SLM prototypes was prioritized. SLM probes were frequently tested regarding aspects such as long term durability or the effect of print job interruption on material strength. The project team spent one year investigating static and dynamic properties, including gas-tightness, based on probes. Findings were reintroduced into the design of the solenoid valve.

To sum up, Nova's SLM solenoid valve impressively shows how part design, functionality and processes have to be consistently aligned to each other. As seen in the example of the sensor integration or the shape of the gas-carrying pipes, the selection of a certain manufacturing and finishing process has an immediate impact on the valve's design and functionality. Only when proper alignment is ensured can the full potential of AM be exploited in the future. In the future, Nova looks forward to optimizing the part with respect to cost reduction and quality assurance for a serial production.

Copyright images:
Nova Werke AG

Swiss Institutes with a research focus on additive manufacturing

FHNW University of Applied Sciences Northwestern Switzerland
Brugg-Windisch, Muttenz

BFH Bern University of Applied Sciences
Biel-Bienne, Burgdorf

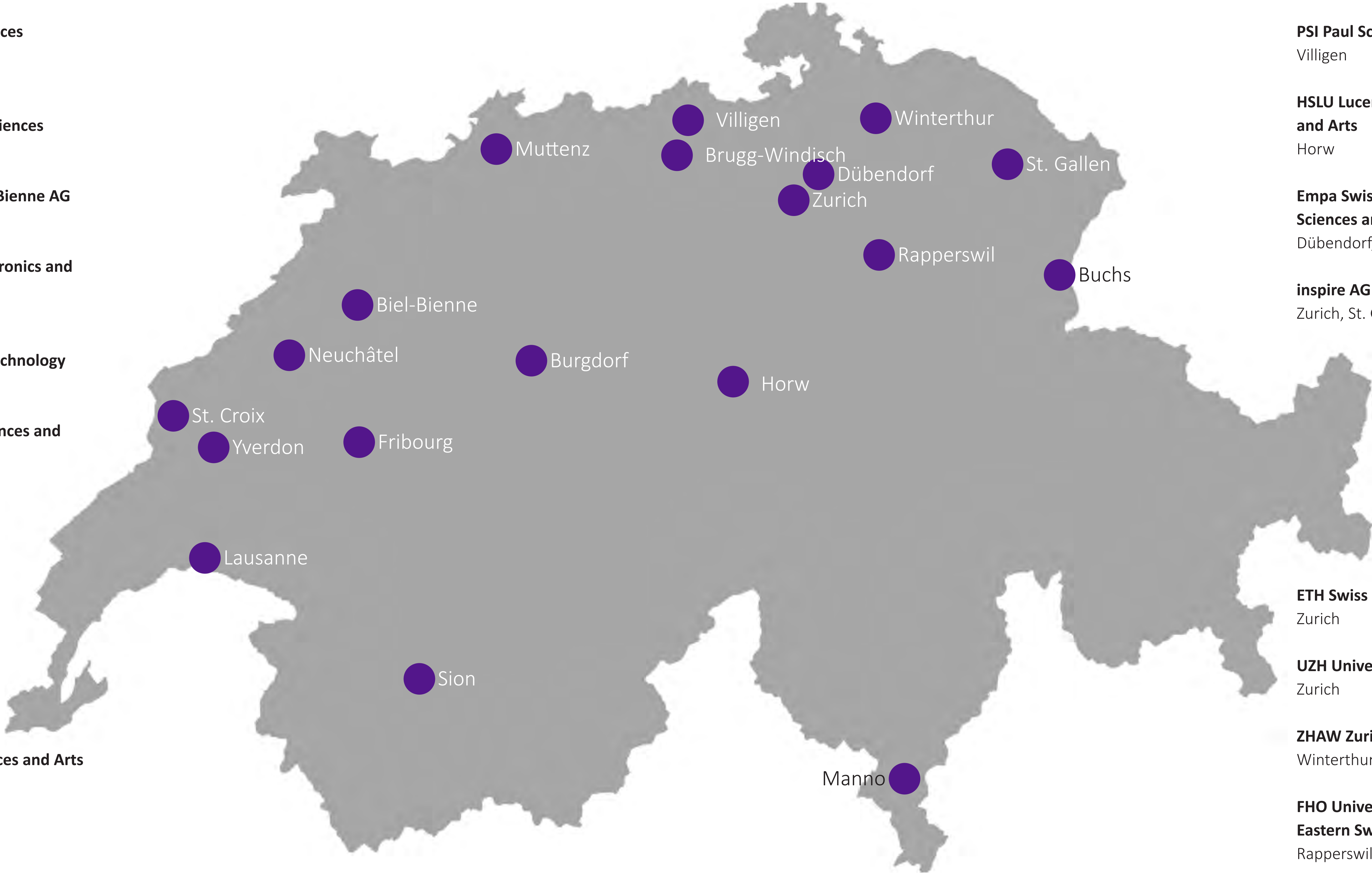
Switzerland Innovation Park Biel-Bienne AG
Biel-Bienne

CSEM Swiss Center for Microelectronics and Microtechnologies
Neuchâtel

EPFL Swiss Federal Institutes of Technology
Lausanne, Neuchâtel

HES-SO University of Applied Sciences and Arts Western Switzerland
Fribourg, Yverdon, St. Croix, Sion

SUPSI University of Applied Sciences and Arts of Southern Switzerland
Manno



PSI Paul Scherrer Institute
Villigen

HSLU Lucerne University of Applied Sciences and Arts
Horw

Empa Swiss Federal Laboratories for Materials Sciences and Technology
Dübendorf, St. Gallen

inspire AG
Zurich, St. Gallen

ETH Swiss Federal Institutes of Technology
Zurich

UZH University of Zurich
Zurich

ZHAW Zurich University of Applied Sciences
Winterthur

FHO University of Applied Sciences of Eastern Switzerland
Rapperswil

Institutes specialized in additive manufacturing research

BFH Bern University of Applied Sciences
Engineering and Information Technology

BFH Bern University of Applied Sciences
Engineering and Information Technology, Print Technology

BFH Bern University of Applied Sciences
HKB Bern University of Arts, Materiality in Art and Culture

CSEM Swiss Center for Microelectronics and Microtechnologies

EPFL Swiss Federal Institutes of Technology Lausanne
Competence Centre for Materials Science & Technology (CCMX)

EPFL Swiss Federal Institutes of Technology Lausanne
School of Engineering, IMT Institute of Microengineering Lausanne

EPFL Swiss Federal Institutes of Technology Lausanne
School of Engineering

EPFL Swiss Federal Institutes of Technology Lausanne
School of Basic Sciences, ISIC Institute of Chemical Sciences and Engineering

EPFL Swiss Federal Institutes of Technology Lausanne
Laboratory of Thermomechanical Metallurgy (LMTM)

Empa Swiss Federal Laboratories for Materials
Sciences and Technology

ETH Swiss Federal Institutes of Technology Zurich
D-MATL Department of Materials, Complex Materials

ETH Swiss Federal Institutes of Technology Zurich
D-MAVT Department of Mechanical and Process Engineering, IWF Institute for Machine Tools and Manufacturing

ETH Swiss Federal Institutes of Technology Zurich
D-MAVT Department of Mechanical and Process Engineering, IDMF Institute of Design, Materials and Fabrication

ETH Swiss Federal Institutes of Technology Zurich
D-MTEC Department of Management, Technology and Economics

FHNW University of Applied Sciences Northwestern Switzerland
School of Engineering, IPPE Institute of Product and Production Engineering

FHNW University of Applied Sciences Northwestern Switzerland
School of Engineering, IPN Institute of Polymer Nanotechnology

FHNW University of Applied Sciences Northwestern Switzerland
School of Life Sciences, Institute for Medical and Analytical Technologies

FHNW University of Applied Sciences Northwestern Switzerland
School of Life Sciences, Institute for Chemistry and Bioanalytics

HES-SO University of Applied Sciences and Arts Western Switzerland
School of Management and Engineering Vaud, AddiPole, Advanced Manufacturing Center

HES-SO University of Applied Sciences and Arts Western Switzerland
School of Engineering and Architecture of Fribourg, Institute for Printing (iPrint)

HES-SO Valais/Wallis University of Applied Sciences and Arts Western Switzerland
School of Engineering, Institute of System Engineering

FHO University of Applied Sciences of Eastern Switzerland
HSR Rapperswil School of Engineering,
IWK Institute of Materials Technology and Plastics Processing

HSLU Lucerne University of Applied Sciences and Arts
Lucerne School of Engineering and Architecture

inspire AG
icams Innovation Center for Additive Manufacturing Switzerland

inspire AG
inspire pdz – Design for New Technologies

PSI Paul Scherrer Institute

SUPSI University of Applied Sciences and Arts of Southern Switzerland
Department of Innovative Technologies

Switzerland Innovation Park Biel-Bienne AG

UZH University of Zurich
Department of Informatics

ZHAW Zurich University of Applied Sciences
School of Engineering, Centre for Product and Process Development, Advanced Production Technologies (ZPP)

ZHAW Zurich University of Applied Sciences
Institute of Mechatronic Systems (IMS)

Bern University of Applied Sciences
BFH-TI | ALPS | Additive Manufacturing

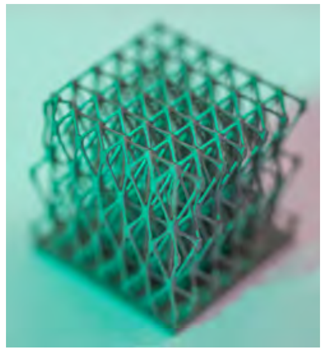
Bern University of Applied Sciences

Institute

Research and Development of processing strategies for Selective Laser Melting (SLM) and Laser Direct Metal Deposition (LDMD) with respect to process efficiency and material diversity.

Main research topics

The "Additive Manufacturing" group focuses on novel processing strategies and aims at increasing the process efficiency and the material diversity for SLM and LDMD. We work in close collaboration with the Switzerland Innovation Park Biel/Bienne and with Protoshape to offer best suited solutions to our project partners.



Offers

The Bern University of Applied Sciences BFH offers R+D for companies in addition to training and further education. In 3D printing/manufacturing, the BFH is represented by the Institute for Applied Laser, Photonics and Surface Technologies ALPS and the Institute for Printing Technologies.

Process efficiency and material diversity as key criteria. Our "Additive Manufacturing" group develops innovative processing strategies within the framework of bilateral or publicly funded projects on topics such as novel scan strategies for SLM and in-situ metal allocation for LDMD processes.

Process efficiency and material diversity are crystallizing more and more as the key criteria for metal-based additive manufacturing processes. Innovative machining strategies for SLM and in-situ metal alloying for LDMD processes can make a decisive contribution to this.

Technologies

- Selective Laser Melting (SLM)
- Laser Direct Metal Deposition (LDMD)
- Process Monitoring and Process Control
- Development and adaption of processing strategies, increasing process efficiency and research on the application of novel materials

Contact

BFH-TI | ALPS | Additive Manufacturing, Pestalozzistrasse 20, 3400 Burgdorf (Switzerland)
+41 (0)34 426 42 29, Thorsten.kramer@bfh.ch, www.alps.ti.bfh.ch/research_groups/additive_manufacturing.html

Bern University of Applied Sciences
BFH-TI | IDT | Institute for Print Technology

Bern University of Applied Sciences

Institute

The Institute for Printing Technology performs industry-oriented R&D of digital printing and dosing technologies in many fields of application eg. production technology, biotechnology, food, textiles, packaging and art in close cooperation with its project partners. The developed systems comprise different jetting technologies from pl to ml for low and high viscosity media or particle loaded media as well as the required fluid management with the corresponding sensor technology.

Main research topics

The IDT focuses on the development of dispenser technologies and print system design in a wide area of 3D printable materials e.g. photopolymers, thermo polymers, bio inks, ceramic loaded inks, starch, fat, cellulose, wax, wood. For the process development and automatisation we focus on fluid-sensor and embedded vision system development, wave form evaluation or rheological investigations.

DLP Printer

Silicone print module

Offers

- Applied R+D-projects (Innosuisse), consulting, services, training
- Development and integration of dispenser and (micro-)extrusion systems, printhead modules, including mechatronic and sensor technique for closed loop control systems
- Parameter studies for new materials and material-dispenser interactions
- Development and optimization of digital printing processes for AM
- Rheological investigation of fluids and polymers
- Numerical simulation of valves and fluid processes with a multiphysics approach
- Process optimization with tools like dropwatching and high-speed camera

Technologies

- Digital Light Processing (DLP)
- Powder bed/liquid binder printing
- Multi Jet Modelling (MJM)
- 3D microextrusion of high viscous fluids eg. thermopolymers, pastes, silicones
- High precision 3D scanning (AICON/Breuckmann smartSCAN)
- Material and surface analysis (mechanical, optical properties, rheology, contact angle, etc.)

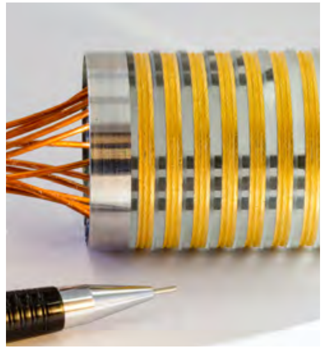
Contact

BFH-TI | IDT | Institute for Print Technology, Pestalozzistrasse 20, 3400 Burgdorf (Switzerland)
+41 (0)34 426 43 29, idt.bfh.ch, www.Drucktechnologie.CH

CSEM Swiss Center for Microelectronics and Microtechnologies

Institute
CSEM is a national innovation accelerator – a catalyst for the transfer of technologies and know-how from fundamental research to industry. This role involves four principal tasks: we develop and maintain technology platforms, we integrate and combine technologies into workable systems, we mature those technologies they are used, we add value to our industrial clients, and we also support the process of transferring those technologies to industry.

Main research topics
- Optimized redesign of existing customer products and design of new products, based on AM technologies
- Advanced manufacturing of high-precision components with embedded functionalities (sensors and actuators) by combining manufacturing technologies
- Optimization of SLM process parameters and quality control
- Qualification of the raw material (initial powders) and SLM-fabricated parts


The picture above illustrates the re-design of the rotor of a SlipRing Assembly (a flagship product of RUAG Slip Rings SA), leading to drastic product simplifications. CSEM and RUAG were awarded the innovation prize by AMX in 2018. The concept developed enables the development of parts featuring built-in electrical wires (patent pending)

Offers
- Combination of AM technologies with microfabrication, surface treatment/grafting and functional printing
- Characterization and optimization of material properties based on the developed protocol (applying post-processing such as HIP). Selection of the initial materials based on the developed characterization protocol (particle size, flowability, residual humidity, crystalline phase, microstructure, chemical composition ...)
- Integration of electrical connections, sensors (resistive, capacitive, piezoelectric) and/or actuators on 3D objects, by combining various AM technologies
- Technology transfer and licensing

Product development offer
- Customer products in-depth system analysis to identify potential improvement areas based on AM
- Product design, multiphysics simulation and multiobjective optimization (Solidworks, Comsol, Optistruct)
- Prototyping and production of high-precision components
- Product performances and metrological characterization

Technologies
Selective laser melting (SLM), UV stereolithography (SLA), UV micro stereolithography (uSLA), multimaterial platform: combination of different technologies within 1 system with up to 24 materials
Inkjet printing (single and multe-inozzle), aerosol jet printing, screenprinting, gravure printing, photonic sintering, characterization systems

Contact
CSEM, Jaquet Droz 1, 2002 Neuchâtel (Switzerland)
+41 (0)32 720 51 11, info@csem.ch, www.csem.ch

Empa – Swiss Federal Laboratories for Materials Sciences and Technology

Institute
Empa conducts cutting-edge materials and technology research, generating interdisciplinary solutions to major challenges faced by industry, and creates the necessary scientific basis to ensure that our society develops in a sustainable manner. Advanced manufacturing and in particular additive manufacturing is one of the focus areas of Empa's Department for Advanced Materials and Surfaces. As part of the ETH domain, Empa is committed to excellence in all its activities.

Main research topics
The AM research activities at Empa focus on the materials science aspects in the additive manufacturing of metals, ceramics and polymers at different length scales (nm–cm). In particular Empa is active in the following three areas:
- New materials for and by additive manufacturing
- Powder processing and functionalization
- Insitu monitoring and modeling of additive manufacturing processes


Prof. Dr. Patrik Hoffmann monitoring lab equipment at Empa in Thun

Offers
Research collaborations:
- Joint research with industry partners where the tasks and the results are shared
- Public research that is supported by research programs, e.g. from SNSF, Innosuisse or the EU
- Contract research where the industry partner pays for the work of Empa and receives the results

Analytical services, e.g. material or product characterization and measurements
Conferences, seminars, workshops or trainings

Dr. Christian Leinenbach operating a SLM machine in Empa's Coating Competence Center in Dübendorf

Technologies
Metals:
- Selective Laser Melting (SLM) powder bed
- Laser Metal Deposition (LMD) powder feed

Polymers and composites:
- Stereo Lithography (SLA)
- Direct Ink Writing (DIW)

Ceramics:
- Fused Deposition Modeling (FDM)
- Selective Laser Sintering (SLS)
- Stereo Lithography (SLA)

Contact
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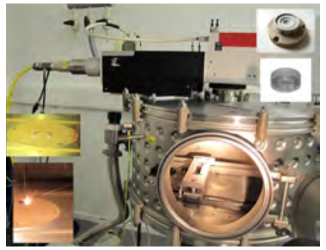
EPFL Swiss Federal Institutes of Technology Lausanne
Laboratory of Thermomechanical Metallurgy (LMTM) – PX Group Chair

Institute
LMTM has expertise in the domain of additive manufacturing of metallic components. The focus is mainly on Selective Laser Melting and on its application in micromechanics, watchmaking, jewelry and medical industries. LMTM is a research partner in the field of additive manufacturing technology in many projects funded by the Swiss Confederation.

Main research topics
One of the research axes at LMTM concerns a better understanding of the metallurgical and physical aspects of Selective Laser Melting (SLM) and the control and design of microstructures in metals and alloys manufactured by this process. Specific research topics include the optimization of process parameters for new materials and alloys as well as of microstructures, and in situ combination of processes like Laser Shock Peening with SLM (3D LSP patented by LMTM) for the 3D control of residual stresses, distortions, grain structures and cracks.


Experimental SLM station and an application

Offers
- Development of an SLM process window for metallic materials (stainless and tool steels, nickel-based alloys, precious metals, high-entropy alloys, metallic glasses)
- Combination of SLM with thermo-mechanical treatments to improve the mechanical properties, wear resistance, tribological performances and/or fatigue life of parts
- Thermomechanical testing of materials (Gleeble 3800 Physical Simulation System)
- Characterization of microstructures (scanning electron microscope with EDS and EBSD detectors)
- Characterization of mechanical properties like hardness by means of microindentation (Qness Q10A)
- Evaluation of residual stresses by means of hole drilling (SINT Technology MTS3000 Restan)

Technologies
Selective Laser Melting: powder bed process for metals: LMTM operates an open SLM station: 500 W per laser, 3-axis scan head, infrared thermometry, powder preheating up to 300 C, controlled atmosphere and powder characterization sensors for thermal conductivity or laser absorptivity
Laser Shock Peening: surface treatment for metals: LMTM is equipped with a SAGA HP laser (wavelength: 1.064 m, high energy per pulse: 2.3 J, low repetition rate: < 10 Hz with pulse duration: 6.3 ns)

Contact
LMTM Laboratory of Thermomechanical Metallurgy – PX Group Chair
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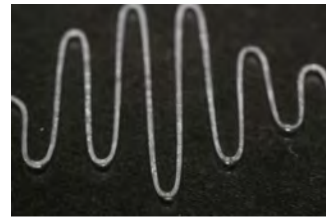
FHNW University of Applied Sciences Northwestern Switzerland
School of Life Sciences, Institute for Medical Engineering and Medical Informatics

Institute
The Institute for Medical Engineering and Medical Informatics at the School of Life Sciences of the University of Applied Sciences Northwestern Switzerland in Muttenz has long-standing experience in medical additive manufacturing. In the context of applied research and development, the close cooperation between the FHNW and regional, national as well as international commercial enterprises allows public institutions to access state-of-the-art research results and to transform ideas into practice-oriented products and processes.

Main research topics
The institute has committed to AM for medical application, using various printing technologies and materials. The application of SLM enables us to realize metallic implants and instruments. We have established the planning, modelling, production and characterization of titanium implants. Printing materials such as ceramics, magnesia and shape-memory alloys expand the technology towards novel unique properties. Bioprinting focusing on AM of biological material like extracellular matrices and cells, for medtech and pharma applications.


Implants from the 3D printer made of titanium and hydroxyapatite


Bioprinted fugitive ink for vascularization

Offers
- ISO 13485-conform process chain for patient-specific implants from the image to sterile packaging, including planning, modelling, production and characterization, as well as microstructural, surface analytical, static and dynamic mechanical and computational analyses
- Porous structures with anatomically adapted gradients with adjustable lattice type, microarchitecture and porosity to adjust the Young's modulus according to the biomechanical needs
- Patient-specific implants for trauma and oncology patients
- Process development and application of AM for novel printed materials like metals or ceramics
- Process development for vital materials like cells and 3D structures such as extracellular matrices

Technologies
Various Selective Laser Melting systems for metallic implant materials; printing system for bioceramic materials; multijet printing system for plastic-like and rubber-like materials; inkjet-based printing platform; extrusion-based bioprinting for combined avital-vital structures; complete testing and environment characterization

Contact
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+41 (0)61 228 58 48, daniel.seiler@fhnw.ch, www.fhnw.ch/im2

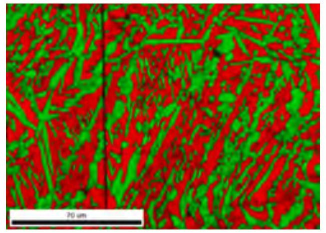
FHNW University of Applied Sciences Northwestern Switzerland
School of Engineering, Institute of Product and Production Engineering (IPPE)

Institute

The Institute of Product and Production Engineering (IPPE) at the School of Engineering of the FHNW performs research and development in the field of metallic additive manufacturing (AM) with special focus on industrial applications such as, aeronautics and turbomachinery. It features a Selective Laser Melting machine on which parts are 3D printed in aluminum, steel and nickel-based superalloys.

Main research topics

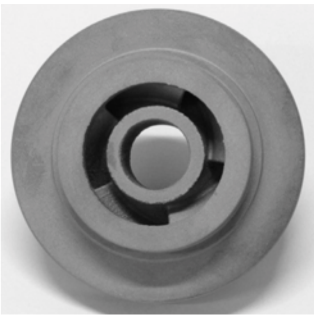
The faculty and staff at IPPE have broad expertise in the entire product development cycle from design, simulation, optimization and validation for AM, to the AM process itself where experts in laser physics and materials science ensure the stability and quality of the manufacturing process. Research projects are always collaborations with industrial partners, often co-funded by the Swiss government, and have a typical duration of 1–2 years. The institute, however, is also at the industry's disposal for rendering short-term services.



Austenitic-ferritic microstructure of Duplex Stainless Steel processed by SLM at IPPE (project funded by CTI)

Offers

- Design for additive manufacturing
- Finite element simulation
- Topology optimization
- Selective laser melting process simulation
- 3D scanning
- Mechanical testing (static, fatigue, random vibration)
- Material characterization (metallography, electron microscopy including EDX)
- Large machine shop



Pump impeller designed and produced by SLM at IPPE (project funded by CTI)

Technologies

- Selective Laser Melting
- Photopolymer Jetting

Contact

Institute of Product and Production Engineering (IPPE)
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HES-SO University of Applied Sciences and Arts Western Switzerland
AddiPole, Advanced Manufacturing Center

Institute

AddiPole is a competence center and a reference in French-speaking Switzerland. We offer a unique position from design ideas to market success including post-processing operations and reverse engineering. Our missions are:

- to help technicians, engineers, companies in developing products and processes
- to develop skills related to advanced manufacturing (additive and scanning)
- to empower industrial and research applications for tech-transfer

Main research topics

We focus on high precision printing in metals and polymers

- Functional analysis, new design rules, dynamic ans topology optimization
- Design for manufacturing (DFM), value analysis, cost to design
- Research into additive manufacturing processes for parameters optimization and monitoring
- Powders improvement and development
- Development of new 3D printing systems for metals and polymers

Offers

Due to our industrial partnership with with Nikon, Trumpf and Prodways, we offer a complete range of services in advanced manufacturing:

- Reverse engineering in high resolution scanning including 3D post-treatment
- Adapted product development including the process
- Economical and technical feasibility studies
- Development of 3D printers and components
- Supporting companies with workshops and education (possibility of on-site residence service)
- Common and customized teaching and training

AddiPole - Scanning and AddiPole - Additive

We are a public institution and eligible to be your scientific partner for INNOSUISSE projects

Technologies

- FDM Fused Deposite Modelling
- SLS Selective Laser Sintering
- SLM Selective Laser Melting
- PolyJet™ technology
- Autodesk's DLP SLA

Contact

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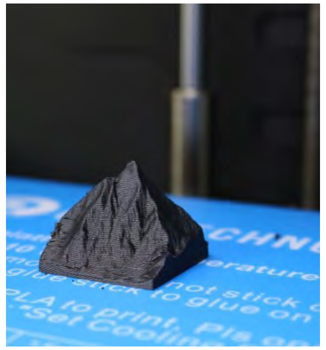
HES-SO University of Applied Sciences and Arts Western Switzerland
iPrint, Institute for Printing

Institute

iPrint is a research institute in digital printing and coating aiming to be one of the major centers of the world for research around inkjet technology and leader in education in inkjet engineering and inkjet chemistry. Unifying leading national and international academic institutions and a substantial part of industry along the value chain of digital printing and coating will offer competitive advantages to its industry partners on the global market.

Main research topics

- Digital deposition of materials for advanced manufacturing
- Inkjet for manufacturing
- Solvent on Granule printing for metals, ceramics and polymers
- Material jetting of ceramic suspensions
- FDM multimaterials gradient deposition
- 3D printing of silicones



FDM printing of Matterhorn, PVB with 15% w/w CNT

Offers

- Development of new AM processes using inkjet alone or in hybrid combination with other digital processes
- Design and manufacturing of research printers
- Over 1000 m^2 of research labs with more than 100 m^2 dedicated to 3D printing
- A state of the art bioprinting lab including bioprinters and cell culture facilities
- Industry training for inkjet and additive manufacturing of polymers
- Commercial printers for rapid prototyping
- Inks characterization

3D printed vertebra made of ethylcellulose, printed using solvent jetting

Technologies

- Material jetting
- Binder jetting
- Plasma deposition
- Aerosol deposition
- Direct Ink Writing
- FDM - Fused Deposition Modeling
- SLA - Stereolithography

Contact

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HES-SO Valais/Wallis University of Applied Sciences and Arts Western Switzerland
Powder Technology and Advanced Materials Research Group

Institute

The research group hosts competencies in the manufacturing of metal and ceramic parts from powders by using a number of advanced techniques. It has extensive experience in powder handling, shaping and characterization. Moreover, it has state-of-the-art infrastructure for particulate materials processing, tailoring powders for shaping and consolidation, debinding and sintering and post-processing operations, mechanical testing and materials characterization. It conducts R&D projects in collaboration with the industry, financed by both private and public funds.

Main research topics

The research activities focus on the manufacturing of parts from powders, including stainless steels, soft magnetic materials, titanium alloys, copper alloys, aluminum alloys, precious metals, superelastic and shape memory materials and advanced ceramics. In the AM field, the group manages standard binder jetting and laser melting technologies. In addition, it has developed its own technology of solvent jetting on metal- or ceramic-based granule beds. The handling and sintering of reactive metals is also a key competence.

Table-top machine for "Solvent on granule 3D printing" of metals and ceramics

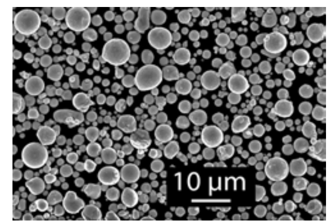
Offers

- Profound know-how on powder technology
- Powder-bed AM facilities: laser melting, binder jetting, solvent jetting
- Powder characterization: size distribution, flowability, apparent and tap density, gas pycnometry, morphology
- Powder preparation: handling in a protective atmosphere under protective atmosphere, sieving, granulation
- Materials characterization, optical and scanning electron microscopy, EDX and XRPD, mechanical tests, heat treatments
- Process optimization for AM classical materials
- Development of emerging materials for powder-bed additive manufacturing

SLM 125 machine (laser power 400W)

Technologies

- Solvent on granule 3D printing
- Binder jetting 3D printing
- Selective laser melting
- Powder compaction, debinding and sintering
- Powder injection molding (MIM and CIM)
- Tape casting
- Hot isostatic pressing



Gas atomized powder

Contact

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HSR University of Applied Sciences Rapperswil
IWK Institute for Materials Technology and Plastics Processing

HSR HOCHSCHULE FÜR TECHNIK RAPPERSWIL
FHO Fachhochschule Ostschweiz

Institute
The IWK contributes innovative and application-based research and development in material and part design as well as metal and plastics processing. It combines science and practice to develop modern materials, multilateral technologies and production processes. In the IWK team, experienced specialists and university graduates cooperate in a straightforward, professional and project-oriented manner to work on industrial tasks in bilateral and publicly funded research projects.

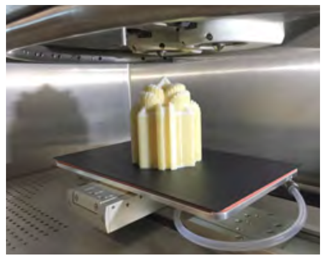
Main research topics
One of our research programs at IWK focuses on Additive Manufacturing (AM) which covers a broad variety of interdisciplinary topics including design, manufacturing and materials processing technologies as well as materials science. Our focus is to apply AM in industrial applications both for plastic and metal parts as well as components to create innovative and disruptive products. The two main topics are material extrusion processes like APF and FDM/FFF as well as laser metal deposition LMD in combination with machining.

Hybrid machine for Laser Metal Deposition (LMD) and machining

Offers
- Design and manufacturing of AM parts made from serial thermoplastic resins or metals
- Material selection and experimental material characterization for AM
- Qualification of new materials and development of suitable process windows
- Testing of material and part properties
- Processing, preparation and production of filaments for FDM/FFF according to customer needs/specification
- Material modification by using the compounding process
- Development of water-soluble support materials
- Integration of endless fibers in FFF process
- Coating of metals and abrasives on metals (surface engineering)
- Repair any types of metal components (repair engineering)

Extrusion of custom specific plastic filaments (FFF)

Technologies
- Arburg Plastic Freeforming (APF)
- Fused Deposition Modeling (FDM)/Fused Filament Fabrication (FFF)
- Laser Metal Deposition (LMD) together with grinding and milling processes (hybrid machine)



Development of water-soluble support materials (APF)

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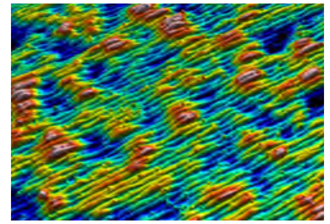
inspire AG
innovation centre for additive manufacturing (icams)

inspire

Institute
Inspire icams has performed basic and applied R&D in the AM-field since 1996, focusing on powder bed based technologies such as SLM for metals and SLS for plastics, next to blow powder technologies such as DMD. The close cooperation with ETH in Zurich allows inspire to cover all aspects in the AM-process chain. Inspire icams researches materials for AM-processes, develops and simulates process windows and optimizes AM machine components. Our long-term knowledge allows icams to develop advanced applications with added functionality (e.g. sensors).

Main research topics
- Quality management in the AM-process chain: From powder qualification to final components
- Alloys (esp. Al) and plastic formulations for AM-processes
- Process simulation, monitoring and process window development for various alloys
- Material qualification and characterization
- Optimization of machine components (re-coater, gas shielding system, ...)
- Advanced applications: Integration of sensors into metallic components



high resolution AM-part surface analysis

Offers
Inspire icams offers all types of collaboration from B2B projects to Innosuisse and European funded projects.
- Powder qualification
- Process window development and qualification
- Material characterization (Porosity, in-deep microstructure analysis (SEM, EBSD, ...), hardness, static & dynamic mechanical testing,...)
  Part characterization (3D scanning, surface analysis, mechanical integrity)
- Development of customized, AM-ready applications
- Process chain qualification
- Simulation

SLM scanning

Technologies
- Selective Laser Melting (SLM)
- Selective Laser Sintering (SLS)
- Direct Metal Deposition (DMD)

Large machine workshop (EDM, cutting, grinding etc)

Powder qualification test bench

Contact
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inspire AG
inspire pdz – Design for New Technologies

Institute
Inspire Design for New Technologies addresses the challenges of new technologies like additive manufacturing imposed on the product development process. Engineers in industry need to understand new technologies with their advantages and disadvantages to identify the right applications and design parts with respect to opportunities and restrictions. Inspire AG is a strategic partner of ETH Zurich for technology transfer in the field of manufacturing technology and a research partner in various projects funded by the Swiss Confederation.

Main research topics
Design for New Technologies research focuses on the three main challenges of implementing additive manufacturing in series products:
- identifying the parts of a conventional design that will result in the most benefits in a redesign for AM
- breaking the rules of conventional manufacturing to exploit the full potential of additive manufacturing's design freedom
- incorporating this new approach into company processes

An interdisciplinary team develops tools and methods to implement new technologies into industrial applications.

Book on design and development for additive manufacturing

Offers
Integrating new technologies into a company requires a change process to build up knowledge and trust. We assist in these processes by transferring knowledge and supporting engineers in gaining initial experience in a learning-by-doing approach:
- Workshops for SMEs and corporations to identify and validate parts and business models
- Agile development of new solutions with additive manufacturing
- Technology transfer through trainings, events and books like "Entwicklung und Konstruktion für die Additive Fertigung (ISBN: 978-3-8343-3395-7)"

These offers are not limited to additive manufacturing. New technologies like the digitalization of products and services (Internet of Things, Industry 4.0), although based on completely different technologies, bring similar challenges to product development: identifying the right applications and creating additional value for the company and the customer. We are therefore able to apply our experience in design for AM to other new technologies.

Technologies
- Applications of additive manufacturing in the production of series products
- Post-processing of complex structures
- Design automation for additive manufacturing
- Digital tools and methods for adopting AM in industry

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IWF - ETH Zürich
Institute of Machine Tools and Manufacturing

Institute
IWF conducts research in the field of Additive Manufacturing (AM) in three technologies: SLS, SLM and DMD. In all three technologies the institute covers research in materials and material behavior, research on the process and process chains for and with AM, research in machines and special applications as for instance lightweight parts and functionalized parts.

Main research topics
SLM (Selective Laser Melting): The main research fields are the solidification process and the resulting metallurgic microstructure generated by the rapid solidification following laser-material interaction, measures to influence the cool-down process and advanced control processes DMD (Direct Material Deposition). The main focus is on the rapid build-up of large structures and quality issues, e.g. for lasercladding of turbine blades and wear resistant coatings.


Lasercladding process for efficient coating against wear and corrosion

Offers
Development support for companies in the following topics:
- simulation and experimental analysis of the melt pool (including laser-material interaction)
- simulation and measurement of warpage and surface tension
- analysis of the microstructure
- analysis regarding the risks for micropores and splatters
- analysis regarding the risks for hot and cold cracking
- quality improvements and quality management – in cooperation with inspire-icams, St. Gallen
- postprocessing technologies (cleaning, machining, sandblasting ...) in cooperation with pdz|ETHZ

Technologies
- SLM (Selective Laser Melting, powder bed fusion with metal powders)
- DMD: (Direct Material Deposition, material build-up with feed of metal powder or wire)
- SLS: (Selective Laser Sintering) – in cooperation with inspire-icams, St. Gallen

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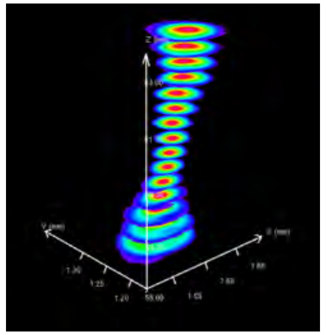
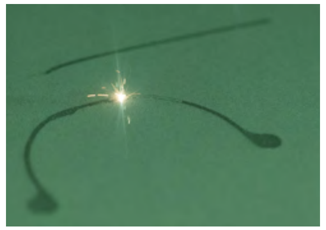
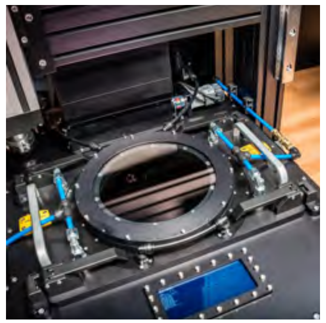
Switzerland Innovation Park Biel/Bienne AG
Swiss Advanced Manufacturing Center







Institute
While having a broad industrial understanding of the AM process, the SAMC focuses its research activities in the area of Advanced Optics & Lasers and Laser-Material Interaction for AM applications. We conduct applied research and development with the aim to be very close to industrial needs. Thus, our labs are equipped with state-of-the-art AM technologies as well as a state-of-the-art open research AM machine.

Main research topics
– Advanced optics, High Power Laser beam delivery & characterization for AM
– Selective Laser Melting process for metals
– Process performance monitoring
– Postmachining operations (surface, heat treatments)
– Quality inspection (3D scanning, metallographic inspection, CT)

Offers
– Laserlab for testing novel beam delivery concepts
– Supporting companies in Optics and Lasers for AM
– Feasibility studies of novel metallic materials
– Process speed and accuracy optimization
– Digitalization acquisition with process monitoring
– Help on AM design & business case
– Mechanical and thermal post-processing variations
– Quality assurance assistance

Technologies
– High Power Laserlab
– Open AM System
– State-of-the-art SLM Machines
– High-accuracy 3D Scanner

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SUPSI University of Applied Sciences and Arts of Southern Switzerland
DTI (Department of Innovative Technologies)

Institute
SUPSI-DTI focusses on engineering sciences for the industrial sector, training and applied research. The Department has been very active in the AM sector for many years, including various applied research projects at national and European level, in the areas of ceramic, polymeric and metallic materials, new processes and machine tools, design of innovative products and services, in particular for the medtech and aerospace sectors as well as for many other industrial applications.

Main research topics
Two key activities focus on AM materials, products design, processes and systems:
– integration of multiple subtractive and additive technologies in hybrid solutions; operating by monitoring and adapting the processes, by relying upon a closed automatic in line CAx chain bound to the CNC to select the best processing strategy and machine settings
– design and additive manufacturing of complex ceramic components for high tech applications such as engine exhaust filters, high temperature solar absorbers, water filtering devices

AM 5-axis hybrid machine designed by SUPSI for the EU Project Symbionica (Reconfigurable Machine for the new Additive and Subtractive Manufacturing of fully personalized bionics and smart prosthetics, 2015-2018) for manufacturing medium to large size metal components

Offers
– AM process design & optimization for metal based alloys (Titanium and Aluminum alloys, Inconel 719, Steel 890, AISI 316 L …)
– Hybrid process implementation based on AM and subtraction of material
– Redundant Machines and Robotic solutions for AM
– Process control and adaptation based on a closed loop monitoring system for AM
– Mechatronic equipment design for multi-material AM (i.e. nozzle, auxiliary gas ejection, gas-powder mix chamber)
– Preparation and characterization of photopolymeric ceramic pastes for AM
– Design, AM and characterization of complex ceramic components
– Mixing and blending equipment; furnaces for thermal treatments (standard and microwave)
– High temperature equipment for AM porous materials thermo-fluid characterization

Ceramic catalytic support designed and produced by AM at SUPSI

Technologies
– Direct energy deposition of small-medium-large parts (up to 800 X 800 X 800 mm envelope)
– Cold spray for coating and repairing of parts
– Laser ablation and texturing with nanosecond laser source
– Femtosecond laser source (soon available)
– Peek deposition
– Stereolithographic devices for ceramic AM

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ZHAW Zurich University of Applied Sciences
Institute of Mechatronic Systems IMS

Institute
As a leading national institution for applied research and development in mechatronics, the Institute of Mechatronic Systems (IMS) specializes in projects for innovative products at the interface of mechanics, electronics and computer science. The know-how of over 50 employees from various fields and a modern research infrastructure make us a flexible and efficient partner in the realization of projects in research and development.

Main research topics
Our strengths lies especially in the following areas: Robotics & Automation, Control Technology & Advanced Control, Drive Technology & Power Electronics, Medical & Systems Engineering. In the field of additive manufacturing the focus lies on the development of advanced hardware and processes as well as on optimizing material properties for the FDM process, to close the gap between 3D printing and injection molding. This also includes the qualification of material properties itself and the properties of printed parts.


6-axis FDM printer with tiltable bed (developed by IMS)

Offers
The activities of the laboratory of rapid prototyping (RapLab@IMS) include the complete development process of functional prototypes:
- 3D scanning of parts for geometry capture
- 3D modelling with CAD tools
- Structural analysis of parts and components using state-of-the-art CAE-tools
- Embedding of actuatory and sensory components
- Manufacturing of parts with various AM-processes

The IMS supports the complete development process chain for new mechatronic products with adaptive integration of additive manufacturing techniques.

Technologies
- Fused Deposition Modelling – FDM (incl. fiber reinforcement, multimaterial)
- Stereolithograhy – SLA
- MultiJet Printing – MJP


Hand prosthesis manufactured with AM (developed by IMS)

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ZHAW Zurich University of Applied Sciences, School of Engineering
Centre for Product and Process Development, Advanced Production Technologies (ZPP)

Institute
The ZPP carries out product and process development from the initial idea all the way to realization. We carry out applied R&D in the fields of innovation playground & development, 3D experiences and advanced production technologies, mainly in additive manufacturing.

Main research topics
- Research into additive manufacturing (AM) processes
- Analysis and optimization of AM processes for metals, ceramics and sustainable materials
- Implementation of AM technology, e.g., new design rules for product development
- Development of innovative 3D printing systems (e.g., ceramic 3D printer) and components

Offers
- Adapted product development for AM incl. topology optimization
- Economical and technical feasibility studies in AM
- Development of 3D printer and components
- aR&Dprojects for product and process development for AM
- Supporting companies in introduction of AM with workshops and education
- Common and customized teaching and training in AM
- CAS Additive Manufacturing

Technologies
- SLM Selective Laser Melting, powder bed process in metal
- FDM Fused Deposite Modelling
- SLA Stereolithography
- MJP Multijet Printing

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