SELECTIVE LASER MELTING
IN TURBOMACHINERY MANUFACTURING

Fraunhofer Institute for Laser Technology ILT

The Fraunhofer Institute for Laser Technology ILT is worldwide one of the most important development and contract research institutes of its specific field. The activities cover a wide range of areas such as the development of new laser beam sources and components, precise laser based metrology, testing technology and industrial laser processes. This includes laser cutting, caving, drilling, welding and soldering as well as surface treatment, micro processing and rapid manufacturing.

Furthermore, the Fraunhofer ILT is engaged in laser plant technology, process control, modeling as well as in the entire system technology. We offer feasibility studies, process qualification and laser integration in customer specific manufacturing lines. The Fraunhofer ILT is part of the Fraunhofer-Gesellschaft.
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Optimum functionality at the lowest possible weight, high mechanical loads and corrosive exposure at high temperatures: these component requirements and operating conditions in turbomachinery place high demands upon the manufacturing processes and materials used. Selective Laser Melting (SLM) provides the user with considerable advantages over conventional production methods due to the component complexity and turnaround times it can achieve.

Challenges in Turbomachinery

Manufacturers in the turbomachinery sector have to accommodate, on the one hand, the need to improve the turbine efficiency and, on the other, the reduction of material and resources needed. This requires new approaches both in the development phase of components as well as in the implementation of functional and weight-optimized structures. Conventional manufacturing processes such as casting and forging often constitute a limiting factor. In comparison to these processes, additive manufacturing with SLM offers, in particular, significant advantages due to its short lead times and great geometrical freedom.

And yet, the extreme conditions faced by the components as well as the required reliability in aerospace and power engineering pose major challenges to the SLM process:

- Processing of highly specialized materials (in particular nickel- and cobalt-based superalloys) to achieve the required thermo-mechanical properties.
- Fulfillment of required quality criteria and ensuring the reproducibility and transferability of the machines, among others, for certification marking.
- Development of new process chains and integration of the process into existing process chains.

Research Priorities at Fraunhofer ILT

Superalloys based on nickel (e.g. Inconel® 718 and 738, MAR-M-247®) and cobalt (e.g., MAR-M-509®) are among the most commonly used materials in turbomachinery because they possess excellent thermo-mechanical properties even at extremely high temperatures. In the end, the properties of the component depend upon the material and its microstructure, the volume defects, the surface quality as well as the residual stresses.

These essential aspects are determined by the running process chain, i.e. by the combination of raw material, the SLM process and the thermal and mechanical post-treatment. Scientists at the Fraunhofer ILT, therefore, are investigating the cause-and-effect relationships along this process chain and working out selected measures to further develop the individual process steps, particularly those of the SLM process.

When crack-resistant materials such as Inconel® 718 or MAR-M-509® are used, one needs to consider the influence of the SLM process in combination with the thermal treatment upon the microstructure and the thermo-mechanical properties.

By contrast, when materials susceptible to cracking, such as Inconel® 738 are processed, the focus lies on the development of the SLM process for defect-free processing of these alloys. Here, approaches are being developed that, among others, reduce thermal gradients through global preheating or selectively control the solidification conditions by using additional local heat sources.

The experimental research is being assisted by the development of CFD- and FEM-models for the simulation of the process-related temperature-time cycles and solidification conditions.

In addition to developing customer-specific process chains, we are examining how individual process steps influence the economics of the overall process and quality of the components, such as how different SLM building strategies and finishing processes influence the achievable geometrical accuracy and surface quality.

Problem-solving Expertise and Scope of Work

The SLM process was developed in the mid-90s at Fraunhofer ILT, which has continuously developed it since then in close cooperation with leading industrial companies and research institutions, while also taking the entire process chain into account. Thanks to our know-how and years of experience, our experts can support you individually and solve your specific problems. You can fall back upon our extensive plant equipment, consisting of different commercial systems and highly flexible laboratory facilities. Through our close cooperation with other Fraunhofer Institutes, the RWTH Aachen University and partners in materials analysis, you benefit from the combined expertise of the Aachen location in the field of additive manufacturing.

Range of Services

Within the scope of turbomachinery we can offer you the following services:

- Application development for your materials and components: from manufacturing-specific component design, process development up to a first material qualification.
- Application testing of the process for your production and support for its integration into existing process chains.
- Manufacturing of functional prototypes out of materials relevant to your application (nickel- and cobalt-based superalloys, titanium alloys...)

Contacts

Dipl.-Ing. Anders Such
Telephone +49 241 8906-511
anders.such@ilt.fraunhofer.de

Dr. Sebastian Bremen
Telephone +49 241 8906-301
sebastian.bremen@ilt.fraunhofer.de

1 Monolithic manufactured turbine seal with honeycomb.
2 Grain morphology of SLM-microstructure after post heat treatment.
3 Guide vane cluster with post machined airfoils.
4 SEM image of solidification crack.
5 Manufactured burner element using SLM (Siemens large gas turbine, burner head, spare part on demand).
6 High-temperature SLM.