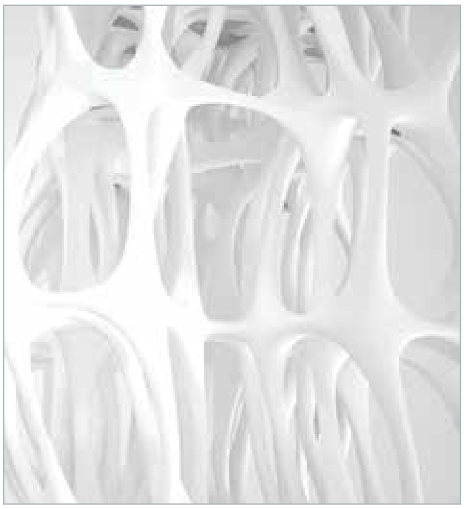
Success Story

Combining Topology Optimization with Laser Additive Manufacturing Reveals New Potential for Lightweight Structures



LASER ZENTRUM NORD

Key Highlights

Industry
Additive manufacturing

Challenge
Development of design and optimization methods to improve components made with laser additive manufacturing methods.

Altair Solution
HyperWorks, OptiStruct and Simulation Driven Design Process

Benefits
- Increased material efficiency
- Lighter and stiffer structures
- Less user training required
- Flexible and adaptable manufacturing process

Many technical innovations are based on designs derived from naturally occurring biological examples. Through evolution, nature has learned over millions of years to adjust shapes to their respective function for maximum efficiency. As engineers seek ways to build strong yet light structures, these natural examples can provide important clues. In a current research project, the Laser Zentrum Nord (LZN) and the Technical University Hamburg-Harburg (TUHH) are investigating how innovative design methods can be combined with laser additive manufacturing, taking into account biological examples and leading to new, unrevealed lightweight potential.

Natural structures, such as bones, provide an extremely high level of material efficiency. However, producing similar structures is a challenge for manufacturing enterprises. In the search for new ways to realize lightweight strategies, new manufacturing methods come into play. Particularly suitable for the production of highly complex geometries is laser additive manufacturing, i.e. selective laser melting, in which thin layers of metal powder are deposited and exposed to laser radiation and melted. This method can be applied to single prototypes and to highly load-resistant metallic components used as support structures in the aerospace and automotive industries. Such components have already proven their value in individual applications.

The Challenge: A research project from LZN for the development of new design methods

The LZN was founded in 2009 to support knowledge and technology transfer from fundamental research to industrial application. The LZN works in close cooperation with the Institute of Laser and System Technologies (iLAS) of the Hamburg University of Technology (TUHH).

Keywords: HyperWorks. HyperMesh, HyperView, OptiStruct, CAD

Laser Zentrum Nord Success Story

"We wanted to think and optimize freely, without any restrictions. This is where OptiStruct helps us, opening up new ways to tap the full lightweight potential from the design methodology and the manufacturing process."

Jannis Kranz
Research Associate
Laser Zentrum Nord

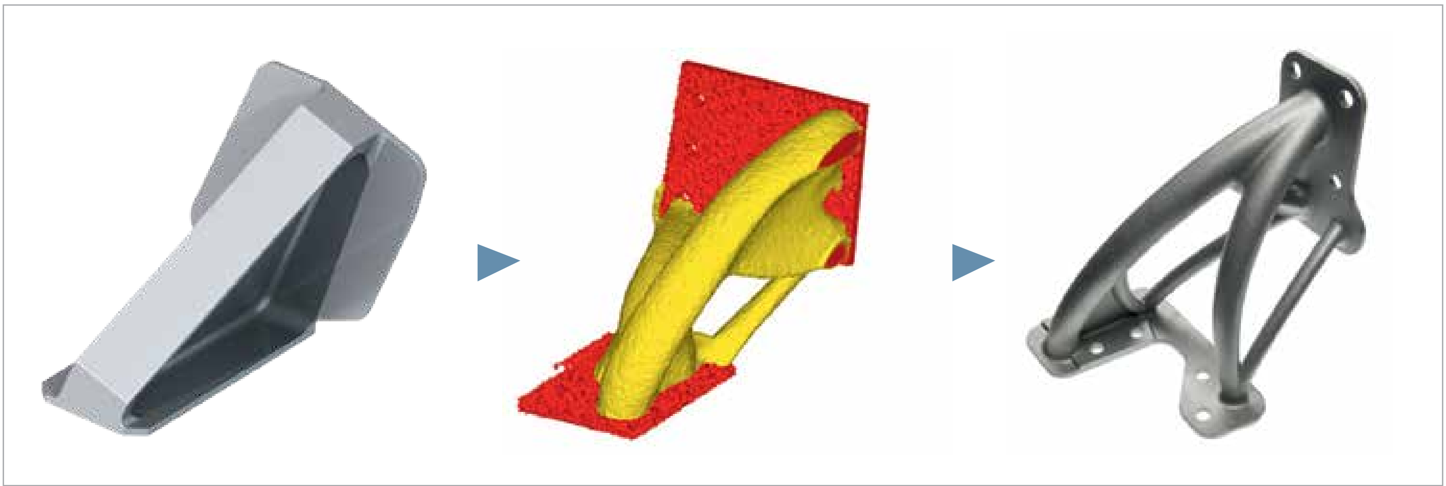
The research project TiLight investigated how innovative design methods can be combined with new manufacturing capabilities to economically manufacture lightweight components from the material $TiAl_6V_4$, a high-strength titanium alloy.

The study was a joint project of the LZN and iLAS and was supported by funding from the BMBF (German Federal Ministry of Education and Research). Besides the additive manufacturing with the material $TiAl_6V_4$ also new design approaches, such as bionics, were analyzed, categorized and put into guidelines and databases for the users to tap the full lightweight potential.

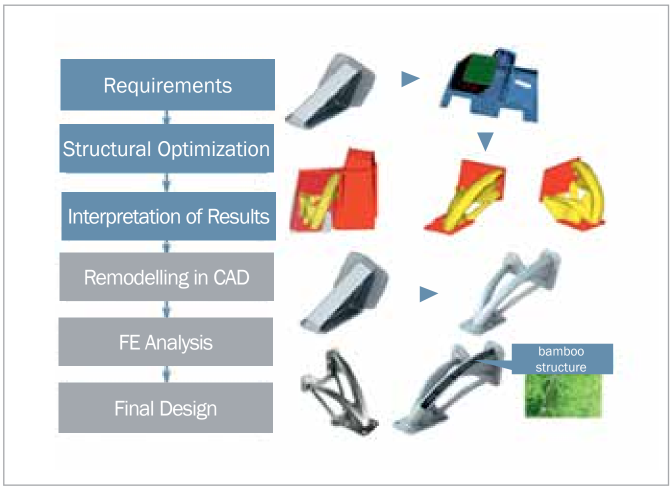
At the start of the research project, the aerospace industry was its primary focus. In aerospace, lighter components pay off immediately, and the industry is known for its openness to new design approaches. Reducing mass enables a higher load capacity or higher range for an aircraft. In space technology, every kilogram of additional load leads to 30 to 100 kilograms of additional weight for the rocket and fuel, which means that enormous savings can be achieved with lightweight structures. Other industries, such as automotive, are increasingly interested in new lightweight approaches as they seek to reduce mass and increase the fuel efficiency of their vehicles.

In the TiLight project, a bracket used as a standard retaining element in aircraft was selected as a test object. In civil aircraft, up to 30,000 bracket units are used to fix the interior cabin system and other cabin components. The results of the research project enable a substitution of the conventional brackets with innovative lightweight structures, leading to a significant weight-saving potential.

Jannis Kranz, research associate at the LZN, intensively investigated the production compliant design of the component bracket and the subsequent laser additive manufacturing of these lightweight structures. Taking the $TiAl_6V_4$ material into account, a customized



With topology optimization engineers are able to create a lighter and more load efficient design, applying material only where it is needed



Newly developed process chain for the design and optimization of additively manufactured components

Every new design should be inspired by structures coming from nature (bio-mimicry)

process chain for the laser additive method was developed, using the optimization tool OptiStruct from Altair Engineering to create the fundamental optimized structure. These automatically created structures were compared and adapted to biological examples from nature before a last numerical verification of the final geometry was performed. Optimization tools such as OptiStruct are ideally suited for such a project, especially when developing completely new design approaches, since the resulting geometries are often complex and therefore well-matched to production methods with low restrictions such as laser additive manufacturing.

Premium Aerotec (PAG), a supplier in the aerospace industry, served as the project's industrial partner. In conjunction with LZN's existing process equipment, the majority of the needed equipment for the project was directly available. Along with access to three additive manufacturing facilities for metal – SLM, Concept, and EOS – the researchers were able to produce the designed components by themselves.

Using the demonstrator bracket, the LZN researchers illustrated that new design and engineering approaches for lightweight metallic structures can be successfully combined with laser additive manufacturing. The manufactured structures take particular advantage of the design freedom. Due to this design freedom, it is possible to use the optimization tools in a much more radical way in the development process and realize the results almost directly, since there are fewer manufacturing restrictions with the laser additive method. The complex structures require little additional manufacturing effort and the results of the topology optimization, depending on the use case, can be well adapted to examples from nature. As an adjunct to the study's primary focus, Kranz also analyzed other design approaches, such as bionics, categorized them, and created guidelines and databases to assist future users in tapping the full potential of lightweight structures.

The Solution: HyperWorks for lightweight design

The LZN used HyperWorks from Altair Engineering as a central tool from the beginning of the TiLight project. HyperWorks is a leading design solution for simulation-driven product development, where CAE tools are used in the concept phase of component design, and provides integrated solutions for modeling, analysis, optimization, visualization, reporting, and data management. In the simulation-driven design process, OptiStruct, the optimization tool of the HyperWorks Suite, is first used to conduct an optimization based on the available design space, the occurring loads, and other boundary conditions. Depending on the use case, additional parameter studies can be executed and boundary conditions changed before the results are interpreted and those design variants most appropriate for laser additive manufacturing are selected. In addition, the created design variants are complemented by biological examples if possible. The proposed design is then refined with a CAD tool and the final design is numerically verified with OptiStruct.

"To develop a new bracket of lightweight design, we started with topology optimization for defining the structure," explains Jannis Kranz. "After identifying the specifications and defining the needed connection points, the geometry results of the optimization represented the basic element for further steps. Based on these specifications, we looked for biologic examples to be implemented. Later in the process, once we derived the design in CAD, we again verified the result with Altair tools like OptiStruct. With respect to optimization and calculation we can cover the complete virtual development chain within HyperWorks."

Why optimization, why Hyperworks?

In order to explore non-conventional design processes, topology optimization was employed from the beginning of the project. Optimization itself is not a prerequisite for laser additive manufacturing, but design engineers are influenced by environment and experiences when designing a component.

That is the reason design engineers primarily design for conventional manufacturing processes such as milling, casting, etc. If optimization is left out in a new process like additive manufacturing, the resulting geometries would be strongly characterized by conventional processes – including their manufacturing restrictions. However, OptiStruct proposes a completely new shape, which can be directly manufactured in the additive manufacturing process with only small adaptations.

“We wanted to think and optimize freely, without any restrictions,” Kranz says. “We tried to implement the simulation-driven design process as radically as possible. We have been able to leave traditional paths and deliver new approaches. This is where OptiStruct helps us, opening up new ways to tap the full lightweight potential from the design methodology and the manufacturing processes.

“There were two major reasons LZN chose Altair and their products," Kranz continues. ”Altair’s tools, such as OptiStruct, are already widely used at TUHH. And, when we contacted other universities who had worked with Altair in the past, they were very pleased with the collaboration. So we decided to work with Altair as well. The advantage of HyperWorks is that the suite includes all the needed software tools for the project and we can cover the entire virtual process without the need to switch between different tools.”

The Results: The advantages of additive manufacturing

Laser additive manufacturing uses deposited thin layers of metal powder which are exposed to laser radiation and melted. In this way, technical metals, such as high-quality steel, tool-steel, aluminum or titanium alloys, can be processed. The mechanical properties of the original material are preserved. An enormous advantage of laser additive manufacturing is the underlying powder-based method, which allows for the reuse of up to 95 percent of the not needed material. In contrast, conventional manufacturing methods such as milling produce material waste of up to 98 percent.

Another advantage of this manufacturing method is that a laser additive manufactured component is produced in near net shape technology and subsequent finishing steps are usually not necessary, although structures with high demands for precision and fitting often still need a conventional finishing.

Furthermore, laser additive manufacturing enables function integration in the component, which contributes to shorter production and assembly times as well as higher economic efficiency. Since the components are produced in layers, there is no need for tooling equipment. It is possible to produce diverse components with different shapes in one single manufacturing process.

Where are we heading to?

The TiLight research project clearly demonstrates the possibilities and advantages of combining topology optimization and laser additive manufacturing. A best practice process chain was developed, making it possible to design optimized models and geometries. These geometries are oriented on natural structures and help tap the component’s full lightweight potential as revealed by the combined methods.

The results of the TiLight project have also shown that the more or less restriction-free manufacturing capabilities of the laser additive process can only be completely exploited when using optimization tools and a development process specifically suited to this manufacturing method. In return, the negative aspects of the ideal optimization result, such as the complex load-specific structure which is hardly producible with conventional manufacturing methods, are compensated by the opportunities of the laser additive manufacturing method. The combination of optimization, the adaptation of biologic structures, and laser additive manufacturing provides significant economic and efficiency advantages, especially in areas such as aerospace, where lower weight is directly linked to product performance.

A follow-up project to TiLight is underway, focused on identifying weak points or other open issues. The design methodology developed in TiLight will be further refined and manufacturing restrictions studied. The TiLight results have already found their way into industry and are being used by a variety of companies. TUHH students are also benefitting from LZN’s research, with these innovative approaches presented and discussed in classes and lectures by iLAS Director and Laser Zentrum Nord (LZN) GmbH CEO Professor Emmelmann.

“We want students to realize that there are new and applicable approaches already available today,” says Kranz, “and our research results are being integrated into industrial projects. We support industrial customers with our research experience and help transfer the results into everyday, real-world use,” concludes Jannis Kranz.

Altair

Altair Engineering, Inc., World Headquarters: 1820 E. Big Beaver Rd., Troy, MI 48083-2031 USA
Phone: +1.248.614.2400 • Fax: +1.248.614.2411 • www.altair.com • info@altair.com

Listed below are HyperWorks® applications. Copyright© 2014 Altair Engineering Inc. All Rights Reserved for: HyperMesh®, HyperCrash®, OptiStruct®, RADIOSS®, HyperView®, HyperView Player®, HyperStudy®, HyperGraph®, MotionView®, MotionSolve®, HyperForm®, HyperXtrude®, Process Manager™, Templex™, Data Manager™, MediaView™, BatchMesher™, TextView™, HyperMath®, Manufacturing Solutions™, HyperWeld®, HyperMold®, solidThinking®, solidThinking Evolve™, solidThinking Inspire®, Durability Director™, Suspension Director™, AcuSolve®, AcuConsole®, HyperWorks On-Demand™, HyperWorks Enterprise™, PBS Works™, PBS Professional®, GridWorks™, PBS GridWorks®, PBS™, Portable Batch System®, PBS Analytics™, PBS Desktop™, e-BioChem™, e-Compute™ and e-Render™. All other marks are the property of their respective owners.