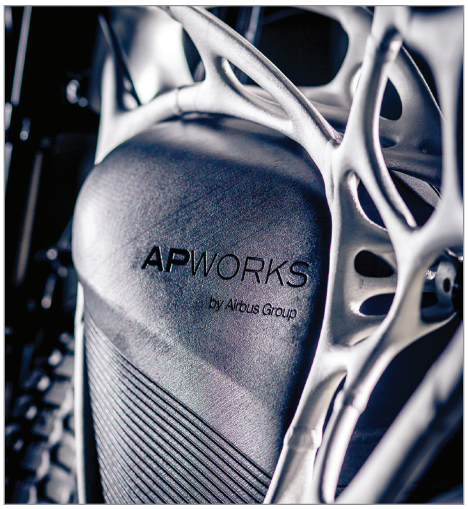
Customer Story

ALTAIR

Inspired by Nature: Electric Motorcycle Goes 3D

Combining Topology Optimization, New Materials, and Additive Manufacturing in the Development of the Airbus APWorks Light Rider Results in a Revolutionary Lightweight Design



APWORKS
by Airbus Group

Key Highlights

Industry
Aerospace, Automotive, Rail, General Machinery

Challenge
Structural design for Additive Manufacturing

Altair Solution
Topology optimization and a simulation-driven design process with Altair® HyperWorks®

Benefits
Optimum lightweight design due to topology optimization and additive manufacturing

Additive manufacturing or 3D printing is gaining ground as an alternative to traditional manufacturing methods because it offers, among other benefits, significant advantages in terms of light weight. Additive manufacturing makes it possible to produce components that are not only light, but also stiff and have a high performance. The aerospace industry has been a pioneer in additive manufacturing, and now other sectors such as the automotive industry are following and are also increasingly making use of this technology.

Especially electro mobility benefits from additive manufacturing, where it helps to reach weight targets, while at the same time ensuring the product's efficiency and enabling the realization of complex geometries.

An example of an innovative product manufactured with this method is the Airbus APWorks Light Rider, world's first 3D printed motorcycle prototype. "Such a complex branched hollow structure cannot be realized with conventional manufacturing methods such as welding or milling," explains Joachim Zettler, CEO at Airbus APWorks GmbH, a wholly owned subsidiary of the Airbus Group. The new design could only be realized thanks to topology optimization and a new material developed in-house by Airbus.

APWorks Light Rider: Design Study Success

The Light Rider was developed by APWorks as a design study to showcase the manifold opportunities of metal 3D printing to existing and potential customers. APWorks stands for the development of completely new components and products by leveraging the triad of re-engineering, material optimization, and 3D printing. The combination of these factors leads to weight and cost savings, can reduce assembly time and helps to integrate

APWorks Success Story

"We enjoy working with HyperWorks because we know that we can rely on the results the Altair products provide and we use the software tools in different development phases."

Patrick Schürmann
Project Engineer for optimization and design
APWorks

new and additional functions in parts and components. The frame design of the electrical motorcycle is based on a structural optimization inspired by natural principles. Visually the Light Rider design reminds of a Cafe Racer, an English series motorbike from the 1960s, rebuilt as a racing machine. After the APWorks engineers had selected the components such as headlight, seat, and color they started the design process.

In addition to topology optimization, the material Scalmalloy®, a high performance aluminum alloy developed by Airbus, was a success factor. The material is not only corrosion-resistant but combines the light weight of aluminum with almost the specific strength of titanium.

“The Light Rider showcases how we are able to save weight by creating a filigree structure, which can only be realized by employing high strength lightweight materials such as Scalmalloy®,” explains Zettler.

Simulation-driven Design with HyperWorks

For the frame design, APWorks engineers used a variety of simulation tools from HyperWorks, which has been one of the company’s standard development packages since its founding in 2013.

Patrick Schürmann, project engineer for optimization and design at APWorks and since a couple of months also the responsible project engineer for the technical development support of the Light Rider, explains: “In our development process we use Altair® HyperMesh® for modeling, Altair® OptiStruct® for finite element analysis and topology optimization, and Altair® HyperView® for post-processing tasks. For the re-design of the frame and styling tasks for the Light Rider project we used an external CAD system. For future projects we intend to handle this development step with solidThinking’s concept design tool Evolve so that the entire simulation-driven design process can then be covered with tools of the Altair product family”.

Meeting 3D Printing Challenges with Optimization

In a project such as the Light Rider, generating a 3D printable, optimized model requires engineers to overcome three major challenges:

1. Creation of the optimal shape based on given boundary conditions – a development step which can be handled well with topology optimization.

2. Derivation of the geometry from the optimization results – instead of using traditional CAD tools, direct modeling tools such as solidThinking Evolve and Inspire lead to quicker and better results.

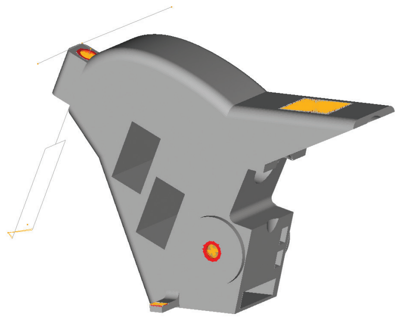
3. Handling of 3D printing specific manufacturing constraints, which are not subject of the optimization step.

Preparation of the Optimization

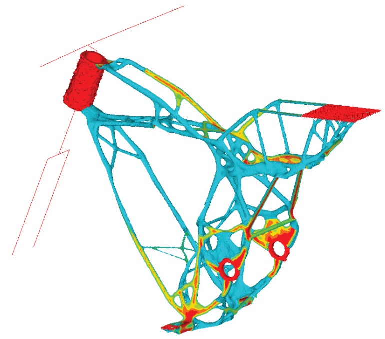
For a holistic optimization of a component such as the Light Rider frame certain design parameters have to be specified as boundary conditions. For example the wheelbase as well as the geometric positions of the handlebar, the footrests, and the seat determine the overall ergonomics. In the optimization itself a large design space, which correlates with the outer dimensions of the motorcycle frame, can be applied. With this input the software knows the positions where loads are introduced and components are mounted.

The software identifies the optimal load path and provides the engineers with details about where and how much material is needed. The load cases of motorcycles, which need to be taken into account in this optimization run, originate from data sheets (e.g. normal forces on the tires, friction, etc.). A motorcycle has different points - for example the handlebar or the footrests - that can be pulled or pressed and are consequently applying loads to the frame.

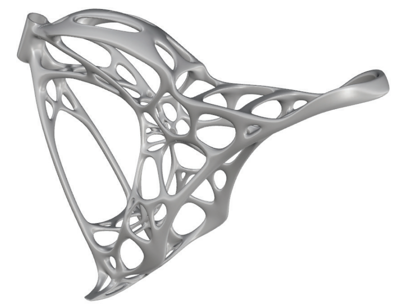
The motorcycle's final assembly also had to be taken into account when creating the design. Specific boundary conditions such as necessary drilling locations and mounting points were considered. Even during the planning phase, the engineers had to determine that all bolt connections were accessible in order to create a ready-to-assemble product without missing any detail.



Maximum Design Space



Optimization result



Re-design

Topology Optimization with OptiStruct and Altair® Inspire™

Topology optimization offers valuable support in the area of simulation and design. After specifying the maximum design space and applying forces and other boundary conditions, the optimization goals are defined: Based on this input the software is able to calculate an optimal design proposal, i.e. a design with minimal weight that also meets all stiffness and natural frequency requirements.

This design proposal derives from natural principles and serves as a template for an extraordinary design concept. Topology optimization is especially well suited for additive manufacturing, because it puts material only where it is needed – an approach which can be realized very well in 3D printing. In addition, tools such as OptiStruct and Inspire allow engineers to define so called non-design spaces right from the first draft of the design space, so that the software does not apply any structural changes at those places. “Our engineers are very experienced in the use of the HyperWorks suite. We enjoy working with it because we know that we can rely on the results the Altair products provide. We use the software tools in different development phases. A simulation-driven design process, which is also pursued and supported by Altair, is especially important for us because this process delivers an innovative, reliable design result, inspired by nature. Without a design-driven process these results would not have been possible,“ said Patrick Schürmann.

The next question is how to handle a complex design such as the suggested topology optimization result in CAD programs or CAE systems. After the optimization run, a redesign is often needed to smooth out the optimization result for 3D printing. “It requires a lot of know-how to realize the design proposal from topology optimization, and production requires thorough planning and implementation,“ explains Patrick Schürmann. Following the redesign, another finite element analysis is conducted to re-evaluate loads and stresses or other important issues. When implementing manufacturing constraints, design guideline catalogues are a useful reference. Last but not least, the APWorks engineers' experience feeds critical knowledge into the process. "It is a combination of experience and software solutions. Since Airbus Group's internal research and development department develops the required material, we are able to directly communicate with the metallurgists. This is important, because in this way, the simulation and design engineers are always aware of how the material behaves, and we are able to produce the desired geometry on the printer,” explains Patrick Schürmann.

Metal 3D Printing

For the production of the metal (Scalmalloy®) 3D printed frame the entire motorcycle and the orientation of the components on the 3D printer had to be considered. Up to this day there is no metal 3D printer capable of printing the entire frame in one piece, therefore single parts of the frame were produced. To do so, the printer was tightly packed and the single parts were oriented to make optimal usage of the available printer space.

Despite all freedom, some special boundary conditions have to be considered for metal 3D printing. In addition to the aforementioned orientation of the components in the printer, specific support structures, depending on the manufacturing direction and when reaching a special angle, need to be included. The support structures are needed to fix the component in the printing process and to dissipate the heat of the laser. These manufacturing constraints have to be considered especially when applying the laser additive metal powder bed process.

Revolutionary Results

The Light Rider prototype showcases the ideal approach of leveraging the symbiosis of topology optimization, novel materials, and additive manufacturing as well as a simulation-driven design process to benefit from the full weight and performance potential. The figures speak for themselves: The motorbike has a total weight of 35 kg, with the frame alone weighting only 6 kg. A 4 kW electric motor accelerates the bike from 0 to 45 km/h in only 3 seconds.

“In our Light Rider project topology optimization, innovative materials, and advances in 3D printing allowed us to realize the nature oriented design we intended for the motorbike. This led to the revolutionary and lightweight design we desired for the project,” confirms Joachim Zettler the success of the project.