Developing Ultra-Lightweight, High Performance Road Bikes

Key Highlights

Industry
High Performance Bicycles

Challenge
Develop a high performance, ultra-lightweight composite bike frame

Altair Solution
Optimization of the carbon fiber layup to reduce weight & simulation studies to accurately assess performance

Benefits

- Weight reduced from 829g to 710g
- All safety & performance targets met

The bicycle industry is a highly competitive market where it can be difficult to stand out from the crowd. As the enthusiasm for riding bikes has grown across Europe, the industry has responded by sourcing products which address diverse abilities and terrains. Manufacturers are attempting to use new technologies and new materials that are more common in the aerospace industry to make their bikes faster, lighter and more comfortable.

In 2011, Adam Wais and Anders Annerstedt, two friends now based in Sweden, believed that the cycling industry was becoming stale, with nothing truly exciting hitting the marketplace. After following the industry for several years, the pair spotted a gap in the market for a range of ultra-high performance bicycles that are tailored to the individual requirements of each rider. By combining a passion for cycling with a unique set of design and business expertise gained in other industries, the team founded Rolo Bikes with the aim of developing the best performing bicycles available.

The Carbon Fiber Challenge

During the development of a new carbon fiber bicycle, the design team at Rolo wanted to develop a frame which exhibited world leading strength and stiffness attributes while keeping weight to an absolute minimum. The team required an efficient process to design the frame and test it in a virtual world against the industry's safety and performance standards.

Carbon fiber material is constructed from layers of carbon fiber patches built up

Keywords: Composite optimization

Rolo Bikes Success Story

“The working relationship we have with Altair ProductDesign has been absolutely fantastic. I’m not sure we’d have been able to take what we had to market without them. I would be thrilled to work more and more closely with them in the future."

Adam Wais
Owner & Co-Founder
Rolo Bikes

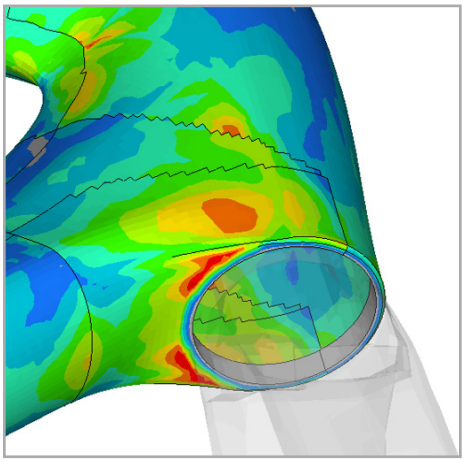
one-by-one to form the desired structure. Identifying how many of these layers are required in any given area of the frame, and which direction the fibers within should be aligned, represented a difficult design challenge for the Rolo team. To achieve the design objective of maximum strength and minimum weight, the team wanted to optimize the structure and find the ideal layout of carbon fiber that did not use any unnecessary material.

The Rolo Bikes team had some exposure to Altair’s HyperWorks suite of simulation tools during the early development of the new frame. However, the team did not have the in-house computer aided engineering (CAE) expertise required to accurately analyze and optimize the frame.

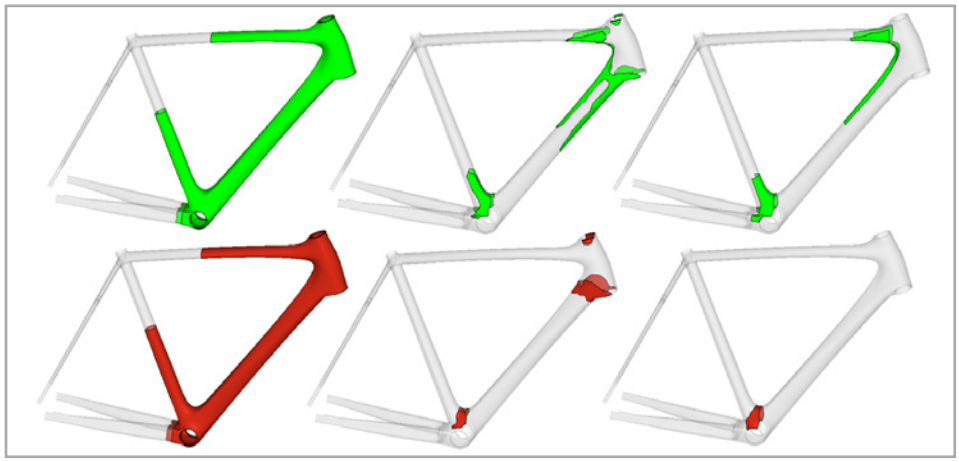
Rolo Bikes approached Altair ProductDesign due to its familiarity with the HyperWorks suite and expertise in the application of CAE techniques to optimize carbon fiber structures. The objective of the program was to optimize the frame to achieve world leading performance for weight, stiffness and comfort. In addition, the team was also tasked with developing an efficient and cost effective virtual testing process to analyze the performance of future bike frames from Rolo and other partner companies.

Optimizing the Composite Frame

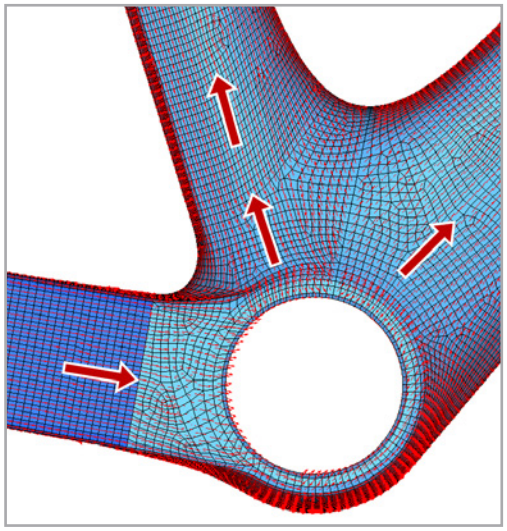
The Rolo Bikes design team had already created virtual test jigs to replicate European Committee for Standardization (Comité Européen de Normalisation or CEN) tests as well as Zedler stiffness tests using HyperWorks. The team had also correlated a baseline frame model to physical testing results. The baseline model weighed 829g



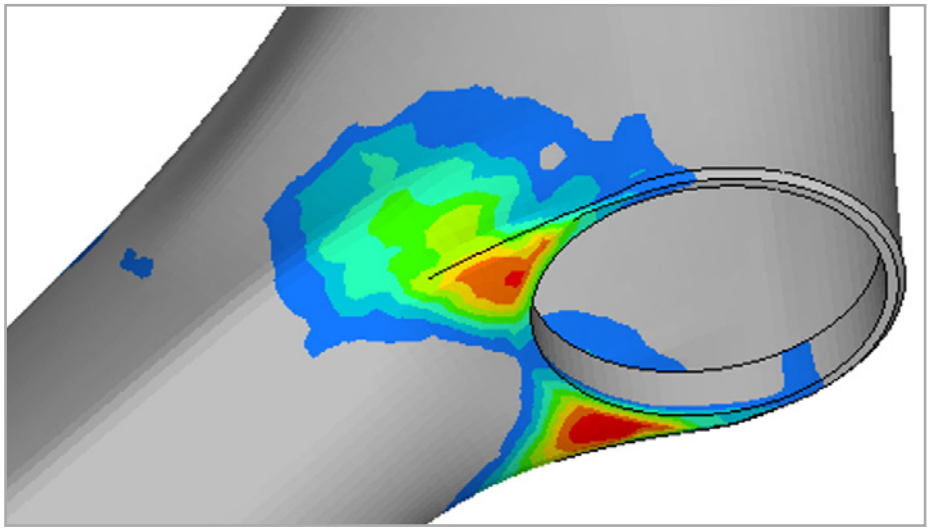
Impact analysis using RADIOSS



Free-size optimization to define the ideal carbon fiber ply shapes



Finding the ideal carbon fiber ply direction



Using size optimization to determine the optimal material thickness

but was extremely difficult to manufacture. Initial virtual analysis of the baseline design highlighted several areas of concern where the frame was under particularly high stresses. The optimization stage of the project would seek to address these high stress areas in a weight efficient way while ensuring a manufacturable design.

To optimize the carbon fiber frame, Altair ProductDesign utilized a three-step approach, during which the shape, thickness, direction and location of each layer of composite material was fine-tuned until an optimum solution had been reached. Each stage was performed using HyperWorks' structural analysis solver, OptiStruct.

- **Step-1: Free-Size Optimization**
  In this first stage the optimum shape and location of each composite material layer is defined by creating 'ply-patches' of material with the same fiber direction.

- **Step-2: Size Optimization**
  During the 'size optimization' stage, the optimum thickness of the ply-patches (created in Step-1) are determined.

- **Step-3: Shuffle Optimization**
  The final 'shuffling' stage evaluates the possible stacking sequence of the composite layers and suggests the ideal order to meet the desired design characteristics.

At the end of this process, HyperWorks was utilized again to analyze and validate the optimized frame against the CEN and Zedler tests, and assess fatigue performance. The resulting composite 'layup' created a component that is manufacturable for Rolo's meticulous hand layup construction process employed in its European based manufacturing center, all within cost targets.

Saving Weight, Improving Performance

As a result of the project Rolo Bikes has a comprehensive and highly accurate set of virtual test jigs which can be used to analyze the performance of any bicycle frame against industry standard performance metrics. This capability has allowed the company's design team to significantly decrease its future development time by cutting down its reliance on expensive prototyping and physical testing processes.

The composite optimization process successfully reduced the weight of the frame from 829g to 792g. Additional material refinement by Rolo's manufacturing team reduced the weight even further resulting in a final weight of just 710g. The design met all performance and safety standards with the stiffness and durability performance being enhanced significantly over the target values. In addition, the optimized design was actually feasible from a manufacturing point of view, something that was missing from the original baseline.

Looking to the future, the accuracy of Rolo's virtual test rigs is set to improve as the design team develops its library of verified material data. As well as significantly enhancing the performance of its own range of products, Rolo Bikes and Altair ProductDesign are now in a position to provide advisory services based on this work to other companies in the cycling industry.

Find out more at:
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About Altair ProductDesign

Altair ProductDesign is a global, multi-disciplinary product development consultancy of more than 700 designers, engineers, scientists, and creative thinkers. As a wholly owned subsidiary of Altair Engineering Inc., this organization is best known for its market leadership in combining its engineering expertise with computer aided engineering (CAE) technology to deliver innovation and automate processes. Altair ProductDesign utilizes proprietary simulation and optimization technologies (such as Altair HyperWorks) to help clients bring innovative, profitable products to market on a tighter, more efficient time-scale.

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About HyperWorks

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