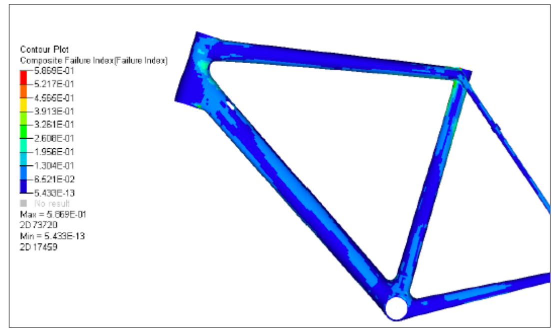
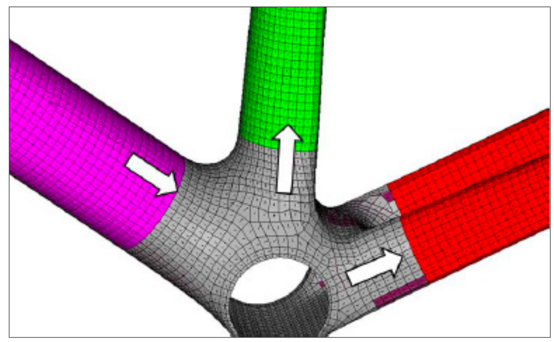
Duratec

Development of a Lightweight, Composite Carbon Fiber Street Racing Bicycle Frame





Background

In recent years, cycling for both racing and leisure have become popular in Europe, leading to increasingly strong competition. Innovation takes center stage as bike developers turn to technology advancements to remain competitive. Carbon Fiber, a strong lightweight composite material, is stronger and stiffer than steel while being lighter, making it the ideal manufacturing material. It has therefore recently emerged as a popular choice in the development of racing bike frames. Since the release of the Kestrel 4000 road bike in 1986, their first bicycle featuring all-carbon with a fully aerodynamic frame design, carbon fiber reinforced plastics have been used more often in bike frames design.

Founded in 1992 by Milan Duchek, Czech company Duratec Ltd., was established as a result of his enthusiasm for handmade bike parts. An innovative bike company, Duratec develops handmade bike frames using both aluminium and composite materials. Rather than mass production, Duratec uses an individualized approach to their customers by providing unique bike parameters for rider satisfaction. With an objective to develop the best possible bike suited to customer expectations, detailed attention is provided to obtaining correct size, frame geometry and optimized seat positioning. The company also participates in collaborative efforts such as sponsorship of Czech Paralympic racer Jiri Jezek, multiple gold-medal winner of four Paralympic Games.

At Duratec, as a result of product improvement and evolution, the bike frame has emerged as the backbone of a reliable bike. Made with high-strength, high-modularity fibers laminated with the best resin, road racing bike PHANTOM at Duratec utilizes maximum mechanical properties of the materials resulting in a high-quality user experience.

Optimization of a Composite Racing Bike Frame

Established in Prague, Advanced Engineering is Altair's channel partner in the Czech Republic, providing consultancy services for structural analyses and optimization of structures. A recent project at Duratec presents the latest approach in development of carbon fiber optimization of the bike frame. The main objective of this project was to optimize a composite racing bike frame in order to obtain world-class performance. This

Industry

Bike Frame Production

Challenge

Development and optimization of a lightweight composite racing bike frame

Altair Solution

Using Altair HyperWorks for model creation in Altair HyperMesh, optimized via the Altair OptiStruct code and evaluated in Altair HyperView.

Benefits

- A lightweight frame exhibiting all necessary strength requirements
- Mass reduction of 28% from the original weight

entailed minimizing mass while maintaining or increasing stiffness and strength of the frame. Loadcases used during optimization and results verification complied with European standard EN 14781 specifying the performance and safety measures requirements.

For the Computer Aided Engineering (CAE) department at Advanced Engineering, it was a real challenge to optimize layer stacking as well as number of plies that were necessary to meet all structural targets. In general, there are three major ways of optimizing or "tuning" composite structures – the fiber angle, the plies sequence and the number of plies through laminate. The capability to increase simple, localized thickness in highly exposed areas serves as the main advantage of composite structures for bike frames. Engineers determined that using the parameters for sequencing and number of plies would allow the creation of a design frame that would meet all strength and stiffness targets without exceeding the material, while remaining very light.

Manufacturing technology of the bike frame developed by the Duratec development center (OnePiece Technology - 100% monocoque) lies in the ability to produce the entire frame as a whole, including tube connections, which are formed and cured together with the entire shell of the frame in one thermal process. This technology ensures the highest manufacturing precision and maximum processing quality. Due to the fact that the frame is not assembled and glued from multiple parts, the manufacturer was allowed to use AFCF technology (Accurately Fitted Continuous Fiber) for fiber lay-up. The technology aim is to keep the fiber uninterrupted in the areas of highest stresses to maximize its mechanical properties, thereby achieving the limit parameters of stiffness and strength together with very low weight.

Using a Three-Stage Optimization Process

Using the Altair HyperWorks™ suite, the frame was optimized to minimize mass while improving stiffness and strength. Using HyperWorks for the entire process, the model was created in Altair HyperMesh™, optimized using Altair OptiStruct™ and the results evaluated using Altair HyperView™.

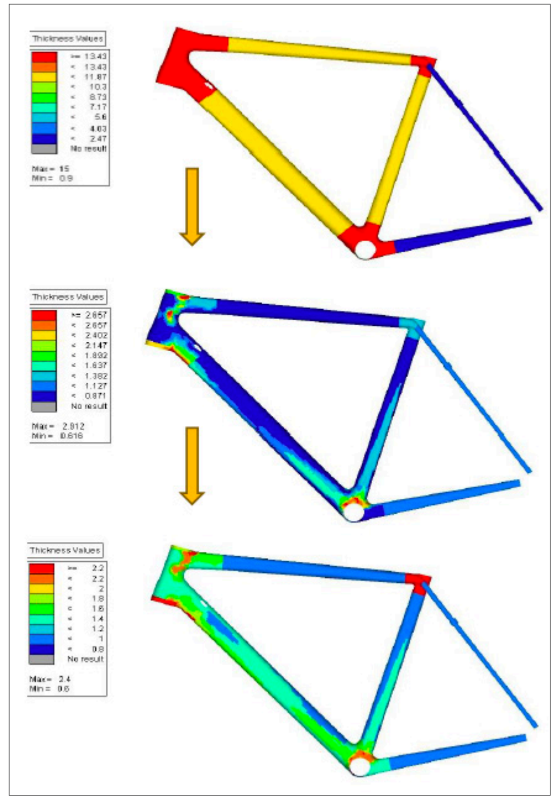
1. **Stage-I: Free-Size Optimization –** In this first stage the optimum shape & location of each composite material layer was defined by creating 'ply-patches' of material with the same fiber direction.

2. **Stage-II: Size Optimization –** During the 'size optimization' stage, the optimum thickness of the ply-patches (created in Stage- I) were determined.

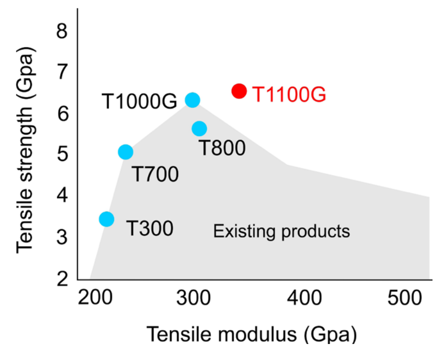
3. **Stage-III: Shuffle Optimization –** The final 'shuffling' stage evaluates the possible stacking sequence of the composite layers and suggests the ideal order to meet the desired design characteristics.

Several loadcases were selected for optimization to make sure the bike frame would meet all required criteria. For each loadcase, a constraint (allowable upper/lower limit value) was set. For the stiffness loadcases (torsion/load transfer) displacement was a constraint, whereas for strength loadcases, the limit value was of Failure Index, which summarizes whether the composite will fail or not. Limit values varied and were dependent on the simulated loadcase. The limit value for the Failure Index was set to 0.7, which includes a certain safety factor (when Failure Index equals to 1, the composite fails).

The new bike frame without painting, stickers, metal joints etc., with a mass of 590g was developed. The ready-to-buy bike frame weighs in at 700g, a reduction of 28% from the original weight of 980g.



Laminae thickness, initial, and after the first and second optimization stages



Material Selection - High-strength UD Material T700 selected

"Next to our development, with the help of Advanced Engineering s.r.o., using the Altair HyperWorks™ suite, our bike frame was optimized to minimize mass while improving stiffness and strength, resulting in a high-quality user experience for our customers."

Milan Duchek, Founder and Owner, Duratec

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