HTX Lector Team mountain bike from GHOST Bikes

Ply-Cycle

ANSYS Composite PrepPost assists in efficient, cost-effective design of a carbon-fiber–based bicycle frame.

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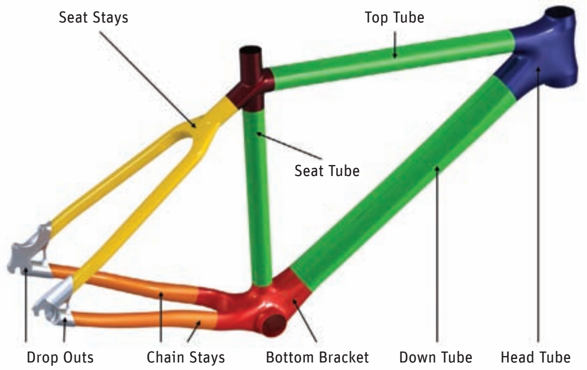
When designing frames for premium bicycles, engineers must take into account a large number of characteristics, including strength, stiffness, weight, durability, ease of manufacture, type of bike and rider preference. Frames can be constructed from metals such as steel, aluminum or titanium, or they can be made of composite materials that are based on carbon fiber. Traditionally, use of conventional simulation in the bike industry has been limited to the metallic materials. However, scientists at the Institute for Lightweight Structures (IST) at Germany's Chemnitz University of Technology used engineering simulation to successfully identify the stresses for a carbon-fiber–reinforced mountain bike frame for GHOST Bikes GmbH — builders of premium bikes of all classes and categories. The research team used ANSYS Composite PrepPost software to analyze potential failure within the complex lightweight structure.

Carbon-fiber–reinforced polymer (CFRP) is an increasingly popular material for mountain bikes due to its lightweight characteristics and ease of manufacturability. In addition, fibers can be oriented to better withstand loads and provide weight-efficient parts with high stiffness that will increase the overall stiffness of the frame — a desirable characteristic. To optimize the use of materials and to determine fiber orientation, complex calculations and numerical simulation methods are required. Conventional composite simulation programs usually require additional work to define fiber orientations and plies.

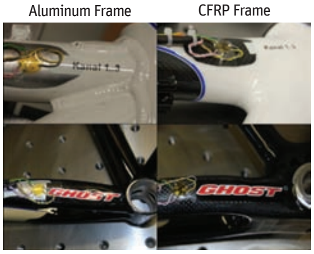


Segmented model of bicycle frame

Composite PrepPost software, integrated within the ANSYS Workbench environment, takes advantage of outstanding features and solver technologies from ANSYS. This technology substantially simplifies analysis of CFRP structures using innovative modeling and analysis capabilities.

Assessment of Load Cases

To perform an effective numeric simulation, the engineer needs to determine the exact loads, boundary conditions and acceptable stress levels for a given component. The technical requirements and corresponding test procedures are defined by standards from the German Institute for Standards (DIN EN 14766 and DIN Plus for mountain bikes). However, these norms do not consider all possible loads the structure experiences, so IST developed the current research projects to expand the scope of these tests. The IST team defined three major load cases that use increased load levels and consider brake loads, saddle loads and handlebar loads.



Strain gauges used for testing

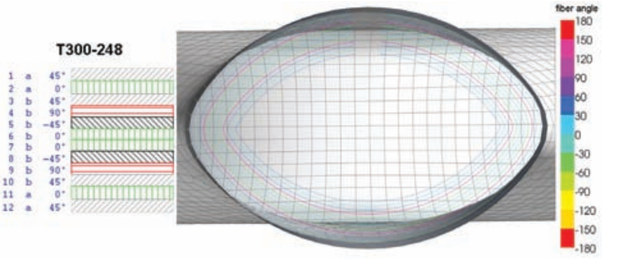
Engineers at IST created a model of the bicycle frame with Pro/ENGINEER® Mechanism Design Extension (MDX). They used simulation to investigate transient loads as well as seven quasi-static loadcases. To optimally define the local material properties, they further sliced the frame into components using ANSYS DesignModeler software. The final verification of the simulation model was made using strain gauges and a test rig at GHOST Bikes.

Simulation in ANSYS Composite PrepPost

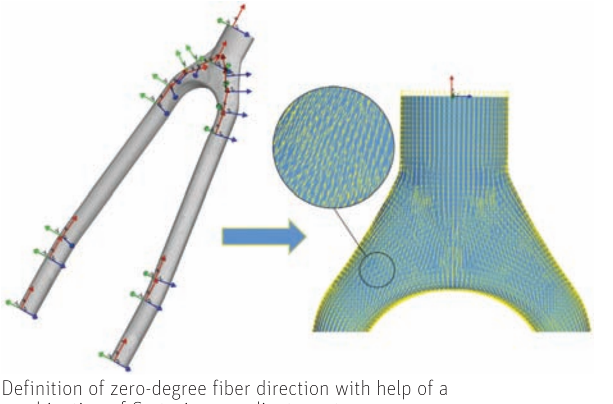
Researchers transferred the model they created to Composite PrepPost using Workbench. For defining specific composites in the bike's frame, Composite PrepPost offers a variety of capabilities for both pre- and post-processing composite structures. The material definitions, including parameters required for a failure analysis, can be manually input or imported from a material library, such as the one available in ESAComp software (from Componeering Inc.) for analysis and design of composites. These material definitions can define fabrics, laminates or sublaminates (a combination of fabrics and laminates) with various properties, including thickness and fiber orientation.

For the failure analysis of the bike frame, the IST team compared 16 laminate configurations to standard carbon fiber for very high stiffness and resistance. The material assignment for the simulation model was applied on oriented sets. These groups of elements could overlap. For each group, the team defined the global draping directions as well as the definition of the zero-degree angular direction. Using Composite PrepPost made it possible to adapt the fiber direction for each element group using a smart combination of Cartesian, cylindrical or spherical coordinate systems.

The post-processing capabilities of Composite PrepPost are impressive: The large number of state-of-the-art failure criteria available as well as the ability to perform layer-wise analysis of the results allow the user to identify critical areas along with the load case for which failure might occur. Moreover, the use of the Cuntze and Puck criteria allowed the team to predict failure in the most critical areas. Engineers investigated several variations of the design using different configurations of plies. As a result of the simulations, the team designed an optimized frame that was able to meet the stiffness requirements but would be cheaper to manufacture than the initial design.



Laminate configuration pre-designed using ESAComp (left) and corresponding definition in ANSYS Composite PrepPost software (right)



Definition of zero-degree fiber direction with help of a combination of Cartesian coordinate systems

With ANSYS Composite PrepPost, the stiffness and resistance characteristics of fiber-reinforced bicycle components can be optimally adapted to meet design requirements; furthermore, design efficiency is significantly improved. Compared to typical trial-and-error development methods used in the bicycle industry, the number of cost- and time-intensive physical prototypes was greatly reduced. ■

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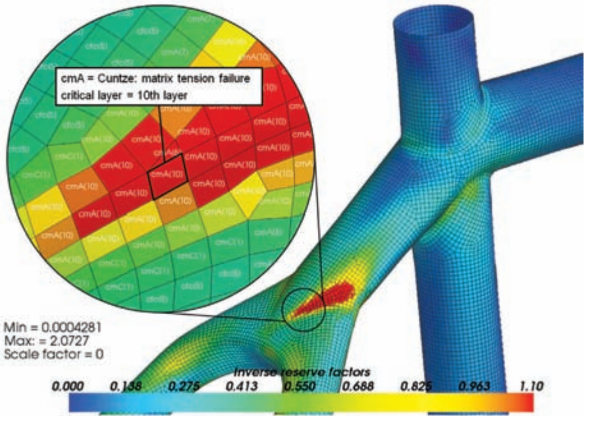
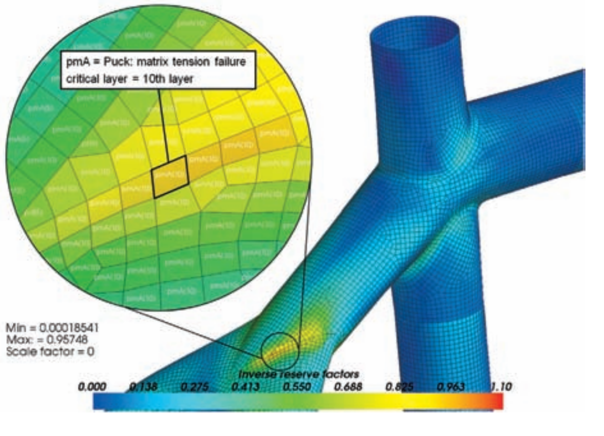


Inverse reserve factor using Cuntze failure criteria; critical areas in red



Inverse reserve factor of optimized design