The highly competitive, fashion- and performance-driven business of bicycle design and manufacture requires the ability to innovate at a rapid pace, bringing products with innovative features to market ahead of the competition. International sports company Oxylane attributes its success to extensive use of simulation to deliver continual performance improvements, ensure safety and reliability, and minimize engineering and manufacturing costs. Each bicycle Oxylane produces has specific design challenges, and practices employing structural simulation from ANSYS help to make the design process more efficient.

**OPTIMIZING BIKE-SHARE FRAME**

The company combines development of sports products with a network of retail stores, including Decathlon in 15 countries with 560 stores. Product brands include Tribord for water sports, Inesis for golf, and b’Twin for cycling.

Oxylane recently developed a new bicycle for a bike-sharing program in Lille, the fourth largest city in France. The nature of bike sharing means that the frame must be extremely robust. Yet cities like Lille that purchase a large number of bikes for such programs are concerned with minimizing cost. Oxylane accomplished these conflicting goals by using ANSYS DesignXplorer to optimize the shape and dimensions of the frame; this minimized its cost while meeting challenging stress requirements.

Oxylane engineers created their initial design concept for the frame using Siemens NX™ software and defined the important design variables as parameters within NX. They imported the design into ANSYS Workbench to read the parameters and set up variables for optimization. The engineering team characterized the loads and constraints for structural analysis in ANSYS Mechanical software.

The Oxylane team defined the objectives of their optimization. Industrial designers wanted the shortest possible length between the top tube and the bottom bracket, while engineers wanted to ensure that strength requirements were met at the lowest possible cost. Engineers set up DesignXplorer to iterate through 200 design variations while varying the length of the top tube. About 120 of these variations met the stress requirements. The software ranked the acceptable design variations by the length of the top tube.

Additional optimization runs were performed to analyze the effect of the thickness of each tube on strength and cost. The resulting design delivered the industrial designers’ unique styling concept and provided the required strength.

**Engineers set up ANSYS DesignXplorer to iterate through 200 design variations.**
The Lille bike-sharing program currently includes 1,100 bikes in 110 self-service stations. Later in 2012, an additional 1,500 bikes will become available for long-term rentals. The current plan is to increase, by 2014, the number of bikes in self-service stations to 2,000 and the number available for long-term rentals to 8,000, for a total of 10,000 bikes. At that point, Lille is expected to have the second largest bike-sharing program in France (after Paris).

SHAPE OPTIMIZATION
In designing another bike, Oxylane designers used the shape optimizer within ANSYS Mechanical software to optimize the shape of the link that connects the rear triangle and the front triangle on a full-suspension frame. An envelope of the initial volume was defined to determine the location of the fixed points at which the link connects to the two triangles. Loads and fixed supports were applied. The software approximated the initial structure as a large volume that was then eaten away at locations with low stresses, leaving a representation of the optimized support structure.

The final design met the attachment point and envelope constraints, weighed 19 percent less than the existing structure, reduced stress by 26 percent compared to the existing part, and provided 39 percent greater stiffness. The component has not yet been produced because manufacturing equipment is already in place to produce the original part. However, Oxylane now recognizes the tremendous potential of simulation-driven design to develop lighter and more cost-effective products before a part is built. The company plans to use the shape optimizer in several upcoming projects in which manufacturing tooling can be designed from scratch.

DEVELOPING COMPOSITE DESIGN GUIDELINES
As part of the normal design workflow, Oxylane uses ANSYS Mechanical to develop high-performance composite frames. Engineers first simulate proposed frame designs under a series of standard load cases to determine the best shape to meet the performance specification. They also determine the direction of principle stresses for each proposed design. This information is used by suppliers who develop the detailed design as guidance in developing ply layout — to determine the direction of the main fibers and required reinforcement areas.

Oxylane recognizes the tremendous potential of simulation technology to create lighter and more cost-effective products.

SIMULATING STANDARD FATIGUE TEST CYCLES ON BICYCLE FRAMES
Each bike frame has to withstand standard fatigue test cycles covered by European standards, such as EN 14764, EN 14766 and EN 14781. These tests are expensive and time consuming because they require large numbers of physical prototypes to be built, and some of the tests require several weeks to run. In the past, prototypes often failed during testing, making it necessary to go back and redesign the product, build a new prototype and rerun the testing cycle. It was not unusual to perform five different design, build and test cycles to meet fatigue test requirements.

The nature of a bicycle’s construction made it difficult to apply simulation to solve this problem. Bicycle frames are made of thin-walled tubes that are welded together to form the frame. The geometries of the welded areas are complex, especially in the bottom bracket area where a number of tubes intersect. Finite element analysis results show that actual loading and standard tests lead to multi-axial stress at critical points in this bracket area, which limits the application of classical weld fatigue analysis.

Oxylane engineers addressed this difficulty by using a fatigue assessment method based on a unique S–N (S=stress and N=number of cycles) curve that works regardless of the geometry of the welded structure and loading mode. The S–N curve was calculated using fatigue tests on a simple welded tubular joint. It takes 35 specimens to define the S–N curve. It would have been expensive to build that many frames. So Oxylane asked each supplier to weld many tee
joints using standard production methods, and these were subjected to fatigue testing to determine the S–N curve. The design stress $S$ is determined by using linear elastic finite element analysis with thin shell modeling and a rigid link to simulate the weld that calculates the geometric stress at hot spots. The automatic ANSYS Workbench meshing tool meshes the geometry, and a user-defined subroutine automatically places rigid elements between the welding lines. Engineers used ANSYS Mechanical to perform a standard stress-life fatigue analysis. This information was employed to calculate the Dang Van multi-axial fatigue criterion.

The accuracy of this approach was validated against physical testing. The method is now used as part of the standard reliability procedure at Oxylane. The result is that bike frames no longer fail fatigue tests, and engineers get the design right the first time.

**AUTOMATED ANALYSIS TOOL**

Oxylane has also developed an automated design tool to work with ANSYS Mechanical software to enable designers to easily simulate the performance of frames and forks in standard tests without the need for a simulation expert. The designer selects the test from within CAD software; the design tool then automatically calls ANSYS Mechanical, transfers the design geometry, defines material properties, meshes the part, sets up any contacts, generates loads and supports, runs the simulation, and displays the results in a standard format. This approach reduces the time required for simulation by 75 percent, enabling design engineers to evaluate more iterations and improve product performance.

Bicycle design is always a compromise among the goals of cost, strength and weight. ANSYS simulation makes it possible to more intelligently trade off these conflicting objectives to deliver a product that better meets Oxylane customers’ needs at a lower cost. Oxylane plans to make increasing use of simulation in the future to deliver even greater performance and value for its customers.