CARBON COMPOSITES

Composites are the future. The possibilities are truly endless. Done right, composites can create some of the strongest, most reliable bicycle components possible.

Last month we talked about the ins and outs of aluminum. This month we'll talk about composite materials. We use the term composite because it takes a combination of an epoxy resin and carbon fibers to create the composite material.

You may remember that aluminum's properties are expressed using the terms, *yield* and *ultimate strength*, *stiffness* (modulus of elasticity) *density* and *elongation* (toughness). While we use many of these terms to describe the mechanical properties of composite materials the differences between aluminum and composites far exceed their similarities.

In addition to the aforementioned terms, when evaluating composites we must learn a few new ones such as *fiber, tow, ply, resin system, pre-preg, fiber areal weight (f.a.w.), laminate, compaction* and *fiber orientation*.

Taking Carbon in Tow

Lets start with some of the terms and descriptions of how they work together.

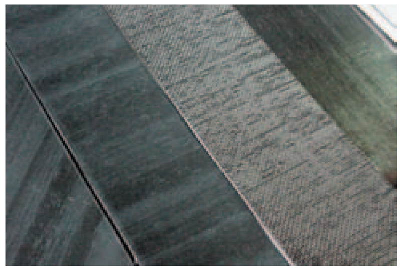
The manufacturing of carbon material begins by bundling individual ***fibers*** into a thread which we call ***tow***. The fibers used in composites are very fine so large numbers can be bundled together to form each tow. Tow is available in configurations from 1,000 to as high as 70,000 fibers per tow. If you had tow containing 10,000 individual fibers, that material would be called *10k*.

> ***"The trick here is to create a ply with all tow spread uniformly without gaps and voids."***

Getting Carbon to Comply

To be useful, tow must be transformed into a sheet. A sheet or ***ply*** is made up of thousands of tow placed side by side and impregnated with a ***resin system***. We call these pre-impregnated sheets ***pre-preg***.

The trick here is to create a ply with all tow spread uniformly without gaps and voids. The best pre-preg materials are made using large, specialized machines similar to machines used in the paper industry. The fibers are stretched tightly between heated nip rollers with thin sheets of resin positioned on top and bottom. The resin film and fiber tows are forced together under great pressure, with precision metering, to form unidirectional pre-preg material. Uniform resin distribution and complete fiber wet-out are key characteristics of the process.



Examples of pre-preg sheets of carbon fiber.

Lower cost methods of making pre-preg exist and are used on composites that come from Asia as well as other overseas suppliers. These manufacturers make their plies by drum winding the tow over big cylinders. It's kind of like putting fishing line on a reel. Unfortunately, no matter how careful you are, gaps and voids occur between the tows. And the resin coverage is less uniform.

While we talk about the tow in terms of how many fibers are included, we talk about ply in terms of its weight expressed in grams per square meter. The term we use is ***fiber areal weight (f.a.w.)***. In our example, let's say our 10k material has a fiber areal weight of 220. That means that one square meter of this material will weight 220 grams. Fiber areal weights run from as low as 20 grams to several hundred grams per square meter. Materials with higher areal weights are generally easier and cheaper to produce than those with lower areal weights.

continued

MATERIALS/COMPOSITES

Staying on Schedule

Composite materials are very light (only two-thirds the density of aluminum). They are also incredibly strong with strengths ranging from 300 to 1,000 ksi (compare that with aluminum's range of 30 to 80 ksi). Similarly, the range for tensile modulus is between 30 to 90 msi (million pounds per square inch). This phenomenal strength is important because carbon's potential for elongation is only in the 1 to 2% range (compared with aluminum's 10 to 12%). So while carbon material is much stronger and stiffer than aluminum, it has less ability to bend before breaking. To preclude the chance of failure, it is critical to design and manufacturer composite components that are over-built from a strength standpoint.

How do we over-build composite components? We make a ***laminate***. In a laminate we gain much greater strength by stacking plies together.

Since the fibers in each ply are oriented in the same direction it is also advantageous to alter the direction of the plies in the laminate. We define this orientation in degrees from zero. Fibers that are oriented in a longitudinal direction are termed zero degree. By adding additional plies using other orientations like +45° and –45°, we give the component the ability to withstand forces from many directions.

A component's ultimate strength and weight is dependent on the skill with which the laminate is designed and manufactured. With composites, fatigue life is generally not an issue because composite materials exhibit exceptional resistance to fatigue.

Taking into consideration the number of fibers per tow; the fiber areal weight; and the number, shape and orientation of plies, the engineer can create an almost infinite number of performance characteristics. When all of these factors are combined to develop an individual bicycle component the final design is referred to as the ***laminate schedule.***

"To preclude the chance of failure, it is critical to design and manufacturer composite components that are over-built from a strength standpoint."

Companies keep their laminate schedules proprietary because they are one of the most important factors in determining the strength and ride characteristics of a component.

Equally important is the molding process. It is critical that the plies have good ***compaction***, insuring that no air pockets or other voids are allowed to develop. Performance is significantly compromised by dry fibers, air pockets and gaps between plies. Trek Bicycle Corp. coined the term *OCLV—Optimum Compaction*

RAISING THE BAR

Pre-preg sheets are laid up by hand around an inflatable bladder.

These hand lay-ups are then inserted into a mold for forming.

The bladders are inflated under high-pressure forming the material to the shape of the heated mold.

Molded parts are cleaned up, color graphics and a final clear coat are applied.

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Low Void. This truly is the key to the strength and performance of carbon components.

All composites are not equal

The manufacturing processes used for composites can make or break—literally—the product being fabricated. The most advanced materials and the best laminate design in the world cannot compensate for a poorly manufactured part.

Easton has a dedicated ISO 9000 certified facility that focuses solely on the manufacturing of composite sporting goods. Easton also spends considerable time and money creating proprietary resin systems and fiber lay-ups.

In addition, Easton has some unique capabilities within the composites industry. Easton can manufacture components using many different processes including bladder molding, resin transfer molding (RTM), compression molding, pultrusion and roll wrapping. This breadth of capabilities enables Easton to chose the right material *and* the right process to create the strongest and most reliable bicycle components on the market. Most composite manufactures are limited to only one or two of these processes.

"The most advanced materials and the best laminate design in the world cannot compensate for a poorly manufactured part."

Rolling it all together

Composite components cost more because the materials are expensive and there is no good way to automate the manufacturing process. Each bicycle component Easton makes is truly hand-rolled by highly trained, skilled technicians.

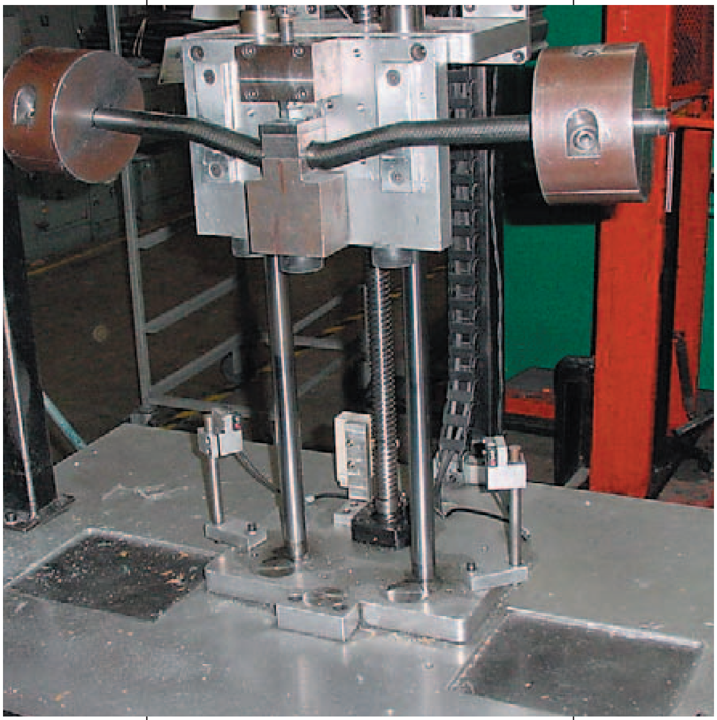
Laminate schedules are developed by engineers with decades of combined experience using materials manufactured to Easton's specifications.

To ensure quality, Easton proof tests every carbon handlebar it makes on its impact drop-test machine. The test load far exceeds the stress the bar will encounter even under the most demanding cycling conditions. By proof testing, Easton guarantees a high level of performance. No other manufacture can make this claim.

Composites offer exciting possibilities for bicycle components. By controlling the design, the material and the manufacturing processes, Easton creates leading-edge bicycle components designed by cyclists for cyclists.

Composites are the future. The possibilities are truly endless. Done right, composites can create some of the strongest, most reliable bicycle components possible.

Easton sets the standard of performance that all others aspire to.



A handlebar is loaded on Easton's drop-test machine with weights secured on each end. When dropped, impact forces far exceed those experienced even during the most demanding cycling.

In the next installment: Process and Design for Alloy