Carbon Composites in the Bike Industry.

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Part 2.

In the previous issue we looked at some basic definitions of what carbon composite is made up of and some brief information on the different ways it can be manufactured into products. We discussed some of the different fibre types and forms ie. woven or unidirectional, we also looked at resin types and their role in the composite. This article will bring this information together to give you an idea of some of the specifics of carbon composites in the bike industry.

Where are composites heading? It seems every day some new parts are being released on the market. Some products are clever in the application of composites, other's it seems are carbon for the trendy look without an engineering advantage. Be warned composites do have limitations, aerospace engineers do not go out to design an entire aircraft from carbon, they use the best available material for the job, be it steel, aluminium, titanium, composites or whatever. Reliable performance is more important than fashion. Look for products from reputable manufacturers preferably with a solid history using composites, companies with a quality test program. Think about this next time you ride.

To know where you are going it's good to know where you have been, so lets have a look at some history of composites in the pro peleton.

History of carbon bikes.

The use of carbon composite first started in the nineteen seventies, that's right what appears to be the latest technology has actually been around for 30 years. It has taken some time however to realise the full capability of the material to get the products we have today. The early products although groundbreaking were nowhere near the performance of today's composite bikes. It has been a steep learning curve in terms of what works and what doesn't.

The first bikes using carbon composite used a methodology where the designer simply replaced steel tubes with carbon tubes. These bikes had stainless steel lugs similar to the old brazed steel frames, which were bonded to the tubes. The biggest shortcoming was the designer didn't really understand the loads on a bike, thus it performed relatively poorly. Failures at the tube to lug joint were also common as bonding methods had not been understood or had been poorly implemented. It took about ten years before anyone looked at the possibility of a carbon bike again.

A new age begins.

In the mid eighties two separate companies came into the market, one from France and one from the United States. The French company T.V.T. made a carbon tubed, aluminium lugged frame and fork, which at the time was mindblowingly light. This bike was used some of best riders of the day including LeMond and Indurain, who used them to win the Tour de France. Although light it was considered quite flexy and did suffer some failures, however this bike started the carbon revolution in pro cycling in Europe. The engineering company T.V.T. still holds many patents and the technology is used in products made by the LOOK and Time companies.

The other company in the United States had a different philosophy on how a carbon bike should be made. As aerospace engineers they concluded one piece or monocoque type frames was the way to go for optimum performance. The company molded smooth lugless frames in a number of sizes, which became the lightest performance frames on the market. These frames were quite successful, but it was their fork which really changed the industry. Previous carbon forks were considered too flexy for general road racing in Europe, the Kestrel fork was the first carbon fork that handled like a steel fork but was lighter and smoother to ride. Prior to this each frame builder made their own fork, now builders were buying carbon forks from other manufacturers.

The top pro riders all demanded the light weight and performance of composites but had sponsorship obligations to a steel frame builder. In the early nineties it was common to see a T.V.T. frame painted tolook like a frame from one of the top steel frame builders, or a Kestrel fork painted in Bianchi celeste colours or other livery. Then the flood gates opened with Trek, Colnago, Look, ……. etc all making carbon frames and evolving their designs.

Then for 1992 Olympics a bike came along that changed the direction of bikes worldwide. The Lotus pursuit bike used by Chris Boardman to win the Gold medal made a huge impact on bike design. It was the first successful bike that was not made of tubes, this had major aerodynamic advantages and changed time trial bikes until the international governing body (UCI) banned this design in the year 2000. During this time composite wheels became common for time trial bikes, designs with 3 or 4 wing shaped spokes as well as discs were almost compulsory.

To the mid nineties, whilst some manufacturer’s where making complete composite frames, the majority of frames were now being made of aluminium alloys using a carbon front fork. By the late nineties carbon seat stays started to appear, these are made by the same companies making forks and tubesets. This design offered a smoother ride and cool looks. Now in the present day most of the frame companies offer a full carbon frame.

How do you make a good Composite bike frame?

There are many answers to this simple question. The major players such as Trek, LOOK, Giant, Time, Colnago to name a few, all have their own methods in regard to making frames. These are often closely guarded secrets mainly for marketing reasons, in most cases you can do a patent search if you want and read all about their process.

There are a few common ways these companies make bikes.

Bladder molding with pre-preg fibre is probably the most common method today. This is used for many bike parts made all over the world from frames to handlbars to rims. This process is common because of its relatively low cost and good quality, it is quite labour intensive however. Hence many bladder molded parts come from Asia, this includes aerospace parts as well as sporting goods.
Examples of this technology are Kestrel, Giant, Zipp rims, Carbon handlebars, Trek lugs.

Tape laying is also common for making tubes. This method is arguably the best way to make a round tube, because the fibre is placed under tension, which ensures there are no strength sapping wrinkles in the tube. Pre-preg is used and the process is usually fully computer controlled, this makes the set up cost high but ongoing costs are quite low. Usually one company makes tubes for a whole range of products from satellites to golf clubs. You can buy a carbon tube set for a bike from these guys if you know the specs of each tube. It is rumoured even Trek buy it's tubes from a major supplier.

Resin tranfer molding is becoming more widely used. With this process all the fibre is placed in the mold dry, the mold is then closed and resin injected under pressure. The initial tooling cost is high but the process is very well controlled and requires little labour. Some aerospace experts say this is the future for composite manufacture. A number of European bike companies are using this technology including Time, Look, Colnago.

What about the shape?

Structurally the conventional double diamond shaped frame is very efficient, it had to be because the materials used in the early days weren't nearly as strong as today's offerings. Aerodynamically however there are better designs available. Composites were able to exploit these designs such as the Lotus pursuit bike and various other time trial bikes. The UCI changed the rules on what a bike can look like, so now we are limited to the double diamond shape with restrictions on tube shape and size. The triathlon market still has some more radical shaped frames however as they aren't bound to the UCI rules.

One Piece or Secondary Bonded?

There are two main ways to make a bike frame. It can be made in one piece (often incorrectly termed monocoque), or it can be made in pieces and the individual pieces assembled (secondary bonded).
History has shown that although proper one piece or monocoque frames can have a performance advantage when made properly, there are problems in a production environment, also the limitation in sizes available due to many different molds being required is a major drawback, this has limited their use in the pro peleton to a point. What most pro bike riders want is custom fit and it is very expensive to get this in a monocoque. So unless you are fortunate enough to fit of the peg geometry you need something else. Therefore most of the carbon bikes these days are secondary bonded. This means parts are made and cured separately and then the individual parts are assembled with adhesive to create the full frame. This has many advantages in terms of production and the ability to custom fit if required. It is much easier to control the manufacturing process of a single tube than a complete bike. This provides a higher level of quality control than one piece frames. If a problem is found in one tube, that tube can be scrapped and a new one made. So instead of the whole frame being scrapped, which can be expensive only a relatively cheap portion of it gets scrapped which is much cheaper. So there are quality advantages to this method. The disadvantage of a bike made this way is that it may be slightly heavier due to the added adhesive, however this can be offset by making higher quality individual parts in the first place. Initially failures did occur with these frames because of poor bonding methods. These days good design and adhesive application has eliminated most of these failures.

What is Trek's OCLV process?

OCLV is an acronym for Optimum Compaction Low Void, this means they use high pressure to compact the fibres close to each other and squeeze out any air bubbles, this makes a stronger and lighter laminate. What is a Void? A void is a trapped air bubble in the composite's matrix, this has a significant effect on the final strength. In aerospace, parts are tested non destructively for voids at major expense, an area with a void content greater than 2% is scrapped. Voids are bad. Trek uses a bladder molding process for all its lug areas, these are easy to spot because they have flowing curves. Tubes made by the tape laying process over a mandrel, these are straight and round. The tubes are ground smooth externally to give a good surface finish prior to assembly of the frame. The frame is then assembled in a jig using an adhesive. This method gives Trek very good control of the entire process and reduces the cost of manufacture. So OCLV is actually a collection of processes optimised for each specific part.

What to look for in a carbon bike.

It is very difficult to tell the quality of a composite bike by just looking at it. It is even harder when the fibre is covered with fillers and paint. So how do you know what your hard earned cash is buying?
Things to look for include:
Does the frame have a good reputation for quality.
Does the fibre look evenly placed, ie no wrinkles or distorted weave.
Are the corners well rounded to help distribute stress.
Look inside the tubes, does the thickness look even.
Does the exterior have lots of filler covering up problems.

Quality, quality, quality.

Quality control in composite manufacture is difficult and expensive. In aerospace it often takes longer for the quality checks than to make the part. Every step of the process is controlled to achieve consistent results. At the end of the line Ultrasonic scans and X ray images are common to check for compliance. These extra processes would make carbon bikes way too expensive, so manufacturers have to rely on process control only combined with some over design. This means they control the steps of manufacture as close as possible and they design quality into the part, which minimizes the things that can go wrong. Having large factors of safety in a design gives you some leeway, if things aren't perfect the part will still meet the minimum strength requirements. Have you noticed how the weight of carbon frames and forks are slowly coming down each year. This is because the factor of safety is getting lower as the manufacturing process and quality control get better. There is a limit however.