Carbon Composites for Bikes FAQ

by Raoul Luescher. March 2008

What exactly is carbon fibre?

Very simply carbon fibres are made by burning a plastic fibre called a precurser in a controlled environment. The precurser fibre is thus carbonised, these filaments are very thin between 5 and 8 um. These individual filaments are then bundled into what are called tows. These tows are commonly made up of either 3000, 6000 or 12000 individual carbon fibres, this is referred to as 3k, 6k 12k etc. The mechanical properties of carbon fibre are very impressive with tensile strength and stiffness.

Why has it only become popular in the bicycle industry relatively recently?
This is due to the increased production capacity from the factories in Asia.

Is it true that the demand for carbon to build new planes such as the Airbus is so great that carbon is in short supply?
The demand for carbon has increased significantly in recent times due to commercial aviation. The new Airbus and Boeing planes have a significant amount of carbon in them. The bike industry is quite small, even golf uses three times the carbon than the bicycle industry uses. Hence bike companies can be at the back of the queue when ordering material. In practical terms this is not a major issue, but it explains why the weave on parts changes at short notice.

What exactly does “high modulus” mean?
Modulus is short for modulus of elasticity, the term for stiffness, this is the rate of deflection when a load is applied. Modulus has nothing to do with strength. Carbon fibre is available in a range of modulus values from about 200GPa to 600Gpa. Bike frames are stiffness critical structures, hence the modulus of the material is very important. Lighter bikes can be made with selective use of high modulus material. Higher modulus fibre can be very expensive, about ten times the price of standard modulus fibre or greater.

Sometimes you see carbon fibre in colours other than black. How are these colours achieved?
This is not carbon, the silver fabric often called white carbon, is a product called Texallium. Texallium is glass fibre coated with a thin layer of aluminium. This has lower specific properties than carbon and is used for decorative purposes. Other colours such as yellow are typical of the aramid range of fibres such as Kevlar. Aramids can be dyed different colours also such as red and blue. Carbon is only available in black.

How is carbon fibre mixed with cheaper materials such as fibreglass and how can a consumer tell?
Glass fibre is significantly cheaper than carbon, however it has much less stiffness, about 80Gpa. So a glass fibre part will flex almost three times more than a standard modulus carbon part. So a frame made this way will be much heavier and more flexible and would thus be obvious. There are non destructive methods such as X ray where it is possible to see what fibre is being used, these are beyond the scope of most people however. I have seen the inside of many bikes and I am not aware of any bicycle manufacturers substituting glass into a structural carbon part. Sometimes the exterior layer of a part is glass fibre where metal will be in contact with the part, such as fork steerer tubes. This is done to avoid galvanic corrosion between the metal and the carbon.

What is resin made of?
There are many different types of resin systems for a wide range of applications. In the bike industry epoxy is the most common. Epoxy is a thermoset polymer meaning that once it cures it cannot be softened by heat and re-used. It is supplied for use in composites mostly in prepreg form, although some parts are resin transfer moulded using a two component system.

What is prepreg carbon and how does it differ to a wet lay up?
The carbon fibres come supplied with the correct amount of resin pre-impregnated. This fabric with resin has to be stored in a freezer until ready to use. It is cured at an elevated temperature usually above 80 C up to about 180 C and does not require resin mixing prior to use. The advantages are many, especially with handling and quality. The fabric is cut to shape and placed in the mould and then consolidated and cured. Wet layup is where dry fabric is placed in the mould and resin mixed and then added to wet out the layers. Apart from being messy to work with, it can be difficult to get the correct fibre to resin ratio and quality usually suffers.
No serious structural bike parts are made using the wet layup method.

What is vacuum forming?
The part is layed up in the mould then sealed with a membrane, usually a plastic bag. A vacuum is pulled to evacuate this bag providing about 100kPa of pressure on the part. This provides compaction and helps to remove excess resin and air bubbles in the part. High quality autoclave or bladder moulding can provide about 800kPa of pressure, this makes a much better part.

What is nanotechnology? How does it relate to carbon fibre?
Lately some companies have talked about Carbon Nano Tubes in the resin blend. Carbon nano tubes are currently the strongest and stiffest material known to man. These are very small carbon tubes about 1/50000th the diameter of a hair that can be added to the resin to reinforce it and hence improve its properties. Some of the data on this looks good in terms of improving toughness and strength. Carbon nano tubes are very expensive, however only small amounts are required. There may be some health issues

with these particles in that they are so small they can get into the body through the skin. This could be a concern when sanding a part made with this technology.

Is there an optimum ratio of carbon to resin, or is it simply the less resin, the better?
The optimum resin content is dependant on the manufacturing process. Typically a fibre volume to resin ratio of between 60% to 70% fibre with the balance of resin is found. Higher compaction pressures require less resin to fill the voids between fibres. Too much resin adds mass and can reduce some mechanical properties. Too little resin allows air to fill the gaps which significantly reduces the composite's mechanical properties.

If you scratch a carbon fibre frame or component does this create a weak point where it will break?
If the scratch is in the paint or clear lacquer this is ok. If fibres are damaged or broken they cannot transfer load, hence the structural properties are compromised. In reality there is usually a factor of safety in the part, but it is best to get it looked at by an experienced technician.

Is carbon easier to damage with clamps such as stems and seat post clamps?
It depends on the design, a light seat post is very susceptible to crushing because the fibre placement has been optimised for bending. It would require more fibre to resist these loads which would add weight. I recommend using a carbon assembly compound for carbon parts such as posts, bars and stems and to follow the manufacturers torque settings.

When carbon breaks does it snap catastrophically or does it just slowly bend or crumple?
This depends on the design, the individual ply angles and layup sequence. If a part is designed as such there can be cracking and delamination prior to failure. Aircraft and F1 race cars do not fail catastrophically. The resin contributes very little to this.

Is the diagonal weave really just decoration or does it add strength?
This layer adds damage protection to the part since the fibres are mechanically interlocked as well as bonded. This requires more energy to create damage than a unidirectional exterior. Woven fabric is marginally heavier in a laminate but does add some toughness. The coloured layers however are mainly cosmetic.

Why do carbon rims need different brake pads?
This is because higher friction on the braking surface with pads designed for aluminium rims can create excessive temperature on the resin. A lower friction material or one with better heat transfer is required. Unlike aluminium rims carbon epoxy composite is a poor conductor of heat. It is not to be confused with the carbon/carbon brakes used on aircraft and F1 cars.

What's the difference between carbon and kevlar?
Kevlar is an aramid synthetic fibre, it has high tensile strength but a lower modulus than carbon and low compressive strength. It is of no real use structurally in a carbon frame. However it is very tough and thus good for wear pads and soft goods.

What are the key differences between a low quality carbon frame and a high quality one?
Apart from cost, the difference is the level of engineering. This means the amount of design work, testing, process control, quality checks etc. A high quality frame will be light, ride well and last a long time. It can be very difficult for the consumer to tell the difference between levels of quality. Generally the higher profile companies have a reputation that they want to uphold.

How do they join lugged carbon frames? What sort of glue do they use?
Lugged frames are usually assembled using an epoxy paste adhesive. This is similar to the resin but has additives to improve toughness and reduce flow so it stays in the joint whilst curing.

Which form of construction is best?
History has shown that although one piece 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 moulds being required is a major drawback, this has limited it's success to a point.
Therefore most of the carbon bikes these days are secondary bonded. Parts are made and cured separately and then the individual parts are assembled with adhesive to create the full frame. Alternatively more carbon is wrapped around the joint to create a lug. It is much easier to control the manufacturing process of a single tube or component than a complete bike. This provides a higher level of quality control when compared with one piece frames. In my experience a bonded/assembled bikes can be better than a monocoque in a mass produced bike.

How much lighter will carbon bikes get?
At trade shows there are some sub 4kg bikes. However the production designs are based on UCI rules. What is happening is that bikes at the UCI 6.8 kg limit bikes are much stiffer, stronger and durable than in the past.

Will carbon that is designed to continually flex during use, such as carbon fork blades and saddles, break through fatigue after a certain number of cycles?
Carbon composite has a high fatigue life, that is one of its advantages. Frames and components that are well designed can have a very long life. Manufacturers test parts on machines until they fail, artificially replicating years of heavy use. Quality control is an issue, hence it pays to buy products from a reputable manufacturer.