Carbon cycle

Black, shiny, expensive, lightweight, strong, fragile? Not everything you hear about carbon fibre is true. Mike Burrows presents a beginner's guide

Photos: Cycling Images

Plastic has an image problem. Whereas metal is seen as 'strong', wood as 'natural' and even stone as 'permanent', plastic is seen as a poor substitute. And not without justification, for many early plastics were just that – PVC tablecloths, cheap polystyrene toys, etc.

But plastics have a lot more to offer. There are specialised bearing grades that cost more per gramme than silver, medical grades of polyetheline that allow replacement hips to work almost as well as the real thing, and of course the plastic that were are interested in: carbon fibre. In its more exotic grades carbon fibre is the strongest structural material in the world. I am not sure it is even fair to call it a plastic, as it is in the fact the charred remains of plastic, although the epoxy resin used to bind it together definitely is.

So plastic should not be thought of as 'bad' so much as 'variable'. Usage ranges from Asda's plastic bags to the Airbus.

MAT BLACK

You should now be in a positive frame of mind, so I can get down to the details of our shiny black composite and how it's used in the cycle industry. Composites are, as the name suggests, a mix of two or more materials, usually a fibre and a binder (glue!). The fibres come in three popular flavours: glass, which is cheap, not very strong and heavyish; aramid (Kevlar™), which is expensive, very tough (bullet-proof) and light; and carbon, which can be very or very, very strong, very, very stiff, light, black, and beautiful. These fibres come in a variety of forms from chopped-strand mat, woven cloth, woven pre-forms (like socks!), or unidirectional (UD) sheets, and as they come they would be more use as curtains than cycles.

It is a different matter when you stick the fibres together with a resin. This can be polyester, which is cheap and cheerful and is usually used with glass to make boat hulls, baths, etc. Better for high-tech applications is epoxy, which is not so much stronger in itself but better at bonding the individual fibres together so you don't need to use as much of it. As little resin as possible is best. Ideally you want 65% fibres and 35% resin.

Not only do you have a choice of fibres, grades of fibres, weaves, resins, grades of resins, etc. but an equally large range of processes to choose from. Most popular of the high tech processes involves 'pre-preg'. That is, sheets of fibre with a controlled amount of resin already applied – a sort of cloth sticky tape. This resin is heat sensitive and so the cloth is kept in a freezer cabinet until needed. It is heated after it is placed in the mould, typically to 150°C. It is not simply *put* in the mould. Most composite structures require many layers. A typical cycle tube could be 15 or more, usually UD laid criss-cross, a bit like making plywood. Once laid in the mould it is then put in a plastic bag and all the air sucked out, which means you have 15psi or so of air pressure pressing down over the whole surface, compacting the various layers and minimising gaps and dry spots.

At the other end of the technical spectrum is 'bucket and brush', which uses dry glass, usually chopped-strand mat, with polyester resin being 'painted on' as the glass is put in the mould. This will result in a 35% fibre/65% resin mix, which is fine for boats etc. And if like me you like rolling your own, as it were, you can make workable prototypes this way using carbon/epoxy (instead of glass/polyester) but without the vacuum bags.

READY, STEADY, COOK

Even the vacuum bag is not enough for some. A mere 15psi is the equivalent of knocking something up on the kitchen table if you are in F1 or aerospace. For in that esoteric world there is the autoclave. This is a sort of pressure cooker, but one

that may be big enough to put your house in! It is pressurised up to 500psi, at 200°C, which would cook the spuds very quickly!

Not many bicycle frames get put into autoclaves but they can have similar pressures in a rather easier way. The pre-preg fibres are rolled and laid up in the form of the frame around a frame-shaped plastic bag. The whole lot is then placed into a steel mould and 150psi or so of pressure applied inside the frame. This pushes everything into place rather nicely.

This is a very good system for making cycle frames but it does require a large, expensive mould for every size of frame, which means that you need to sell lots of bikes to make it pay. So racers who buy lots of shiny new toys get them, while tourists who are sensible and conservative tend not to. You can still get a very strong and light frame using the original method for composite frames – using aluminium lugs and individual composite tubes bonded together. Both Trek and Giant made a lot of very nice bikes this way in the '90s. Lots of them should sill be out there: when the Giant frames were put through the Japanese Industry Standard fatigue test they reached four times the requirement (two million cycles – pun not intended) before they were taken off intact.

So composites really are quite wonderful. They're stronger for their weight than any other material, stiffer in the more esoteric grades, and they have a fatigue life better than any metal. Should we be making everything from carbon fibre? Well, no. There are one or two shortcomings of composites, in particular carbon. Best known is carbon's lack of toughness. There are no bent carbon frames, just broken (or unbroken) ones.

Carbon suffers from 'catastrophic failure'. This usually only occurs during catastrophes, i.e. if you hit it very hard and sharply. This is of course relevant to the size of the object, in the same way that light bulbs break very easily and milk bottles less so. A carbon spoke is very small and under tension and could easily be shattered by a blow that would barely dent the paint on a carbon down tube. So the new Mavic wheels are very nice – but keep them away from other people's pedals. Similarly, carbon handlebars are very good for racers with a following car, as they could easily be the first bit to hit the deck in a pile up. Ally ones will bend but you can still ride with bent bars – not so two-piece bars.

AGAINST THE GRAIN

More difficult to understand are the design limitations caused by the 'anisotropic' nature of most composites. They are a bit like wood, with a strength that follows the grain/fibre and much *less* strength across the grain/fibre. Metals, on the other hand, are isotropic, having very similar strength in all directions. To appreciate just how good carbon can be you have to pick up a fisherman's 'roach pole', where virtually all the fibre runs in the same direction and no allowance has to be made for crashes. For the opposite, you need to look at a complex object like a chainset, where there is a complex set of forces and a complex shape, and it is hard to see how you would get the fibres in just the right place.

Shimano themselves have been saying this for some time. They have been making their metal cranks rather elegantly as a one-piece hollow forging (a story in itself). But they are due to launch a carbon one this autumn. Ho hum. Even Shimano can't beat fashion – even when it's a bad idea.

There are lots of good composites around in the cycling world. As always, you just have to avoid any fibres of a woollen nature being pulled over your eyes…