Damage Control

Ask any armchair expert and they'll probably tell you that carbon fibre bikes are fragile, disposable and certainly not repairable. In reality this is far from the case.

Raoul shows off two of his home made toys; a monocoque MTB from the early 90s and a superlight 600g road frame (and that's a 58cm with integrated seat post too!).

If you've ever flown in a modern commercial airliner, then you have entrusted your life to a repaired carbon fibre part. Just about every plane in the sky has been repaired and many of the carbon fibre aircraft components are patched up before they even leave the factory. Why so you ask? Well unlike the bicycle industry, aircraft parts go through a strict series of 'non-destructive inspections' using ultrasound and other approved methods.

These tests expose any manufacturing defect; folds in the fibre or compaction issues such as porosity in the laminate or air pockets in the resin. Sure, the bike industry has its own set of quality control tests, but these usually entail a check of frame alignment, confirmation of the weight to see if it's within a predetermined range and a visual inspection for obvious faults. As a result, some pretty serious structural flaws can slip through to the end user.

While this may sound risky, most bikes are designed with a fair buffer for manufacturing defects. In other words; they are built with extra material to ensure that in the majority of cases these faults will never surface as a structural failure—and when they do, they are covered by the warranty department. Obviously that approach wouldn't cut it in the aviation business but most bike riders don't have the budget that Boeing has! If every bike was manufactured to aviation industry QC standards, our carbon machines would be lighter again, as any excess material could be removed, but they would also be many times more expensive.

So what happens to the new yet faulty aircraft parts? There's a lot of money tied up in the carbon fibre tail of a Boeing 787, so rather than grinding the entire structure up into carbon dust, the imperfection is repaired. Trained technicians assess any issue and fix it using industry-approved practices; a repaired carbon part winds up with the same strength and structural qualities as a fault-free example. The key point here is that it needs to be fixed properly, and the aviation industry has a strict set of standards that any repair must meet—planes falling from the sky due to dodgy repairs wouldn't be good for their public image!

Much of this translates across to the blingy new carbon fibre bike that you've been ogling. Carbon fibre bikes and parts can be repaired; in fact the material is more repairable than most metal counterparts, which can suffer from heat related issues once a welded repair is done. The main limiting factor with carbon repairs will be the cost. While a competent carbon technician can repair just about any damage, even to the point of remanu-

facturing shattered frame tubes, there comes a point where the expense makes it no longer viable. Why bother repairing a damaged carbon handlebar for $200 when you can buy a new one for the same amount?

The biggest hurdle in getting a carbon bike repaired used to be finding someone willing to attempt the job. With the recent mainstream growth of composites in cycling, a number of carbon bike repair businesses have emerged, many evolving from other fields where composite materials are used.

Options are certainly a good thing but how do you pick a truly professional carbon repair business from a potentially dodgy one? Well a little research in the following areas should point you in the right general direction.

- Patching up carbon fibre dashboards on suped-up Hyundai's is one thing, but the frame on your bike is a structural member and a whole different scenario. Knowledge of composites in structural applications is vital, if they've worked with bikes before then, even better. Familiarity with bikes means the repairer should be aware of the loads that the repair needs to handle as well as having background knowledge on the type of carbon and manufacturing techniques used to build the bike in the first place.

- Ask about their track record. In my research I found repairers with up to 25 years experience in fixing carbon bikes. Stan Sokolowski from Bike Addiction in Manly (Sydney, NSW) started repairing the old Centurion and Vitus carbon road frames back in the 80s and has been doing it ever since. It's now a full-time job for him and he has averaged five or six frames a week for the past two years. That's over 250 frames a year and he hasn't had a single repair come back due to failure. Likewise, Glen Oldfield from Carbon Cycle Repairs in West Australia (www.carboncyclerepairs.com.au) has done 300 repairs in the past three years with no issues. Glen has been working in the composites industry for over 20 years in fields ranging from Formula 1 cars (McLaren and Jordan) to aerospace with the Beagle 2 Mars planetary lander.

- Don't just believe the repairer, seek out customer references. These can be from other riders who have had work done, or from bike shops and importers of carbon bikes—who do they entrust for their carbon repairs?

- Find out who the insurance companies use. In the same way as your insurance company will recommend a panel beater to fix your car, specialist bike insurers may look into frame repair rather than outright replacement for damaged carbon bikes. To maintain their good customer relations, the insurer would only select a repairer that they trust entirely. Find out who the bike insurers use and you'll be on the right track.

- Warranty and insurance. Ask whether the repairer offers a guarantee on their work—Stan from Bike Addiction offers a five-year warranty on his repairs. Reputable repairers will have liability cover. Glen Oldfield pays thousands of dollars a year for liability cover, just in case a repaired bike goes wrong. Shonky backyard repairers won't have liability insurance.

Acoustic testing can detect internal delamination, but only where the damage affects a reasonably large area. By comparison, ultrasound can reveal the tiniest discrepancy.

This road frame had obvious top tube damage from a handlebar impact. In this case, Raoul found delamination way back at the seat tube junction—it's unlikely that this would have been detected without ultrasound.

Test Case

After damaging the top tube on my four-year-old Scott Spark, I went through the process of looking for a suitable repairer. My research led me to Raoul Luescher of Luescher Teknik (www.luescherteknik.com.au and www.carbonbikerepair.com.au). A cyclist himself, Raoul has been dealing with composites for 20 years, working for Boeing Aerospace, the Defence Force and the Australian Institute of Sport. Major bike brands also consult with Raoul on frame design and manufacturing process.

In his spare time he has employed his knowledge of composites to build his own toys; home-made carbon monocoque MTBs in the early 90s and more recently he's thrown together a superlight road frame that comes in at around 600g—just for fun of course! He's dabbled in everything from making carbon-soled road shoes to carbon seatpost clamps.

Knowledge gained from years of working in the aerospace field, combined with a passion for cycling has placed Raoul in a unique position, so recently he took the plunge and went into business for himself, repairing, designing and consulting on composites in cycling.

One of the key points that swayed me to use Raoul for my repair was his ability to thoroughly inspect carbon using ultrasound, X-ray and various other fairly advanced testing methods. Most carbon repairers will assess damage acoustically (tapping on the frame) and visually. While acoustic testing has its place, ultrasound examination provides a far more precise picture of what's going on inside the frame.

Why don't other repairers use ultrasound? To start with the equipment is very expensive—upwards of $10,000 for a portable device and around $1,500 for each probe. Beyond that, it takes many years of specific training – usually in the aerospace field – to accurately assess the readouts. Australia-wide approximately 60 people are qualified to pass an aircraft component as being safe to fly; Raoul has held certifications and approvals in both commercial and military aerospace for this duty. Overkill for your pushbike? Perhaps, but the knowledge that your repair is being handled by a consummate professional and inspected to aerospace standards will certainly give peace of mind the next time you hit the trail. And if the technology is available, why not use it to have your repair inspected?

You may wonder why such a highly qualified individual is working for himself fixing broken carbon bikes when he could be on $100,000 plus at Boeing. I asked and it basically comes down to a lifestyle choice. After 20 years in aerospace he was bored, and Raoul likes working on bikes; every repair presents its own engineering challenge, he's working to help like-minded people with his passion now serving as his day job.

Carbon already dominates the high-end road market and is rapidly gaining numbers in all aspects of mountain biking. Despite this, many remain sceptical of carbon or simply don't know that it can be fixed. So rather than keeping the process under wraps, Raoul was happy to explain the repair steps and to offer a real insight into what's involved. Demystifying the material can only help, as carbon becomes more and more commonplace in the dirt.

I damaged the frame when I crashed and the gear shifter pod slammed into the top tube. Normally I'd have the brake/shift lever tight enough to stay put but loose enough that they'll move in a crash before damaging the frame or breaking themselves. For whatever reason I'd done my levers up too tight and the head of a bolt on the shifter gouged the top tube. Over four years of general trail riding, my frame had copped plenty of general wear and tear, rock bashes on the down tube, chain suck and so on. In this case, the depth of the gouge concerned me, as I know the Spark is such a lightweight frame; at 1,830g including the shock there can't be much wall thickness to the frame tubes. To start with I e-mailed a sharp close-up photo to Raoul and he suggested that it warranted inspection.

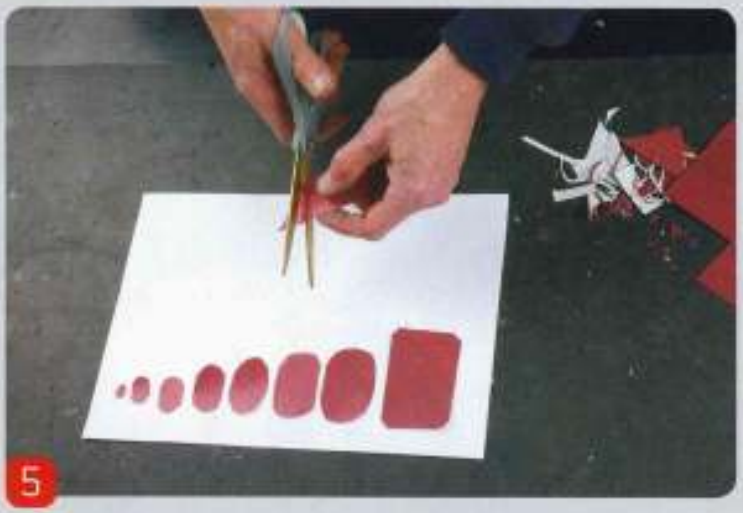
While the inspection technique varies depending on the part, ultrasound is probably the most common method used. Ultrasound lets Raoul gauge the wall thickness and assess the integrity of the carbon. Internal delamination, porosity, air bubbles and bonding issues will all show up as an 'indication' on the readout—if you know what you are looking at. Indications as small as 3mm or a single ply of damage in the layup can be detected—it is extremely sensitive.

In addition to checking the area immediately surrounding the damage, Raoul will often go right over the frame—especially where a frame has been subjected to a really heavy impact. Internal delamination can sometimes appear in areas distant from the main impact point.

The ultrasound revealed that the top tube on the Spark averages just 1.0 to 0.9mm thick and the gouge had gone through four plies of carbon. Each ply is approximately 0.1 to 0.13mm thick, so the damage had compromised close to 0.5mm of the carbon—that's around half the wall thickness on the Spark and definitely something to worry about. Raoul also checked right over the frame, looking for any other damage. He didn't find structural issues in other areas, so the frame was well worth repairing.

Once the problem has been assessed, the damaged area is taped off and sanded back by hand. The frame needs to be taken back to solid base material with a long, gradual taper out to the edge. What was a 2mm wide gouge now expands out to an 80mm wide depression. This forms the base for a 'scarf taper joint' and the strength of the bond between the repair and the original material relies on the taper providing lots of surface area. Various engineering calculations apply to ensure that the strength offered by the bond exceeds the strength of the patch. This step is done on a vacuum extraction table—it's got holes in the bench top with a fan underneath to suck away the carbon dust. In addition to keeping the job clean, it reduces the chance of breathing in potentially harmful carbon fibre dust.

After a wipe over with a solvent to remove any residue, you get a much clearer picture of the frame construction. It's now easy to see all the different layers or plies of carbon that make up the frame tube. Raoul now gets in close with a magnifying glass and notes the number of plies, as well as the orientation of the fibres in each ply. Unidirectional carbon forms the structural heart on most carbon bikes and the direction that the fibres travel in determines the performance characteristics of each part of the frame. Diagonal placement of the fibres provides more torsional stiffness while linear placement limits longitudinal stretch. Taking note of the fibre orientation means the patch can be matched to produce the same performance characteristics as the original frame material. In addition to retaining the same ride quality, matching the strength and stiffness ensures the patch doesn't place undue stress on the surrounding material.



Raoul uses unidirectional prepreg carbon for the bulk of his repairs. Most carbon frames are made from this material, so once again the repair material should closely match the original frame construction. Prepreg comes in flexible sheets of carbon cloth which has already been infused with the appropriate amount of resin. This fabric needs to be kept in the freezer to prevent it from curing (going hard) whilst in storage. With tens of thousands of dollars tied up in a stockpile of prepreg rolls, Raoul runs two freezers in different locations as well as a back-up generator in case the power goes out.

Following his notes on the orientation of the fibres at each spot within the tube, he cuts out patches to match the shape of the indent. The scarf taper has exposed eight plies of carbon at the deepest point, so eight patches are cut starting with the smallest one at the bottom of the hole. This part of the process looks more like patchwork quilting than advanced composite repair.

The backing material is removed from each unidirectional patch and they are carefully positioned on the frame. There's no glue involved as the resin that's held within the prepreg is tacky and holds each patch to the frame. With all eight patches in place, a little heat is applied with a hot air gun to soften the material and help it mould to the frame.

The carbon patch needs to be under compression when it cures to adhere properly to the original frame material. There are various ways of achieving this and the vacuum bag illustrated here is one of the most popular methods. An airtight bag was formed around the top tube using double sided tape and a sheet of heat resistant plastic. The patch itself is padded to ensure that the pressure is applied evenly over the repair. A vacuum tube is inserted to suck all the air out.

Next Raoul pops the frame into the oven. His special oven even has its own vacuum fitting on the inside because the vacuum bag needs to maintain compression on the repair. Once heated to over 100-degrees the resin in the prepreg turns to liquid. Under compression, it moulds completely to the existing frame material, with any excess resin pushed out the sides. Once cured, it's the carbon fibre that provides the real strength; the resin is only there to hold the fibres in place. Excess resin or air pockets within the resin will compromise the structure and maintaining good even compression during the curing process ensures there are no anomalies. The frame is left to bake overnight.

Some repairers rely on general-purpose resins that cure at lower temperatures (often found in boat building or general industrial use). Raoul chooses to use aerospace-approved repair resins with a high glass transition temperature (Tg), as they maintain their structural qualities when hot—like when your bike has been sitting in the back of the car in summer.

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After three hours in the oven, the frame is allowed to cool and is removed. Once the bladder is removed, the patch is sanded back on the vacuum bench to tidy it up. In this case the resin has run around the edges and bled a little beyond the repaired area—a pretty normal occurrence as the resin has a viscosity similar to water when it is in the oven. With the excess resin removed, a light going-over with wet-and-dry helps to polish it back and provide a seamless finish with the rest of the frame. The finished wall thickness is now comparable to the original structure with close to identical mechanical properties—in effect it is as good as new.

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To provide a complete service, Raoul also paints and finishes his repairs, and does so with durable automotive two-pack paint. In this case the resin had run over the red pin stripes, so they were masked off and touched up too. Another spell in the oven to bake the finish and the frame is ready to roll.

With such a rare blend of qualifications and bike know-how, Raoul has found a high demand for his services; both in consulting to bike manufacturers and repairing bikes for riders and insurance companies. If it came to it, painting is one aspect that Raoul would consider outsourcing, allowing him to focus more completely on the important part of his job; the structural carbon repairs.

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Usually done before the painting, Raoul will inspect the finished repair with ultrasound. This will reveal if there were any vacuum/compaction issues when it was in the oven or if any plies in the patch shifted inside the bag. Carbon fibre is extremely strong, but only when the fibres themselves are laid out in a straight and consistent manner. The final inspection ensures there are no kinked or folded plies within the repair. While you can see the repair patch through the clear coat, it is smooth to touch. The repair doesn't look that different to the rest of the finish, which like most unidirectional carbon bikes, is a patchwork of different plies anyway. Frames that have a more consistent woven finish can also be matched with the same 3K, 6K or 12K carbon used on the visible outer layer.

COST & WARRANTY

Raoul offers a five-year warranty on his repairs—in most cases that will be better than the original manufacturer's guarantee. While it obviously varies depending on the complexity of the work, a repair such as mine will set you back a few hundred dollars. It's more than reasonable when you consider the cost of a replacement frame and professionalism of the repair and his equipment.

Raoul also conducts frame inspections for customers who have heavily crashed their bikes but can't see any obvious damage. Likewise, some people request this service for peace of mind when buying or selling a second-hand bike. Non-destructive frame inspection using ultrasound will set you back around $210.


NON-DESTRUCTIVE TESTING AUTHORITY