THE ROUGH TUNING

CARBON FIBRE

One of the hottest materials on the market, not only can carbon fibre enhance your car's looks, it can also improve its performance. Words: Roy Carvalho Photos: CA Automotive and various

By now most of us are familiar with the composite material carbon fibre (often shortened to CF or carbon), with its unique woven patterns and amazing strength-to-weight ratio, offering the aftermarket car scene a great new flexible medium for engineering, performance and styling applications.

The use of carbon fibre dates back as far as the 1800s when Thomas Edison used it as a filament in early light bulbs. It wasn't until the late 1950s, though, that high tensile strength carbon fibre was discovered. Then, in the 1960s and 1970s, a more reliable manufacturing process for the production of carbon strands and composites was developed, finally enabling a limited but reliable production rate for commercial supply. Making high quality structures from carbon fibre, however, requires great skill and expensive tooling, adding to the costs and difficulty in successfully mass producing such products.

It will come as no surprise then that it was the Rolls Royce aircraft division who quickly embraced this new technology during the '70s to produce casings and compressor blades for its new RB-211 aero-engine. Although this particular use had limited success (due to the impact weakness of early carbon composites, the compressor blades would break too readily on impact with birds and large flying debris), it was not long before the rest of the aircraft, space flight, military and motorsport industries caught on to the amazing potential of carbon composites, and began employing them to build items as diverse as aerofoils to complete fuselages and chassis.

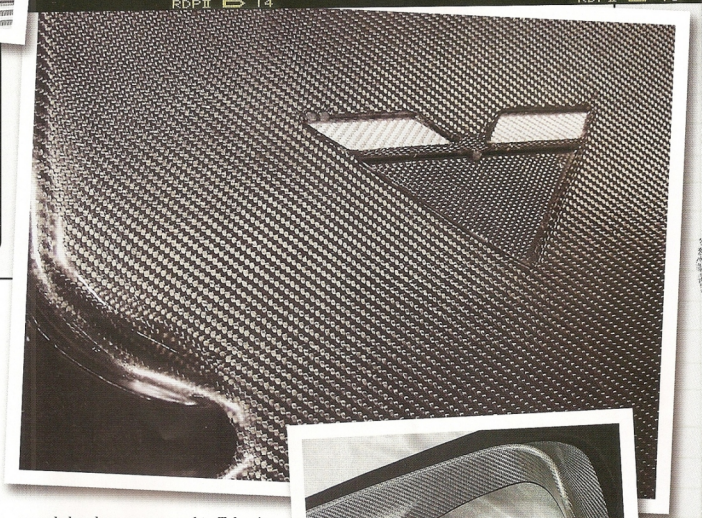
As usually happens, this high-end technology gradually filtered down into more everyday uses and carbon composites were being put to good use in such diverse areas of manufacturing as civil engineering, sports goods, decorative trims, wheels and so on. And from the late 1990s demand for such products increased enormously to the point where in the mid 2000s there was a global shortage of high-grade carbon fibre composite raw materials due to increased demand from

THE SCIENCE BIT

Carbon fibre consists of extremely thin fibres (about 0.005–0.010mm in diameter) composed mostly of carbon atoms, aligned in crystals in such a way as to make it extremely strong for its size and weight. These fibres are twisted together and woven into a fabric, which is then impregnated with a plastic (often epoxy) resin to form what is commonly referred to as raw prepreg carbon fibre composite sheets, blocks, rods, etc. The fact the resin is pressure impregnated into and around the carbon weaves leads to increased product strength once the item is fully cured. These

GUIDE

the likes of Boeing and NASA, which put the price of raw carbon material up even further. Discerning modifiers now wanted their stuff to be made in carbon, or at least made to look like it was, but at a more affordable price, leading to a whole new global parallel industry of specialist (and not so specialist) carbon fibre lamination over non carbon core parts. More on this subject later...



sheets are made in various thicknesses, which can then be laid up and bonded in flat sections or moulded as required in three-dimensional structures, curing usually being done in a high-pressure oven called an autoclave.

In terms of strength-to-weight ratio, carbon fibre composite is currently the best material that our civilisation can produce in appreciable quantities, possessing a higher tensile strength than steel at a fraction of its weight. Such items are particularly high in tensile strength (i.e under compression, stretching and bending) but comparatively weak on direct shock (i.e impact resistance). For example, a carbon composite rod can withstand great bending forces and stress loads, but hit it hard with a hammer and it will likely crack, break or shatter, in the latter case also often fragmenting into fine dust. Interestingly this apparent disadvantage of fragmentation is often turned on its head with respect to human safety in head-on crashes, where the direction of the impact is more or less parallel to the carbon weave as opposed to perpendicular to it. In other words the difference between hitting the front or rear end of a car made from carbon panels head on, as opposed to T-boning it (side-impact); if the right type of composite is used to make the chassis and/or panels, then the process of the carbon sacrificing itself in stages to the impact greatly absorbs and reduces the kinetic energy passed on into the driver area, offering greater levels of safety at less weight when compared to other usual composites like glass- or fibre-reinforced plastic, Kevlar and so on.

WEAVES

Carbon fibre can be woven into many different weave patterns so as to provide strength in one particular direction or plane, as required, or in all directions equally.

Common terms to describe the pattern of these weaves include: 1x1 Twill (also known as narrow diagonal) and 2x2 Plain (wide linen, or square) – where the numbers denote the tightness of the weaving (2x2 is a two over two under weave, 4x4 a four over four under weave). Twill, Plain and Linen denote the apparent visual orientation of the pattern. Other terms like Tow size and density are used to complete the description of a particular carbon matting.

CARBON PRODUCTS IN MOTORSPORT/TUNING

Great reductions in weight can be made to a vehicle with little or no loss of practicality and functionality by replacing metal panels and structural items such as arches, bootlids, roofs, suspension, brake and drivetrain components with carbon fibre composite materials, thereby greatly improving performance and handling. As a rough rule of thumb, on an average 2.0-litre coupé, shaving 5kg off its weight gives the same performance gain as increasing engine output by 1.5bhp. As the late, great Colin Chapman said: "for speed, add lightness".

Carbon fibre composites are also used for their visual appeal in race or street applications for interior/exterior mouldings and trims and so on. Construction methods for such items normally fall into the following four main categories:

100% PREPREG CARBON FIBRE

As the name suggests, these products are made entirely from resin pre-impregnated carbon fibre, in flat sheets or 3D pressure moulded formats, and represent the pinnacle of carbon fibre composite construction in terms of expense, engineering and skill of manufacture. The pre-impregnated raw material is normally supplied in rolls of different thicknesses, widths and lengths. A multitude of items from whole body panels to suspension arms are made in 100% prepreg.

During the aforementioned global shortage of carbon fibre raw materials, the industry-standardised widths of prepreg carbon rolls and larger surfaced area panels (for example, bonnets) could not always be made from just one continuous sheet of carbon, necessitating seams where the carbon sheets abutted each other. The level of skill in terms of visual creativity and manual dexterity with the positioning and joining of these seams determined if the finished product looked great or garish. In some cases seams would successfully be camouflaged by part painting the surface, leaving only unseamed areas of carbon – which look like one piece.

Whilst most of us want a nice even continuous carbon weave across our street parts, in the race world where aesthetics are not the primary concern, making a non-structural item up (for example a dashboard, inner door lining) in carbon patches and swatches is not unusual, nothing is compromised and the job gets done faster.

100% PREPREG CARBON FIBRE WITH LIGHTWEIGHT CORE

Essentially the same as the above, but employed for double walled or layered items where a solid carbon construction is not required/desirable, for example, some street vehicle panels such as bonnets, bootlids, wings and so forth. In these cases, the centre void of the panel will consist of a honeycomb multi-walled lightweight core (for example Nomex), as this is both lighter and more flexible (therefore less prone to high-impact damage) and less expensive than making a solid carbon pane, also offering better thermal dissipation in most cases.

CARBON FIBRE LAMINATION

Due to the cost of producing full carbon fibre parts and the negligible weight saving over the factory plastic items, aesthetic items such as vehicle interior trims and, exterior-wise, grilles, are very rarely made from 100% carbon composite, but instead by laminating a thin real carbon fibre matting on to the core plastic/wood part. When done properly the item is visually indistinguishable from a full carbon version, and is guaranteed to fit perfectly as there will be no variations in shape due to using a mould of the original part (as cheaper version items do). Two main forms of carbon lamination exist:

WET LAY

Wet lay is the cheapest and worst quality (and unfortunately all too common) type of 'carbon fibre' lamination on the aftermarket scene. This involves carbon fibre matting (usually of dubious quality/carbon percentage and usually not pre-impregnated with resin) being adhered on to the core piece (interior trim pieces, fibreglass core bonnets, dashboard, etc), and wet resin is then applied to it by hand and allowed to cure (usually without an oven or autoclave); a process not dissimilar to the production of some fibreglass products. Unlike the dry laid carbon process detailed further down, wet laying in this way does not allow the resin to fully permeate the carbon strands and coat them evenly to provide the best strength and aesthetics. Typical problems with such wet lay products can include:

- The carbon layer can delaminate easily, especially in hot and/or humid climates
- Often uneven surface finish with poor lustre, can discolour, especially in conditions of heat and engine fumes
- No real additional structural strength is added to the core part
- Possibility of air bubbles developing in the finished item (due to lack of vacuum bagging processes, more on this below) further reducing its quality and visual appeal

Some full carbon constructions can also be made in a similar manner, but again

quality and strength are usually compromised in relation to dry 100% prepreg carbon products. Almost all cheaper carbon products will be of this wet lay type construction. They may appear good value at first, but if you compare them with well-made dry carbon laminated items over a period of time the wet lay item usually ends up looking cheap and nasty.

DRY LAY

Conversely, dry carbon lamination is the term for the best quality lamination process. Normally dry prepreg carbon matting is laid on to the core part or mould, then the whole item is placed into a strong airtight plastic bag with a built-in valve that when connected to a vacuum pump extracts all the air from inside the bag, a process called vacuum bagging. The bagged items are then cured, usually in an oven or autoclave. The vacuum bagging process therefore eliminates all air pockets and bubbles and their damaging effects (due to the rapid expansion during the natural exothermic or oven curing processes) from the finished product, ensuring greater adhesion, strength and smoothness of finish.

If you want the quality of your carbon fibre to match the quality of your BMW then dry carbon is the only option.

SURFACE FINISHES

Whilst good quality carbon composite products, both full carbon and dry laminated, are fine to use in their raw matt finished form, most companies will provide their products finished with several layers of clear coat lacquer in matt, satin or high-gloss finishes. This adds depth and a kind of 3D effect (more prominent on some weave types than others) and also provides extra protection to the item's surface. Interestingly, having such items made in the Far East no longer necessarily means poor quality as was once the stigma; one reason being that this part of the world can use certain types of resins and lacquers that are illegal in European and American manufacture due to their solvent-based toxicity, but provide a superior deep, durable and hard-wearing finish compared to many similar Western-sourced products, resisting discoloration due to strong sunlight, heat and engine bay fumes compared to their counterparts. Some may recall the years of problems AC Schnitzer suffered with such discolouration issues on many of its carbon products from the late '90s onward.

It should be stressed these materials are only toxic in their uncured or fumed form, and present no danger whatsoever once the whole lamination process is cured and completed.

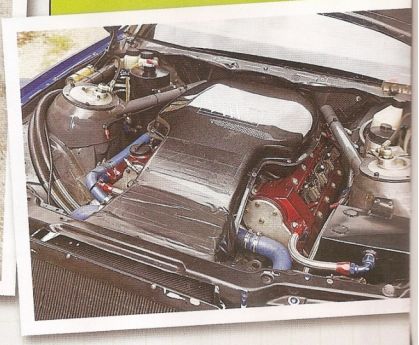
MYTH BUSTERS

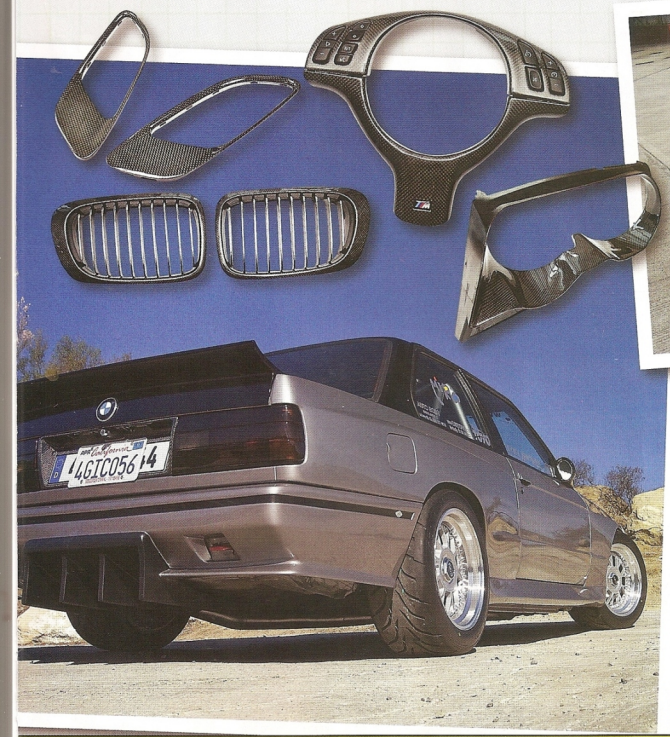
- **Carbon fibre as an insulator:** Carbon fibre is normally electrically conductive, so almost by definition it is thermally conductive, meaning it is not a good insulator of heat or electricity. Whilst carbon undoubtedly gives a great quality visual finish to products such as air intakes, shrouds etc, be wary of claims of increased performance due to any insulation properties. Also be aware that many so called 'carbon fibre' heat shields on air intakes that are in fact fibreglass/plastic cores with a thin layer of carbon composite laminated over the top, further reducing their effectiveness as a heat shield.
- **Coloured carbon fibre:** In its natural form carbon fibre is black. It is near impossible to colour true carbon fibre. Consequently products advertised as silver or red carbon, for example, usually have no carbon fibre content at all, the base fabric being made from other materials such as strands of Kevlar or coloured glass fibre, but definitely not carbon. This is not to detract from the visual appeal nor the intrinsic quality of such products, which definitely have their place in the market.
- **Carbon parts made in the Far East are bad quality:** Not so. As touched on previously, it all depends on the quality of the process and materials being employed. BMW and many other prestige car manufacturers now have many of their carbon interior kits and such like made in the Far East.
- **You can't paint real carbon fibre:** It may take more preparation, priming, flatting etc than some other surfaces, but there is no reason why a good, smooth paint finish cannot be achieved on quality raw carbon.

HOW DO I CHOOSE?

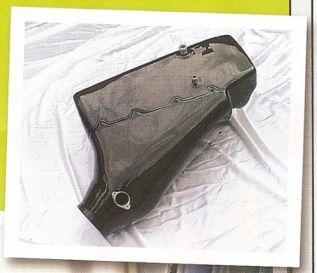
A good quality carbon fibre composite part is, by definition, custom and hand-made, carrying with it a certain premium in price and manufacturing time. Having said that you don't always have to break the bank to get a nice carbon part that will last and perform well, just be sure to follow our tips:

- Choose a supplier who can offer a truly custom service (weave patterns, lacquer finish/colours and so on) as well as good off-the-shelf products, therefore giving you the widest and most individual options possible for your project.





- Be aware that the majority of good carbon parts are made to order, so you have to allow say two to four weeks to account for obtaining core parts, delivery times and the actual manufacture process.
- Try to physically look and touch the carbon product you want and compare it to other suppliers' offerings if you can, as photos can be misleading.
- There are some manufacturers who supply good quality items where the carbon is laminated on to a moulded FRP or GRP core; if you can though, choose a supplier/product using original BMW part(s) as the actual core of the finished product because this will normally be a more substantial and better fitting option (notable exception to this being USA-based Autotecknic's carbon range, whose FRP moulded parts are first class). However items such as grilles mainly come with a plastic replica core, and these have proved to be of perfectly good quality.
- Take your time choosing. Chances are you will be looking at that carbon part for a long time to come. If you have not yet seen quite what you want in terms of finish or the actual part to be carbon'd then ask the supplier if they can make it for you.



TRUSTED SOURCES

Vorsteiner
Carbon fibre and woven plastic body panels and spoilers, expensive but currently best quality and fit on the BMW market

Carbonio
Effective carbon fibre and laminated intakes and quality minor trims

GruppeM
Arguably the most prestigious intake systems on the BMW scene, made from very good quality wet laminated carbon and/or Kevlar

BMW Performance
Very well-priced dry laminated carbon items, many with added coloured Kevlar strands in the weave

Wald International
Body kits, again expensive, but excellent quality

CONTACTS

Ind-Distribution
001 847 963 4520
www.ind-distribution.com
(USA, suppliers for Vorsteiner and other quality carbon parts)

Autotecknic
001 626 275-4155
www.autotecknic.com
(USA, supplier of extremely good quality dry laminated carbon parts on to high-quality FRP moulds)

CA Automotive & AL Tuning
0871 231 1010 / 0870 961 9997
www.ca-automotive.co.uk
www.a-ltuning.com
(UK and International, exclusive high-quality custom carbon manufacture and lamination of all types, as well as UK agents for all the above mentioned brands)