UNDERSTANDING CARBON FIBER REPAIRS

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Carbon fiber material for car design is becoming more and more popular with OEMs because of its superior strength and light weight. Everything in life is a trade-off and although Carbon Fiber Reinforced Polymer (CFRP), or carbon-fiber laminates, is costlier than steel, aluminum or traditional composite materials, carbon laminate is the next-generation material for making cars lighter, more fuel efficient and safer. Carbon laminate is extremely strong and stiff because of its woven layers of nearly pure carbon fibers bonded together by a hardened plastic, such as epoxy resin. CFRP is a combination of thin carbon filaments bonded together with a plastic polymer resin to form a composite material. Because the fibers are entirely carbon, their density is only about 1.6 grams per cubic centimeter (g/cc), comparable to the density of table sugar, resulting in carbon laminates with densities of around 1.3 to 1.5 g/cc.

However, the carbon laminate manufacturing process is complex and requires either manual labor or expensive robotic machines, both of which result in high costs for the finished part. And, the most commonly used polymer (epoxy resin) requires 24 to 50 hours to solidify after it's infused into the carbon fiber, further increasing costs. In contrast, the density of steel is about 7.8 g/cc. Carbon fibers are slightly stiffer than steel, but have one fifth the weight. Carbon laminate density is so low, it even beats the lightest structural metal, magnesium, which has a density of 1.8 g/cc.

PHOTO: ALFA ROMEO

ALFA Romeo Spider 4C body-in-white

Visually, CFRP has a woven or weaved design look that is exposed; you have probably seen it many times on vehicle components, such as roof panels, fenders and hoods. Most likely what you saw was wraps of "carbon fiber look" material on a fiberglass or composite panel on inexpensive vehicles. CFRP components are very expensive and very light weight. Generally, you will see CFRP components on high-end luxury vehicles, high-end muscle cars and sports cars and super cars. Now keep in mind some OEMs will refinish CFRP components used for exterior and/or interior components. Manufacturing vehicles like the McLaren 570S or SLR with an entirely composite structure is a massive undertaking. In 1981 the world was introduced to the first Formula 1 carbon-laminate car. As the years passed, the technology transitioned to only a select few low-production high-end models. Despite intense research and development efforts over the past 35 years, we are just starting to see carbon fiber laminate in vehicles under $50,000. Some of the most complex challenges are producing carbon laminates in complex shapes, ensuring uniform penetration of the epoxy throughout the parts, taking into account the differing strength properties when the material is struck from different angles (strength is better in the direction of the fibers) and ensuring quality control. Overcoming these challenges is expensive, so carbon-laminate composites are only used extensively in models that are entirely performance-oriented, including the Alfa Romeo 4C, the new Ford GT

and the hybrid Porsche 918. But BMW changed all that in 2013 when they introduced the i3 and i8 CFRP electric vehicles. Then BMW redesigned the 2016 7 Series, from the F01/02 to the new G12 platform, which features what they call a "carbon core" that blends carbon fiber, aluminum and high-strength steel components together. Carbon fiber is the key part to providing additional rigidity to the unibody structure. The systematic placement of the CFRP compliments the aluminum components and in other areas is actually a standalone structural member. On the BMW 7 Series, CFRP is found in key areas for added strength, the B- and C-Pillar reinforcements, roof bows, the upper sides of the center tunnel, the package tray, rocker panel reinforcement, upper quarter panel brace and the upper outer roof rail reinforcement (A-Pillar/Windshield Post to Quarter Panel Sail Panel). Aluminum extrusions and castings are utilized for critical suspension and engine mounting points and aluminum stampings make up the exterior body sheet metal. Steel stampings make up the remaining structure of the vehicle.

The more complicated production techniques and molding requirements for manufacturing carbon fiber parts keep the costs high, but as more and more OEMs choose to use CFRP components, there should be some advances in manufacturing technology, which will hopefully bring down the costs of using carbon fiber. As the price for manufacturing goes down, we will see the material usage gain wider acceptance in more mainstream vehicles.

According to many reports, carbon-fiber reinforced plastics (FRP) will be poised to gain widespread adoption for automotive light weighting by 2025, as the CAFÉ rules will force OEMs to make drastic changes to meet the gas mileage requirements. Helping move CFRP is the drive to produce the material cheaper and there has been faster-than-expected pace of technology development.

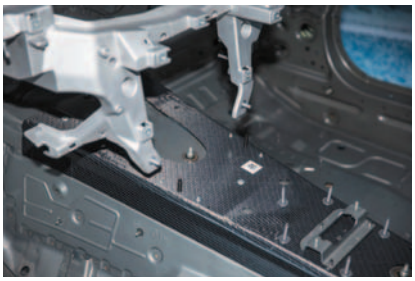
PHOTOS: BMW

2016 BMW 7 SERIES (G12) body-in-white CFRP, aluminum and HSS and AHSS

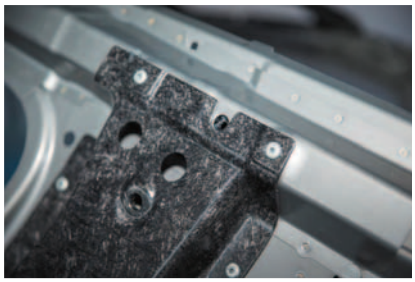
Cosmetic vs. Structural repairs to CFRP

Although the repairs to CFRP is similar to repairs to Fiber Reinforced Plastic (FRP) and Sheet Molded Compound (SMC), it is important to understand the difference between a cosmetic and a structural repair when it involves CFRP. Most of the repairs you will be performing will be structural repairs to the cosmetic CFRP panels — for example, mending a breach (hole) in a carbon-fiber panel. Although the cosmetic carbon-fiber panels add some strength to the car, they are not structural to the integrity of the whole vehicle. The majority of the carbon-fiber panels in use now are mechanically fastened to the car, although there are some panels, such as on the Tesla and BMW i3/i8, that are bonded to the base structure.

As for choosing the proper adhesive for making a repair, only follow what the OEM says to use in their repair procedures and only repair what they say can be repaired. Never listen to a sales representative. Generally, bonding will be done with a urethane adhesive or epoxy adhesive, while, to my research, repair work is always done with an epoxy. The reason for epoxies being the choice for repair is that epoxies are not flexible and will form a solid attachment, whereas urethanes are too flexible for most repairs. A repair is classified as cosmetic when the carbon fibers are not damaged or have been breached, such as when the surface of the panel is scratched or some minor



2016 BMW 7 SERIES (G12) center tunnel upper reinforcement CFRP



2016 BMW 7 SERIES (G12) inner quarter reinforcement CFRP

2016 BMW 7 SERIES (G12) inner quarter reinforcement CFRP full

pitting is visible. This basic type of repair involves hiding the imperfection and painting the repaired portion. An epoxy filler can be used to make this repair, since it is as rigid as the panel. When more significant damage has directly impacted or penetrated through the carbon fibers, such as a hole, the damaged fiber must be replaced with a suitable repair fiber and an epoxy adhesive.

Carbon fiber repairs

When a carbon-fiber-intensive vehicle sustains damage to the structural components, the repair procedures and protocols take more skill and technique, and the OEM will have specific materials and products for the repair. Carbon fiber material for automobiles is made up of multiple layers and the amount of layers will be a contributing factor in the repair vs. replace decisions, joining methods, adhesive material type, the type of carbon fiber repair cloth and the direction of the orientation utilized for the required repairs. Keep in mind carbon fiber cloth has a directional weave (think like directional tires). According to some repair procedures I have reviewed, repair procedures may require the various layers of carbon fiber cloth used for the repairs to be rotated — 30 degrees, 45 degrees, 90 degrees. The reason for this is the cloth has more strength in one direction than another direction. Additionally, the procedures may call for 12 to 14 layers or more of CFRP.

2016 BMW 7 SERIES (G12) inner quarter reinforcement CFRP full

2016 BMW 7 SERIES (G12) upper roof rail, front header and inner B-pillar reinforcements CFRP

Understanding the difference between plastic bumper repair, SMC, FRP and CFRP is to consider that to make a repair to CFRP, you perform a process they call "scarfing." In this process, the repair technician uses a tool to dress the area (grind) outwards to expose each layer of cloth (think a SMC pyramid repair process) and then begins to build the repair from the low center outward. Now the hard part is that each layer of repair carbon fiber cloth must be oriented to match the original structure. The crucial question that has to be answered when deciding to repair or replace a carbon fiber part is the same question we have asked ourselves with steel and aluminum:

- What does the OEM say about the repair?
- Will the repair adversely affect occupant safety, airbag deployment timing or collision pulse management?
- But for CFRP, will the repair be strong enough to survive the life of the vehicle?

Some basic and general recommendations are as follows:

- If a damaged carbon fiber part has a hole in its center, that repair will be strong since it is surrounded by support.
- If a carbon fiber part is missing a corner piece, such as a corner broken off of a hood, can that part be repaired or does a new hood have to be ordered? Or if the edge of a fender panel is cracked, can it be repaired? Because the repair area is hanging off the edge of the hood panel or the edge of the fender panel, the repair may not be strong enough for the lifetime of the vehicle, due to the applied stress.

Carbon fiber education

As we mentioned before, as carbon fiber becomes more and more mainstream as a manufacturing material ("cheaper to produce"), it will be used in more areas of car design. Since carbon fiber is extremely strong and lightweight, we will eventually see OEMs using CFRP as reinforcement in A or B pillars, rocker panels, roof rails and on closure panels on higher-production, more affordable vehicles, instead of just super cars. As SMC and FRP was an alternative to fiberglass in the 1990s, carbon fiber is being used as an alternative to SMC or FRP. Training will become paramount for the collision repair industry, but not to worry — most of the procedures for repair to CFRP is similar to those for SMC. Additionally, several training programs are available, such as Abaris Training, I-CAR training programs and Alliance courses for those interested in learning more about carbon fiber repairs.

PHOTOS: BMW

2016 BMW 7 SERIES (G12) upper roof rail reinforcement CFRP

Many OEMs such as BMW, Audi, McLaren and Alfa Romeo to name a few, have courses that their Certified Collision Repair Facility (CCRF) Program shops are required to attend, along with required specific equipment purchases. The industry is changing rapidly and shop owners must invest in training and equipment purchases in order to be ready for these changes.

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