INTRO TO CARBON FIBER

Even though carbon fiber has been in use for some time, most people are not very familiar with what it is or how it’s made. This white paper will provide you with some basic information about carbon fiber fabric and composites, where they come from and how they’re made.

What is carbon fiber?

Carbon fiber is a synthetic material that offers a unique combination of qualities -- high strength, high stiffness and low weight. Carbon fiber composites are about 10 times stronger and 5 times lighter than steel, and about 1.5 times lighter than aluminum. Together with the right resin systems, carbon fiber composites are also known for being extremely corrosion resistant and able to withstand high wear. Those qualities make it useful in a wide variety of aesthetic and structural applications.

Where does it come from?

Carbon fiber starts with a precursor polymer material called PAN (Polyacrylonitrile) which is heated until it becomes carbonized. It’s spun into extremely fine fibers (thinner than a human hair) which are washed and stretched to obtain the desired fiber diameter. This process also helps align the molecules within the fiber and helps create tightly bonded carbon crystals.

Then, the fibers are heated to 400°-600°F in a process that adds oxygen molecules and rearranges the atomic bonding pattern to convert their linear pattern to a more thermally stable ladder bonding. After they’re stabilized, the fibers are heated to 2,000°-5,500°F in an oxygen-free environment to expel non-carbon atoms from the material. The remaining pure carbon atoms form long-chain, tightly bonded crystals that are parallel to the long axis of the fiber. This is what gives the fibers their great strength.

Here is a typical carbon fiber shown against a human hair:
How do they make carbon fiber fabric?

Those fibers are collected into thread-like bundles called “tows” (pronounced “toes”) which are wound onto large bobbins. Standard tow sizes are 1k, 3k, 6k, and 12k, but specialty products use tows that are 48k and higher. The K designation means “thousands of filaments per tow”. For example, a 3k fabric has 3,000 carbon fiber filaments per tow and a 6k has 6,000 filaments per tow. This is the key to the strength and weight of the material.

The weaver loads the tows onto a loom where they are woven into a fabric. The most common forms of fabric are:

- Woven (plain weave, twill, satin)
- Unidirectional, Multidirectional (biaxial, triaxial, quasi-isotropic)
- Nonwoven (chopped or continuous strand mats)

How does it become a carbon fiber sheet?

There are several ways to make carbon fiber panels – hot press, vacuum infusion and wet layup are among the most common methods. At Protech, our primary production method is a vacuum infusion process. This involves laying carbon fiber fabric on a flat surface and injecting it with epoxy resin (matrix) under vacuum. The resin penetrates every tow and filament in the carbon fiber fabric (reinforcement) and cures under heat for several hours.

At Protech, we use a UV-stabilized epoxy resin as our matrix for its low density and high compression strength as well as the crystal clear clarity it adds to our gloss panels. The epoxy brings rigidity to the strength of carbon fibers, creating an end product with incredible material properties.
How is the gloss finish applied?

It isn’t! The deep, crystal clear, gloss finish on our products is created during the manufacturing process – it’s not a secondary coating. It comes from using a very flat, very smooth mold surface when we make a gloss product. As the resin permeates the carbon fiber fabric, a thin layer contacts the mold surface and transfers that perfectly smooth finish to the carbon fiber. The result is a mirror-like gloss finish.

What’s Prepreg?

Prepreg is a term used to describe a reinforcement, such as carbon fiber fabric, that has been pre-impregnated with a matrix, such as epoxy resin. The fabric is coated on one or both sides with an epoxy that cures when subjected to heat. Prepregs are typically shipped and stored frozen to prolong the shelf life, and thawed to ambient temperature for production.

How thick are the carbon fiber sheets?

We make 100% carbon fiber sheets and panels to specific thicknesses by layering sheets of fabric. For example, one layer of 3k fabric produces a very thin veneer about .25mm (.01”) thick, while one layer of 6k fabric makes a sheet about .5mm (.02”) thick. The layers compress as the thickness increases, so it takes 8 plys of 6k to create a 3.1mm (.125”) panel. Most of the panels we make are ¼” or under, however we can go well over ½” in solid carbon fiber.

Are they flexible?

Yes and no. The thicker the panel, the more rigid it becomes. A thin carbon fiber sheet only bends in one direction at a time, much like a sheet of construction paper. You can roll it into a tube, but it won’t wrap around a ball. The sheets are not thermoplastic, meaning it will not become pliable or moldable with heat and return to a solid state upon cooling. In terms of flexibility, our thinnest veneer at .25mm (.01”) thick, will wrap around a 1” pipe. The .5mm has a flex radius of approximately 4” and the 1mm (.04”) has a flex radius of about 12”. Thicker panels have much less flexibility.

On the other hand, if rigidity is your goal, a sandwich panel made with a Nomex honeycomb, foam, or balsa core might be the answer. They are extremely rigid and amazingly light weight.

Thinking about a project in carbon fiber?

Give us a call at (360) 573-7800 or email us at sales@protechcomposites.com. We’ll be happy to talk through your project or give you a quote.