Nonwoven carbon fiber composites

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Carbon fiber papers ranging in weight from 25 to 204 g/m² can be made in wet systems from chopped carbon fibers.

Our company manufactures a unique carbonizable pitch, known as A-240, from a heavy, specially selected feedstock from our crude oil refining operations. Its primary use is as a binder and densifier for carbon and graphite electrodes used in steel and aluminum smelting processes.

Many traditional uses of A-240 pitch have been explored, and one of the most promising is its conversion into a low-cost carbon fiber. Over the past 15 years, intensive research and development efforts resulted in novel methods of forming fibers in a nonwoven mat. Stabilizing and carbonizing treatments have been developed that can reduce manufacturing expenses compared with conventional processes that convert polyacrylonitrile precursor fibers into carbon fibers.

Currently, our company is manufacturing and marketing a low-priced, multipurpose carbon fiber under the name Carboflex®. Here, we will look at certain developing uses of carbon fibers in nonwoven composites.

Characteristics of carbon fibers

The outstanding properties of carbon fibers make them appealing to today's composite designers. Carbon fibers are strong, stiff, lightweight, abrasion resistant, and self-lubricating. They conduct heat, have a low coefficient of thermal expansion, retain their mechanical properties at elevated temperatures, and resist oxidation at temperatures up to 500°C. Carbon fibers are good electrical conductors, but they are transparent to X rays and are not magnetic. In addition, they are highly resistant to chemical attack and are biologically inactive.

Table I presents some of the properties of Carboflex fibers. As indicated, the fibers are as strong as steel but are one-fifth the weight, which makes them a good reinforcement for secondary structural composites.

High-performance carbon fibers are priced too high for general composite uses other than for aerospace purposes and in sporting goods. However, multipurpose, pitch-based carbon fibers are now available for cost-efficient component designs. The carbon fiber product forms attracting the most attention are the low-priced nonwovens such as mat, stitched mat, paper, and needled mat.

I. Selected properties of Carboflex fibers

Density, g/cm³	1.6
Electrical resistivity, ohm·cm	0.005
Diameter, μm	12
Tensile strength, psi	60,000-80,000
Tensile modulus, million psi	5.0-6.0

Nonwoven mat

Nonwoven mat is a three-dimensional material composed of semicontinuous fibers. In certain advanced structural composites, high-modulus, unidirectional carbon fibers are shaped and placed into a mold, and structural thermoset resins such as epoxy are injected. By virtue of the high modulus of elasticity, a bending radius is found at each location in the composite at which the carbon fibers change directions. This is especially obvious at intersections of structural members bearing angles of 90° and greater.

From this bending radius, a resin-rich area results and serves as a site for cracks to initiate in the matrix. Multipurpose, pitch-based carbon fibers with a lower modulus can be used to fill and reinforce these problem areas, thereby preserving the structural integrity of the composite.

Stitched mat

No binders are used in our nonwoven mat, and the pull strength, both wet and dry, is insufficient for certain composite processes. Stitching the mat consolidates its thickness from about 25 mm down to 3 mm and makes it easier to handle. For composite use, fiberglass, Kevlar®, or conventional stitching, thread can be used. Hybrid nonwovens can be formed by incorporating a fiberglass or other type scrim as a backing.

For composite tooling, the stitched mat provides a uniform and efficient heat transfer surface for rapid heating and cooling. This advantage is due in part to the low specific heat and low density of carbon fibers. Close tolerances can be maintained through molding cycles because of the slightly negative coefficient of thermal expansion of carbon fibers. Warpage of composite tools is

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II. Selected properties of Aerocarb impregnant

Density, g/cm³	1.27
Softening point, °C	204
Glass transition temp., °C	171
Carbon assay, wt. %	
Coking value	74
Total carbon	94
Quinoline insolubles, wt. %	0.4
Toluene insolubles, wt. %	17
Temp. at selected viscosities, °C	
1 poise	342
5 poise	301
10 poise	288
20 poise	277
60 poise	262
100 poise	256
140 poise	252

III. Potential uses for carbon fiber

- Brakes: aircraft, industrial, automotive, racing; carbon-carbon-fiber composites
- Friction materials, clutch plates
- Packings, gaskets, high-temperature insulation
- Plastics-carbon-fiber composites, with thermoplastics and thermosets; injection, reaction injection, and compression molding; reinforcement, shielding, conductance, fatigue enhancement
- Electrostatic dissipants: garments, fabrics, yarns, carpets; composites, circuit boards, electrical equipment, operating room furniture
- Electromagnetic shielding: communications equipment, computers, typewriters, telephones, military nuclear blast protection
- Ablations and ablation coatings and paints
- Battery electrodes
- Filter material
- Cement reinforcement
- Conductive paints
- Synthetic graphite
- Heating tapes, strips, walls
- Fire retardants, fire protection equipment, clothing

not of concern because the mechanical properties of carbon fibers are maintained even at elevated temperatures.

Hoods over engines in racing cars have been known to slump and adhere to the engine. These conventional reinforced composites can be redesigned to incorporate stitched carbon fiber mat, which will not only retain its reinforcing properties during the race but will transfer heat out of the engine compartment. The mat also serves as a flame barrier, which can mean more safety for the driver.

Another application under development is the use of stitched carbon fiber mat as an abrasion-resistant undersurface for boats and canoes. Certain areas of high wear areas, as in the rear undersurface of a canoe, can be made less susceptible to damage from rocks and sand when stitched mat protects the primary reinforcing fibers.

Paper or veil

Carbon fiber papers ranging in weight from 25 g/m² to 204 g/m² can be made in wet systems from chopped carbon fibers. Binders can be used that are compatible with the matrix system. Various thermoplastic fibers can be added to impart thermoforming qualities to the paper.

Situated at the surface of a composite, carbon fiber paper creates an electrically conductive layer for static dissipation. Surface resistivities of 40 ohms/m² were measured on a composite made from our Arimax® reaction injection molding compound and Carboflex paper. Effective shielding for electromagnetic interference and radio frequency interference can be achieved in composite housings for protecting sensitive electronic equipment. The layers of paper and fiberglass mat are simply alternated so that waves transmitted through surface layers can be further attenuated. Composite walls have been developed for heating animal stalls by connecting the carbon fiber paper to an electric supply for resistance heating.

The uniform quality of carbon fiber paper makes it an excellent surface-finishing material for eliminating the show-through of reinforcing fibers in the composite. A carbon fiber veil is also useful if corrosion resistance and abrasion resistance are required.

Needled mat

Needled mat is the most recent form developed from our nonwoven mat. The nonwoven mat can be consolidated, and the multiple layers of nonwoven mat can be needled together by punching a certain percentage of the fibers into the *z*-direction. The pull strength of the needled mat is five times greater than that of the nonwoven mat.

The primary use of needled mat is for high-temperature furnace insulation in both rigid and flexible forms. However, we will soon begin to evaluate composites of carbon and carbon fiber for brakes and for ablations in the aerospace industry.

The needled mat can either be preimpregnated with phenolic or with our new Aerocarb® high-carbonizing material. Selected properties of Aerocarb are shown in **Table II**. As a companion product to Carboflex, Aerocarb can be used in a hot isostatic press for densifying composites of carbon and carbon fiber. Its cooking value (*1*) of 74% vs. 35-55% for phenolics enables composite manufacturers to meet density specifications in fewer cycles of impregnation and carbonization.

Conclusions

Multipurpose, pitch-based carbon fibers can be used cost effectively in composites. The many beneficial characteristics make it appealing to designers. However, many other markets are envisioned for our low-priced fiber, as illustrated in **Table III**. Some of the best prospects among these are: friction materials, packings and gaskets, ablations, fuel cells, filters and coalescers, injection molding compounds, and static dissipant yarns and materials (*2*, *3*).□

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