FEATURE

Lowering the cost of carbon fiber

Mark Holmes

Carbon fiber offers a great many performance and lightweighting benefits for composites. Lower cost manufacture and increased use of recycled material now promise to widen the range of applications that could benefit from its properties.

High cost has been a major block to widespread use of carbon fiber as a strong, stiff reinforcement for advanced composites. One initiative underway to reduce these costs is taking place in the United States where researchers at the US Department of Energy's Oak Ridge National Laboratory (ORNL) have demonstrated a production method they estimate will reduce the cost of carbon fiber as much as 50 percent and the energy used in its production by more than 60 percent. ORNL's new lower cost method, demonstrated at its Carbon Fiber Technology Facility, builds on more than a decade of research in the area. The researchers' success promises to accelerate adoption of carbon fiber composites in high-volume industrial applications including automotive, wind turbines, compressed gas storage and building infrastructure. After extensive analysis and successful prototyping by industrial partners, last year ORNL made the new method available for licensing.

FIGURE 1
The Carbon Fiber Technology Facility at ORNL.

''Through a competitive selection process, ORNL is working to negotiate up to five license agreements for its low-cost carbon fiber process,'' says Dr. Alan Liby, deputy director of the Advanced Manufacturing Program at ORNL. ''LeMond Composites was the first to sign a license agreement and other licenses are still in negotiation. The licensees range from start-ups to established players in the carbon fiber production field. Partners will be selected based on their capabilities, business plans, and commitments to manufacture in the United States. Expectations are to see this technology in the marketplace by 2018 and the licensees will explore additional market opportunities.

''The innovation is about the production of low-cost carbon fiber,'' he adds. ''The properties of the material that the licensees produce will dictate the end-use applications. The carbon fiber produced by ORNL meets the performance criteria prescribed by some automotive manufacturers for high strength composite materials used in high-volume applications. However, the process promises to accelerate adoption of advanced composites in other industrial applications. Future markets for this material could include applications in the wind turbine and gas storage industries. The technology was developed at the Carbon Fiber Technology Facility as a pilot scale plant with a capacity of up to 25 tonnes per year. The expectation is that licensees will increase that capacity in their own operations.''

First licensee

LeMond Composites – headed by three-time cycling Tour de France champion Greg LeMond – is a new company offering solutions for high-volume, low-cost carbon fiber. The licensing agreement with ORNL will make the Oak Ridge-based company

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0034-3617/ http://dx.doi.org/10.1016/j.repl.2017.02.001

Please cite this article in press as: M. Holmes, Reinf. Plast. (2017), http://dx.doi.org/10.1016/j.repl.2017.02.001

FIGURE 2
The 118-meter (390-foot) process line has been designed to be flexible and highly instrumented to demonstrate advanced technology scalability and produces market development volumes of prototypical carbon fibers.

the first to offer this new carbon fiber to the transportation, renewable energy and infrastructure markets.

LeMond Composites adds that the carbon fiber will provide advantages to many industries by improving strength, stiffness and weight reduction, and the process will have global applications. The company is now ready to move forward with scaling up the technology.

Growing demand from the automotive industry is due in large part to the global push to increase the fuel economy of nearly every vehicle produced. In the USA, the demand is being driven by the Corporate Average Fuel Economy standards. These standards demand a fleet-wide average fuel economy of 54.5 mpg by 2025. The single best way to improve fuel economy is to reduce the weight of the cars and their component parts. For the wind power industry, carbon fiber can be used to make turbine blades lighter and stiffer, thereby increasing the efficiency of the system. Previously, carbon fiber was too expensive for maximum utilization in this market. Additional sectors, including shipping, air travel and marine, could see significant energy savings through the use of carbon fiber in the lightweighting of their containers, planes and ships. Carbon fiber composites can also be used to build, reinforce, or repair bridges, tunnels, commercial and residential structures.

The low-cost process

According to ORNL, more than 90 percent of the energy needed to manufacture advanced composites is consumed in manufacturing the carbon fiber itself. Reduction in energy consumption in manufacturing will enable earlier net energy payback – energy savings gained in using products made from lighter weight material compared to the energy consumed in making the material. A detailed analysis compared the new process to a published baseline for conventional carbon fiber production. Cost factors were considered for nine major process steps, starting with the precursor and pre-treatment and finishing with surface treatment, sizing, winding, inspection and shipping.

Carbon fiber is produced by converting a carbon-containing polymer precursor fiber to pure carbon fiber through a carefully controlled series of heating and stretching steps. In current commercial practice, the precursor – polyacrylonitrile, or PAN – is chemically modified and optimized to maximize the mechanical properties of the end product. The high cost of specialty precursor materials and the energy and capital-intensive nature of the conversion process are the principal contributors to the high cost of the end product.

However, acrylic fiber of similar chemistry is produced on a commodity basis for clothing and carpets – a high-volume product that costs roughly half as much as the specialty PAN used in the carbon fiber industry. ORNL researchers believed textile-grade PAN was a pathway to lower-cost carbon fiber, but laboratory-scale experiments could not fully explore its potential at a production scale. In order to provide that capability, the US Department of Energy's Advanced Manufacturing and Vehicle Technologies offices have funded research and operations at ORNL's Carbon Fiber Technology Facility, a highly instrumented, semi-production scale carbon fiber conversion plant. Extensive mechanical property tests have been performed on carbon fiber from the new process, and several automotive manufacturers and their suppliers received quantities suitable for prototyping, with encouraging results.

The Carbon Fiber Technology Facility at ORNL was designed, manufactured and installed by Harper International – a company specializing in thermal processing solutions and technical services essential for the production of advanced materials. The 118-meter (390-foot) process line has been designed to be flexible and highly instrumented to demonstrate advanced technology scalability and produces market development volumes of prototypical carbon fibers, and serves as a key step before commercial production scale. With a production capacity of 4.3 kilograms per hour, it allows industry to validate conversion of carbon fiber precursors at semi-production scale.

With a rated capacity of 25 tonnes per year based on 24k PAN tows, the carbon fiber line is configured for PAN, polyolefins, lignin and pitch precursors, as well as being upgradable for rayon and high-modulus carbon fibers. Internally, it has been designed with high degree of corrosion resistance for alternative precursors. The facility is designed for 3k to 80k tows and web up to 300 mm wide by 12.7 mm loft. An oxidation temperature of 400 °C is possible with airflow configurable for parallel, cross or down flow, and driven pass-back rollers are installed for slip prevention at low

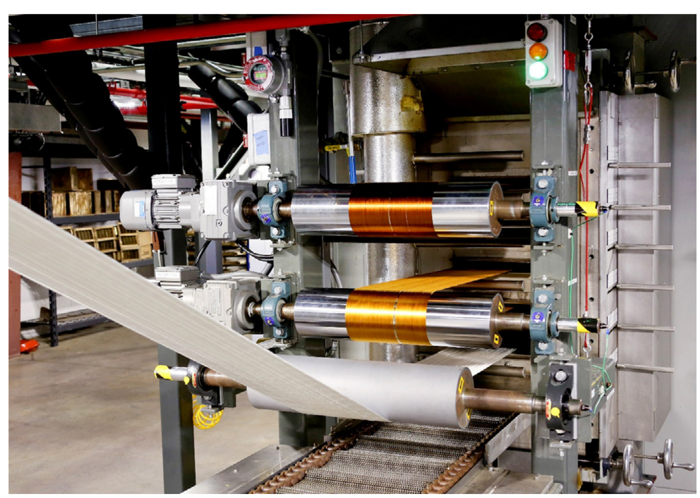

FIGURE 3
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Please cite this article in press as: M. Holmes, Reinf. Plast. (2017), http://dx.doi.org/10.1016/j.repl.2017.02.001