Glass Fiber Meets Stiffer Competition

Natural-fiber composites are no longer just subjects of academic interest.

By Michael Tolinski

The research and development behind natural-fiber reinforcements for plastics is still heavily relegated to major universities—but big OEMs and small manufacturers are showing more interest in these materials, given their potential for lowering life-cycle costs. The directions of recent research were indicated by presentations at two recent SPE events: last September's Automotive Composites Conference and last month's Global Plastics Environmental Conference (GPEC). Some background ideas and notable findings from conference papers on natural fibers are summarized below.

Lower "True" Costs?

The potential benefits that drive natural-fiber research aren't always clear-cut. Typically, manufacturing industries have focused on direct, per-pound raw-materials costs when selecting plastics reinforcements, but this ignores the big cost picture, argue Harry Hickey and Garry Balthes of FlexForm Technologies LLC. "In this simplified approach, natural fibers seldom will come out to be the low-cost alternative, but, when considering the benefits derived from one-step processing, the end cost of the finished component becomes highly competitive through a reduction in both capital and the growing cost of internal labor," they note.

Natural-fiber composite (NFC) manufacturers like FlexForm are betting on greater automotive industry use of fibers such as hemp, kenaf, jute, flax, and sisal (a leaf fiber). In nonwoven form, the fibers are commingled with thermoplastic fibers and formed into interior door panels, seat backs, armrests, and consoles. Additive-enhanced formulations with higher heat stability will open up additional applications, as will higher-strength nonwovens that have longer, "cleaner" fibers in more linear arrangements. Moreover, as replacements for glass fibers, natural fibers are being evaluated for use with thermosets for more extreme exterior applications like bumper reinforcements and wheel-well liners.

The first North American auto applications for NFCs appeared in the 1990s, but growth was slow, despite NFCs' potential for reduced part weight and simplified processing. "Companies were downsizing, relocating manufacturing to reduce labor, and few were investing capital in new technologies," say FlexForm's Balthes and Hickey. Interest was revived in 2003, as the lower "true" costs of NFCs were discovered.

Researchers cite multiple cost-related benefits of using natural fibers instead of glass fiber as reinforcements. Plant-based fibers have about half the specific gravity of glass, allowing lighter parts, and they lack the abrasive nature of glass fiber that makes it hard to handle—and hard on tooling. NFCs can be compression molded with cheaper aluminum tooling and lower forming pressures (around 55 psi, says Hickey). And the trim waste is reusable; for example, NFC waste from the door substrate processes in the 2005 Mercedes Vision concepts and M-class vehicles reportedly will be used in extruded decking.

Greener SMC

Still, natural fibers' higher per-pound costs and lower mechanical properties make NFCs a tough sell for replacing glass-fiber composites in engineering applications. But the situation may be changing. "While economic and, to some extent, performance demands have slowed the integration of NFCs into the mainstream of automotive applications and other markets, their use is gaining momentum," conclude Balthes and Hickey.

At least one automotive OEM, Ford, is devoting resources for adapting NFCs for traditionally glass-reinforced applications, like SMC. Researchers at Ford have evaluated SMC made with various combinations of nonwoven hemp mats, hemp twine, and hybrids of chopped glass and hemp fibers. In a paper presented at

GPEC, they reported that some natural-fiber combinations offer properties that approach those of traditional glass-reinforced SMC (though they also found that without a barrier-coating additive, hemp/SMC absorbs a lot of moisture, correlating with a "significant decrease in mechanical properties"). Similar research on natural-fiber/SMC has produced similar mixed but encouraging results.

Ultimately, the success of hemp in SMC may depend on the selection of the right applications. Researchers at the University of Toronto's Centre for Biocomposites and Biomaterials Processing compared their findings with the mechanical requirements of various SMC auto components. They found that SMC prepared with a combination of 45% hemp fibers and 5% glass fibers offered a tensile strength (over 80 MPa) and modulus (2 GPa) that are the "same or better than" requirements for body parts such as rear liftgates and front fenders.

All Natural

The holy grail of natural fiber research is a completely bio-based composite with a plant-based resin matrix and natural reinforcement. In this research, the bio-resins of choice are both derived from corn: poly(lactic acid) (PLA) and poly(trimethylene terephthalate) (PTT), a low-melting-point polyester. The fiber of interest is both natural and recycled: cellulose pulp from reclaimed newspaper.

In a GPEC paper on cellulose-fiber biocomposites, Todd Bullions, a research scientist at Virginia Tech, described using compression molding to form multiple plies of pulp fiber combined with PTT into a nonwoven, "fabric-like prepreg" material. Besides being partially bio-based, the PTT offers a lower processing temperature (225ºC) that will not degrade cellulose fibers during molding, while providing engineering properties that lower-temperature polymers cannot.

The mechanical properties of the cellulose fiber composite, particularly the flexural modulus, were

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found to be "comparable" to those of glass-fiber-reinforced PTT—especially when factoring in the higher density of the glass composite. Bullions noted that the characteristic shape of cellulose fibers aids their effectiveness as a reinforcement. "Their high aspect ratios, along with their ribbon-like shape, provide large amounts of surface area for load transfer from matrix to fiber."

All-natural composite properties can be enhanced with additional ingredients in the mix. Teaming up with Michigan State University in another GPEC paper, Ford scientists looked for the optimum combination of PLA, pulp fibers, and another natural reinforcement, talc. Talc's stiffening effect was evident in a triple composite of 60% PLA, 30% newspaper, and 10% talc, which showed 20%–100% higher strength, modulus, and impact properties than 70% PLA with 30% newspaper fibers.

Flexural Strength and Modulus of Corn-Based Polymers and Their Composites Containing Recycled Newspaper Fiber (NF).

Composition	Flexural Strength (MPa)	Flexural Modulus (GPa)
100% PTT	108	2.6
40% PTT + 60% NF	108	7.6
100% PLA	99	3.3
70% PLA + 30% NF	78	4.9
60% PLA + 30% NF + 10% talc	94	10.8

Sources: GPEC papers mentioned in this article from Virginia Tech, Michigan State, and Ford Motor Co.

Bamboo Too

Slightly off the beaten track, GPEC presenters from Asia are studying a fiber rarely discussed in the Western Hemisphere. Bamboo's inherent strength is well known, and researchers from Doshisha University in Kyoto, Japan, are looking into the properties of bamboo-fiber/PLA composites. Its longitudinal fibers have high strength, but the poor interfacial strength between the fibers and thermoplastic matrix limits the composite's usefulness.

However, as in the Ford/Michigan State study, researchers found that the key for solving this problem was the addition of a third component—a "nano-sized" natural fiber called micro-fibrillated cellulose (MFC). With 10% MFC, the bending strength and fracture toughness of the bamboo/PLA were significantly improved. The reason? "We may conclude that a small amount of MFC improved interfacial properties between bamboo fiber and matrix, and tangled MFC fibers prevent crack growth along the interface." PE