Composites from wood and plastics

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Composites made from thermoplastics and fillers or reinforcements derived from wood or other natural fibers are a dynamic research area encompassing a wide variety of composite materials. For example, as the use of biopolymers grows, wood and other natural fiber sources are being investigated as renewable sources of fillers and reinforcements to modify performance. Nanocellulose, whether cellulose nanocrystals or fibrillated cellulose, have interesting characteristics and offer new composite opportunities if efficient, economical, and scalable methods of producing both the reinforcements and the composites are developed. Experimental and analytical tools are being developed to evaluate the intrinsic material properties of the interphase or to examine the highly nonlinear behavior of large-scale, structural components, for example. This research will result in improved understanding of material behavior and identify new opportunities for composites that may be quite different from those currently produced.

Background

Wood and other natural fibers have been used in composites for many years. However, interest in their use as fillers and reinforcements waned with the development of synthetic fibers such as glass and carbon fibers. Recently there has been a resurgence of interest, largely because of environmental considerations, legislative directives, and technological advances. It was estimated that 900,000 tonnes of thermoplastic composites were produced in 2007 containing wood or other natural fibers.

These composites have been used in applications such as automotive paneling, signs, and consumer products. However, the largest use in the United States is in the construction industry. Over one-half of the composites produced from thermoplastics and wood and other natural fibers in North America are used in decking applications, and the great majority is in exterior building products such as deck boards, railings, and window and door profiles. There has been considerable interest lately in other applications such as furniture, siding, and roofing as well as a variety of marine and construction applications requiring greater structural performance than in current applications.

As several of the large markets for these materials begin to mature, manufacturers seeking to differentiate themselves are driving the next generation of these composites. For example, some manufacturers are using new co-extrusion technologies to apply a durable, scratch and stain resistant layer to wood-plastic composites. Of particular interest are economically improving durability, improving structural performance, and reducing weight. Foaming continues to be of interest as manufacturers seek to balance cost, weight, and performance.

There are many reasons that wood or other natural fibers are used as filler and reinforcements. Customer and builders have a certain familiarity with wood in applications such as decking and railings and often desire an alternative that may have similar attributes. Mixing wood flour with plastic is seen as a way to use wood in these applications yet improve its durability without chemical treatment or the need for painting or staining.

Environmental considerations are also driving increased use of wood and other natural fibers since they are derived from renewable resources, do not have a large energy requirement to process, and are biodegradable. They are lighter than inorganic reinforcements, which can lead to benefits such as fuel savings when their composites are used in transportation and packaging applications. In the U.S., wood-plastic composites represent one of the largest domestic outlets for recycled film. With changing consumer perceptions, some manufacturers use the natural look of these composites as a marketing tool. Others have added wood or other natural fibers to increase bio-based material content.

As part of the Forest Service, FPL also views such composites as potential outlets for wood-based materials from manufacturing residues, recovered post-consumer wood-based materials, and other recycled and underutilized forest-based resources in cost effective, durable products. Use of these wood-based resources as well as natural fibers other than wood offer an opportunity to provide an effective way of meeting the needs of people in the global community while helping to promote a sustainable natural fiber resource base.

Research

Perhaps not surprisingly, some research trends in the wood-derived filler and reinforcement technology parallel those of other fillers and reinforcements. For example, methods for maintaining fiber length for better reinforcement and improved impact performance, the use of biopolymers as matrices, or the application of nanotechnology may result in very different types of composites in the future.

As the use of biopolymers grows, wood and other natural fiber sources are logical, renewable sources of fillers and reinforcements to modify performance. In many instances, their biodegradability can be an attribute rather than the detriment it is sometimes considered in some current applications (e.g., exterior building applications) where considerable durability is required.

Nanocellulose, whether cellulose nanocrystals or fibrillated cellulose, have interesting characteristics (e.g., very large surface areas, low percolation thresholds) and offer new composite opportunities if efficient, economical, and scalable methods of producing both the reinforcements and the composites are developed. Our research focuses on developing a variety of technologies (metrology, production, composite processing, chemical modification, etc) to facilitate and expand the use of cellulose in high-performance products.

Nano-scale additives and reinforcements are also being explored for use with macro-scale composites to affect a wide range of performance criteria and to explore new opportunities. For example, nano-scale additives for controlled-release of moldicides or improved resistance to UV degradation are being investigated.

From a processing standpoint, more advanced technologies are being applied to these composites to overcome current limitations or explore new opportunities. Reactive extrusion offers the opportunity to significantly improve material behavior. Multi-material processing options such as co-extrusion or co-injection molding are other methods to engineer performance, avoiding the detrimental effects that sometimes occur when simply blending the materials or perhaps localizing expensive or more structural components in a surface layer, for example.

Considerable effort is still underway in evaluating the performance necessary for various applications. For example, durability is still a key area of research as exterior applications are still their largest outlet and extending service life is a major goal. New or modified methodologies are being developed that more appropriately measure the moisture sorption, UV or biological degradation, and creep and the relationships between them.

As these materials are used in more applications where greater structural performance is required and the materials are more heavily engineered, experimental and analytical tools are necessary to develop or validate required structural performance. Because of the complexity of these materials, more sophisticated approaches are necessary. For example, FPL researchers and collaborators are using data-driven methodologies and multi-degree of freedom mechatronic loading to examine the highly nonlinear behavior associated with strain-induced micro-cracking and to predict the response of the structural components.

At the other end of the spectrum, new technologies examine material performance and structure at the micro- and nano-scale. For example, nano-indentation methods that separate the intrinsic material properties of the interphase from the effects of the neighboring bulk polymer matrix and wood cell wall are being developed and verified so that the size and properties of the interphase can be more accurately established.

Conclusions

Although not large compared to more traditional wood composites, composites made from thermoplastics and fillers or reinforcements derived from wood or other natural fibers are a varied and dynamic area of research. From cellulose nanocomposites to large structural wood-members, current research is leading to new materials and application areas, greater structural performance, and a better understanding of material behavior.

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