Locally grown natural fibers for industrial applications

Monika Bubacz
The Citadel, Charleston, SC

Abstract

The Citadel is currently working with South Carolina Hemp Farmers Association in order to increase South Carolina farmers interests in growing industrial hemp as a commodity. Many engineers, scientists, and technicians are dedicated to furthering the usage of natural fibers in new and innovative applications. Hemp fibers have applications in the construction, automotive, electrical and electronics, cosmetics, recreation, oil and gas, and various other industries. However, for the fibers to be used as a drop-in replacement for traditionally used glass fibers, they must undergo several types of mechanical and/or chemical processes to be compatible with polymer matrices. This paper will analyze the applicability of locally grown hemp fibers in automotive, aerospace and other local industries.

Keywords

Composites, natural fibers, hemp

Introduction

The use of natural fibers as reinforcements in composites has grown in importance in recent years. Plant fibers have specific stiffness similar to synthetic fibers and this makes them attractive as renewable alternatives for glass-reinforced thermoset matrix composites. Thermoplastic and thermoset matrix resins have traditionally been synthetic resins, but bio-derived resins are now becoming available, creating the possibility for polymer matrix composites in which both the fibers and the matrix are bio-derived[1]. Thus, natural fiber composites could be 100% biodegradable. Biological and environmental durability are also often cited as a key advantage of natural fiber composites over traditional materials[2]. Much effort has gone into increasing their mechanical performance to extend the capabilities and applications of this group of materials[3].

Natural fibers are commonly used to make nonwoven mats, such as natural insulation, acoustic mats, filters, natural house wrap, and interior car panels, such as doors, pillar trim, trunk liners and package or rear-parcel trays. Early composites, replacing wood fiberboard, were a mixture of flax and sisal fibers in an epoxy matrix, first used on the Mercedes E-Class door panels in the early 1990s[4]. The automakers have adapted natural fibers for other interior panels, seat backs and trunk liners. Beside the auto industry, the applications of natural fiber composites have also been found in the electrical and electronics, cosmetics, oil and gas, building and construction industry, sports, aerospace, and others[5,6].

"Bast" fibers, such as flax, hemp, jute and kenaf, are noted for being fairly stiff when used as a composite reinforcement. Bast plant stems are characterized by long fibers surrounding a core of pulp or short fibers and covered with a protective bark layer. Separation of the useful fibers from the bark and core starts with a process called "retting," in which the cut stalks are soaked in water or left in the field in a humid environment for several weeks to degrade the natural binders. This makes the fiber bundles easier to process by mechanical means, or by hand, as is the case in many developing countries. As of the mid-1990s, flax and jute were the principal fibers used in bio-composites, but have been joined by higher strength industrial hemp and kenaf, at least in automotive applications[4].

Hemp is a robust plant, able to grow in less than perfect soils and across a broad range of climate zones[4]. The process of producing natural fiber reinforcements includes a drying step, where the natural plant moisture, including that gained during the retting process, must be removed. Over time, however, the fibers will absorb moisture from the air to return to some equilibrium point, which varies by fiber, but is typically in the range of 5 to 15 percent by weight. Encapsulation of the fiber in composite resins retards this pickup significantly, but the overall moisture pickup still exceeds that of fiberglass composites. Historically, this has precluded the use of natural fiber composites in high moisture environments such as exterior automotive body panels, although some breakthroughs and developments are occurring in that area.

Fiber Preparation

Bast fiber plant stems are made up of two constituents, a woody core called hurd, core, or shive, and the fiber. Both of these materials can be used in a variety of ways. Before natural cellulose fibers from bast fiber plants can be utilized for composites, a process of cleaning and separating needs to occur to extract the fibers[7]. The fiber can then undergo any necessary surface treatments in order to meet customer specifications[8]. More often than not, the fiber undergoes a chemical cottonization process in order to become suppler and can thus be a drop-in replacement for use on cotton textile equipment. The main mechanism of promoting fiber-polymer adhesion or compatibility is to be able to break the intra and inter molecular hydrogen bonds so that the –OH group of the fibers can be accessed to modify the surface. The most common surface treatments are as follows: silane treatments, coupling agents, acetylation and potassium permanganate. Specific fiber/matrix bonding promoter treatments are available for resin systems including: polyester, polypropylene and epoxy[8].

The fibers can be made to common sizes (150-500 microns) and cut to desired length. Common sizes of ¼” to 4” lengths are typical for use in injection molding and various nonwovens. Fibers can also be refined, or “beaten” in order to process them for further uses, such as pulping and paper-making.

Future Work

The Citadel has been contacted by South Carolina Hemp Farmers Association to facilitate different areas of research on industrial hemp and the different end products that it can produce. The association is set up as an educational arm for South Carolina farmers who are interested in growing this new rotational crop, but also the educational branch for the farming community on how to grow and manufacture all aspects of hemp[9].

A driving force in industrial hemp research is access to pretreated fiber. Fortunately, a biomaterial manufacturing company Sunstrand, LLC has recently opened a plant in South Carolina. The company will work closely with farming partners to procure natural materials (bamboo, hemp, flax, kenaf) by producing bulk biomaterials for manufacturers, wastewater remediation companies and animal bedding distributors across North America. The company is a supplier of natural fiber reinforcements and fillers for a variety of industries and is North America's only commercial decorticator of technical grade bast fibers. A sample of hemp fibers prepared for composite fabrication is shown in Fig. 1.

Figure 1. Sunstrand hemp fiber treated for composite application.

The best mechanical properties of fiber reinforced composite materials can generally be obtained when the fiber is aligned parallel to the direction of the applied load. However, it is more difficult to get alignment with natural fibers than for continuous synthetic ones[3]. The fibers are generally supplied in a needle-punched nonwoven mat format, and the simplest method involves placing the mat into the mold, pouring liquid resin on top, and pressing until cured. Most thermosetting resins, including polyester, epoxy, phenolic and urethanes, can serve as the matrix for natural fiber composites[4]. Such low-viscosity resins provide excellent fiber wetting and adhesion, and the composites can be compression molded in more complex shapes than wood fiber-based materials.

The future research will concentrate on the best fiber placement and resin impregnation methods in order to create natural fiber composite panels that can be tested and presented to the local industries. Currently, based on the features of supplied materials, which are 6 mm non-directional fibers, the author is investigating using resin transfer methods for composite production.

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Monika Bubacz

Monika Bubacz is an Associate Professor in the Department of Mechanical Engineering at The Citadel. She received both her B.S. and M.S. in Mechanical Engineering from Poznan University of Technology in Poland, and the Ph.D. in Engineering and Applied Science from the University of New Orleans.