Natural Fibres composites: Green And Ecofriendly

Vivek Patel

Introduction

Natural fibres composites are delectable class of biocomposites which is consisting of bio-fibres reinforcement with synthetic matrix or bio-based matrix. It offers a significant potential market for crop-derived fibres. "Bio-fibres" could be very short wood fibres from both deciduous and coniferous sources, straw from corn, wheat and rice crops, and various natural grasses. From a commercial standpoint, the most viable structural fibres come from purpose-grown textile plants and some fruit trees. Further, it is subdivided into "bast" fibres, such as flax, hemp, jute and kenaf and leaf fibres including sisal, pineapple, banana and henequen. The former one is noted for being fairly stiff when used as a composite reinforcement while later one is noted for improving composite toughness with somewhat lower structural contribution. The seed and fruit fibres such as cotton, kapok and coir (from coconut husks) demonstrate elastomeric type of toughness, but are not structural. Among bio-fibres, bast fibres represent the vast majority of natural fibres with potential for composites usage.

The jute plant is native to Southeast Asia, with India and Bangladesh responsible for more than 90 percent of worldwide production; so that natural fibres composites penetration in these two countries should be high, but it is not the fact inspite of meager presence. The jute is popular for the production of carpet backing, tote bags, sack cloth and rope, although jute has been partially replaced by other bast fibres in some of its earliest composite applications; it continues to be popular in sectors like interior automotive components.

The use of kenaf fibre as a reinforcement has grown substantially in the past decade. Resembling the hibiscus plant and related to cotton and okra, kenaf is grown widely in India and China, which together account for more than 75 percent of worldwide kenaf production. In the U.S., south Texas and eastern North

Carolina supply relatively small amounts of kenaf.

Hemp is a robust plant which is able to grow in soils that are less than perfect and across a broad range of climate zones. Industrial hemp is grown in more than 40 industrialized countries, although it is illegal to grow today in the U.S. It is banned since the 1950s because it is a variety of the plant species *cannabis sativa;* industrial hemp contains less than one percent THC (delta-9-tetrahydrocannabinol), the active ingredient in the similar marijuana plant (which contains 5 to 20 percent THC). Hemp is grown in most of the countries in Europe, with Romania the largest producer. End uses include rope and twine, clothing and composite products. Hemp is having potential applications such as extruded plastic fencing and decking, and furniture padding.

Advantages of natural fibres composites

- Low cost and light weight alternatives to fibreglass
- Better thermal and acoustic insulation
- Local availability
- Carbon dioxide neutrality: the natural fibres reportedly give off no more carbon dioxide when they burn so that it reduces global warming effects
- Lower energy consumption: the production of natural fibres suitable for composites as it takes 60 percent lower energy consumption than the manufacturing of glass fibres
- Ease of recycling
- Environmental friendly

Limitations of natural fibres composites

- Lower impact strength
- Medium to high moisture absorption uptake which causes swelling of the fibres
- Limited processing temperature
- Low and poor fire and smoke resistance
- Processing limitations
- Poor environmental stress crack resistance (ESCR)

Natural fibres composites are manufactured by compression moulding often in conjunction with a hot press, injection molding, extrusion process, pultrusion technique, Vacuum Assisted Resin Transfer Moulding (VATRM) and Seemann Composite Resin Infusion Moulding Process (SCRIMP). The prerequisite is surface modification of natural fibres before processing in order to develop composites product with better mechanical properties and environmental performance. It is done by chemical reaction with suitable coupling agents or by coating with appropriate resins so that it decreases natural fibres moisture absorption and increases wettability of fibres with resin and improve the interfacial bond strength.

Applications

Natural fibres composites have been major applications in automotive sectors, mainly driven by increasing environmental awareness, low Co_2 emissions, low cost and light weight which lead to the automakers in the 1990s make significant advancements in the development of natural fibres composites, with end-use primarily in automotive interiors. The first use of natural fibres composites was started in European continent mainly Germany. As of the mid 1990s, flax and jute were the principal fibres used in automotive applications, but have been replaced by higher strength industrial hemp and kenaf in automotive applications. Prior to this attempt, it has also been made to commercialize the stalk fibres for composites applications but were only marginally successful and have been largely abandoned. However, textile flax, a much taller plant and the source of commercial linen fibres used in clothing, now is the source for almost all flax-based natural fibres composites. It is grown widely in Russia, China and, to a lesser extent, Northern Ireland, Belgium and France. A number of vehicles models, first in Europe and then in North America, featured natural fibres reinforced thermosets and thermoplastics in door panels, trunk liners, package trays, and seat backs.

Bast fibres composites are predominantly used in automotive interior panels, such as doors, pillar trim, trunk liners and package or rear-parcel trays. The 1990s was the golden era for natural fibres composites commercialization, on the same year, fibreboard was first used on the Mercedes E-Class door panels, and were a mixture of flax and sisal fibres in an epoxy matrix. Most thermosetting resins, including polyester, epoxy, phenolic and urethanes, can serve as the matrix for natural fibres composites. Such low viscosity resins provide excellent fibres wetting and adhesion, and the composites can be compression molded in more complex shapes than wood fibres based materials. Efforts to replace fibreglass in sheet molding compound (SMC) with natural fibres also are underway.

With increasing emphasis on recyclability, thermosets have been largely supplanted by thermoplastics in natural fibres interior components. Selection of the resin matrix is limited to polymers with lower melt-points generally polypropylene and to a lesser extent, polyethylene. Thermal degradation of natural fibres begins as low as 120°C, with temperatures above 230°C causing rapid decomposition of cellulose. Keys to minimizing this degradation include lower process temperatures and short thermal exposure with both polypropylene and polyethylene used due to its processable melt viscosities at or below this higher temperature. Sometimes multilayer sandwich forms, incorporating barrier films or external plies of polypropylene/PET fibre blends (the PET fibre does not melt) can improve cosmetics and surface sealing. In-mold decoration technologies, permit comolding of carpet, fabric or decorative film overlays with the natural fibres composite, generally without the need for adhesives, resulting in a single-step manufacturing process.

Jute is the principal fibre used in mat materials supplied to Tier 1 molders by FlexForm Technologies (Elkhart, Ind.). FlexForm products are used in a number of vehicles produced in North America, including the Chrysler *Sebring,* Mercedes M-Class SUV and R-Class *Sport Tourer,* and the Ford *Freestyle* and *Expedition.*

Quadrant Plastic Products AG (Lenzburg, Switzerland) is the world's largest supplier of glass mat thermoplastic (GMT) composites and through its subsidiary Quadrant Natural Fibre Composites GmbH (Lambrecht, Germany) has established a strong position in natural fibres composites market. Among the vehicles using Quadrant's natural fibres composite are the Audi A8, Mitsubishi *Space Star* minivan, BMW 7-series, and an Iveco heavy truck line. The most structural application of natural fibres composites is the load floors of the Volkswagen, *Touareg*, Porsche *Cayenne,* and Audi Q7 sport utility vehicles. These parts are a sandwich of expanded polypropylene foam covered on each side with 1,400 g/m2 natural fibres/polypropylene composites, and topped with PET carpet.

Composite Products Inc. (Winona, Minn.) produces compounding and molding systems for D-LFT, and has developed an extensive database on

Figure 1: A door panel from the new Mercedes M-Class and R-Class (inset) is made of natural fibres composites, Source: Flexform Technologies

polypropylene reinforced with 40 percent kenaf, flax and natural fibre/glass hybrids. The company recently reported on efforts using corn hull particulate, from 0.5 mm to 5 mm (0.02 inches to 0.20 inches) in length, as a substitute for talc and calcium carbonate filler, with similar strength properties and 15 to 20 percent lower density.

Using the D-LFT process, DaimlerChrysler AG (Stuttgart, Germany) introduced the first large-scale application (about 40 metric tonnes/88,000 lb per year) of natural fibres composites in an exterior application, starting with the 2005 Mercedes A-Class, two-door vehicle. The car's spare wheel pan cover is produced by Rieter Automotive Systems (Winterthur, Switzerland) using polypropylene resin and abaca fibre.

TeelGRT (Baraboo, Wis.) was started in 1996 to commercialize the compounding of natural fibres/thermoplastic composites. The company provides polypropylene and polyethylene materials with 25 and 50 percent (by weight) natural fillers, including wood flour and rice hulls, and reinforcements such as kenaf, hemp and cellulose fibres. TeelGRT does in-house compression molding and profile extrusion with the materials and sells the compounds for other processes, including injection molding. Targeted applications include not only transportation but construction and consumer markets as well.

Increasing competitive pressures, especially in the automotive industry, are clouding the outlook for natural fibres composites. Although the end-of-life directives in Europe will force more recycling of vehicle components, they do not dictate the use of natural materials. Further the market penetration, therefore, will occur only if the cost of natural fibres composites can be justified against competing technologies, such as the injection-molded unreinforced thermoplastics used today on many vehicles. Petroleum costs favour natural fibres composites, as they are only 50 percent thermoplastic and therefore less sensitive to price increases. Other opportunities existed in hybrids of glass and natural fibres, or the use of natural fibre as the core of a structural sandwich surrounded by glass fibre composite, particularly for exterior components subject to moisture

Table 1: Snapshots Of Major Applications

Sectors	Major Applications					
Automotive	Truck floors	Ducting	Door and head liners	Spare tyre covers	Interior panels	Rear Shelves
Construction	Window frames	Roofline products	Door frames and components	Ducting	Fascias, soffits and barge boards	Cladding-exterior horizontal and vertical
Interiors / Internal Finishes	Interior panels	Kitchen Cabinets	Laminate flooring	Office Furniture	Sound proofing	Office Furniture
Industrial / Infrastructure	Railings	Handrails	Rubbish Bins	Signage	Marine pilings	Pallets/ Crates/totes
Others	Decking	Fencing	Garden Furniture	Playground surfaces	Park benches	Hot tubes

Figure 2: The rear cargo area load floor of the Porsche Cayenne is composed of structural layers of natural fibre composites surrounding an expanded polypropylene foam core and covered with a carpet cloth, Source: Quadrant Natural Fibre Composites

exposure.

Apart from that natural fibres composites have applications in construction and industrial applications such as window frames, ducting, railing, roofline products, and others. If natural fibres composites achieve requirements for flame, smoke and toxicity performance then it can penetrate aircraft, rail and subway markets that could benefit from the lower weight potential. At the same time it is replacing wood in construction and furniture. Sporting goods and consumer product markets also may offer opportunities. The fragmentation of these markets will pose a challenge, but the natural fibres community has already shown it can survive in a tough environment. The brief applications are depicted in table 1 and pictorial presentation is given in figures 1 and 2 respectively.

Market Potential

Natural fibres composites are commercialized two decades ago so that we can assume that it is the new entrant in the composites market as biocomposites. The development in this field had grown from laboratory scale fundamental research to industrial implementation. The USA is the number one consumer of the natural fibres composites whereas Europe falls under number two, however, it was the first user and Asia-pacific retains number three position including Japan and china being the major players. Despite the demonstrable success of the product in the USA, market development in Europe has been slow but still they are

the number one user of natural fibres composites in automobile sectors. The European market growth is predicted and expected but there is a significant lack of confidence as to when this is going to occur. Market development in the USA has been particularly effective when established suppliers have introduced natural fibres composites as more attractive products, with major chunk in construction industry. Although there are conflicting views as to which application will offer the greatest opportunity for natural fibres composites manufacturers, the applications most likely to emerge and achieve significant growth in the short to medium term are outdoor products (decking, fencing and garden/outdoor furniture), doorframe profiles and window profiles. The current global natural fibres composites market is approx $ 1.3 billion (2009) and by the volume shipment it is 540 Mill lbs. In India natural fibres composites market is negligible and it will take long time to penetrate market.

The market growth is respectable between 12 to 15 percent per year. Factors that have retarded growth include limitations in processing technologies and molded part performance as well as the recent economic lull that depressed auto sales and prompted a renewed focus by OEMs on purchased part price, which temporarily overshadowed potential weight savings, and concerns for recyclability and environmental stewardship.

Conclusion

Natural fibres composites can be a potential candidate for partial replacement of high cost glass fibres for low load bearing applications on the basis of low cost, light weight (Approx half than glass fibre), environmental friendly, and others. It is formed by matrix and reinforcement in which reinforcement is natural and therefore originating from plants. Some of these fibres can be hemp, jute, flax, sisal, banana, kapok, grass, wheat-straw etc., whereas matrix may be thermosets such as unsaturated polyesters, phenol formaldehyde, isocyanates and epoxies along with thermoplastic matrix such as polyethylene, polypropylene, polystyrene, polyvinyl and others. The ample market opportunity is existing

Vivek Patel
(Contact : vivepatel@gmail.com)