

Industrial Fibres: Recent and Current Developments

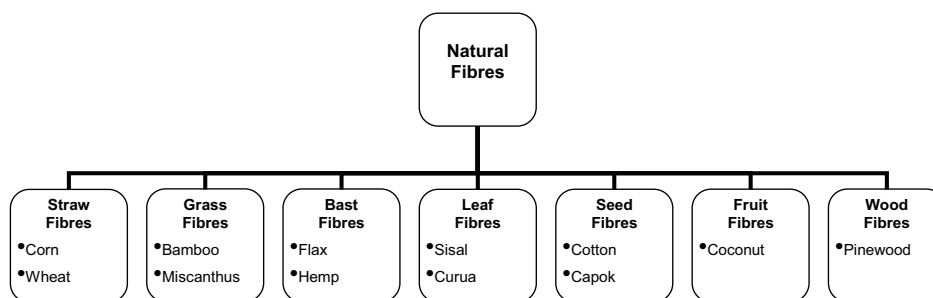
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INTRODUCTION

While the use of natural fibres in composites may be viewed with scepticism by some, as a step back to the original mud and straw era, the new generation of natural composite materials is proving this to be far from the case. These natural fibre composites demonstrate high strength and high toughness and have been developed for a range of rigorous environments. The ancient Egyptians taught us a great deal about the potential of natural fibres, both in paper and mud and straw building materials. Since that time there have been few developments in natural fibre composites until around 20 years ago, when a surge of interest in utilising these ‘greener’ materials for a number of applications put them back in the spotlight. The recent increase in consumer environmental awareness, along with increased commercial desire to use natural materials, has led to new innovations, a number of which will be discussed in this paper.

These natural materials are predominantly used as a replacement for conventional synthetic petroleum based composites systems. Three main categories of natural fibre composite can be defined: composites where the natural fibre serves as a filler in commodity thermoplastics; composites where longer fibres enhanced with compatibilisers and other additives attain additional strength and toughness in thermoplastics; and composites where natural fibres are used with thermosetting resins as designed elements within engineered components. In parallel to these developments there have been many advances in biodegradable polymers, both thermoplastic and thermosetting in nature. Composites using natural fibres and bio-based resins are poised to see explosive development within the next ten years.

Figure 1. Natural Fibre classifications



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Fibres can be classified into two main groups: man-made and natural. In general, natural fibres can also be subdivided as to their origin: plants, animals, or minerals. The natural/vegetable/plant fibres, which are the main type of fibres discussed here, can be further subdivided into seven subgroups, such as bast fibres, leaf fibres, seed fibres, fruit fibres, and wood fibres, as shown in Figure 1. Further commercially important fibre types along with their world production levels are presented in Table 1.

Table 1. Commercially important natural fibres

Fibre	Main Countries	Origin	World Production 2004 (tonnes)
Wood	Various (>10,000 species)	Stem	1,750,000,000
Bamboo	China (>1250 species)	Stem	10,000,000
Jute	India, Bangladesh	Stem	2,861,000
Kenaf	India, China	Stem	970,000
Coir	India, Vietnam, Sri Lanka	Fruit	931,000
Flax	China, Europe	Stem	830,000
Sisal	Brazil, Tanzania, Kenya	Leaf	378,000
Ramie	China	Stem	249,000
Hemp	China, Europe	Stem	214,000
Abaca	Philippines, Ecuador	Leaf	98,000
Agave	Columbia, Cuba, Mexico	Leaf	56,000

Figure 1 also shows examples of each classification, for example, the bast fibre subgroup includes fibres of the flax, hemp (Figure 2), jute, and kenaf plants, to name but a few. Bast fibres provide a good reinforcement in composite materials as the bast fibres task is to act as a reinforcement within the plant and provides stability. Using leaf fibres gives improved toughness and incorporating seed or fruit fibres imparts elastomeric type toughness to the component in question.

Figure 2. Industrial Hemp growing in China (Photo taken by the author on a visit to China in 2001)



A number of reasons for the increase in natural products can be cited, such as, recent concerns over dwindling petroleum supplies and their ultimate exhaustion in the distant future; increased government legislation such as land fill taxes; and a greater emphasis on sustainability and biodegradability. In short, there is a need to be seen to be using 'greener' products and processes.

In parallel to the increased awareness of natural materials as potential feed stocks for industrial products, there has been a great political drive towards sustainable technologies. Western governments have been seeking polymer materials

which are not reliant on crude oil; seeking lighter weight materials which can reduce carbon emissions by reducing vehicle weight; seeking natural insulation materials to improve energy efficiency of buildings; seeking carbon sinks such as forests (and forest products – timber) to lock up carbon dioxide; seeking recyclable or compostable materials which can reduce the landfill crisis. These policies have given a considerable “push” to the research community, with many interesting results.

INDUSTRY SECTOR APPLICATIONS

Composites currently occupy many market sectors of which a number are suited to the introduction of natural fibre composites as an alternative. Currently, the largest areas in which natural fibre composites are being employed include the automotive and construction industries.

Fibre quality for high end applications is often proportional to cost, for example the strongest flax fibre is slightly more expensive than glass due to competition with the textile industry, but lower grades of flax from linseed oil production are less expensive. The relative costs of other natural fibres such as jute, coir, sisal, hemp are considerably lower than glass, and vary with proximity to market and various agronomic factors between regions.

Production costs are reported to be reduced by 10-30% when natural fibres are used in place of glass fibre. The use of conventional processing methods means there is no need for new processing equipment and the equivalent processing conditions make transfer to this alternative feedstock very simple. Natural fibres are a good candidate fibre to use in products where traditionally glass fibres have been used. It is estimated that there are some 2.3 million tonnes of glass fibres being used in various applications around the globe, so there are a number of opportunities for natural fibres to be used in place of existing glass fibres. Natural fibres have several advantages over glass fibre: low density, low cost, high toughness, acceptable specific strength properties, good thermal properties, low embodied energy, reduced tool wear reduced tool wear in the moulding process and have better acoustic properties thereby reducing cabin noise, reduced irritation to the skin and respiratory system, and they also have a low energy requirement for processing. In addition they are biodegradable or recyclable depending on the selected matrix.

The biodegradable polymer matrices are still considerably higher priced than the “big four” thermoplastics (PE, PP, PS and PVC), although the costs have in general fallen during the last ten years as industrial production has scaled up. The costs are now roughly equivalent with the costs of more specialist polymers such as polycarbonate.

If we address a few of the main industrial sectors highlighted above we can see what has been showcased as the most recent developments in these sectors.

AUTOMOTIVE INDUSTRY

In the early 1930's, Henry Ford examined a variety of natural materials including cantaloupes, carrots, cornstalks, cabbages and onions in a search for potential candidate materials from which he could build an organic car body. He developed a prototype based on Hemp but due to economic limitations at that time the vehicle was not mass produced. Interest in natural materials diminished with the advent of other more durable materials, such as metals, and it was not until the 1940's that natural fibres began to make a comeback¹. Ford scientists discovered that soybean oil could be used to make high quality paint enamel and could also be moulded into a fibre based plastic². The company claimed that the material had 10 times the shock-resistance of steel. Henry Ford

delighted in demonstrating the strength of the material by pounding the soybean boot lid with an axe. If it was not for the fact that the material required a long cure time, and did not suffer from moulding problems, we might well be driving cars made from this material today.

Composites, particularly natural fibre reinforced plastics, have been receiving increased attention since 1941 in other industries such as the aerospace and marine industries³. The composites were used for making seats, bearings and fuselages in aircraft and for bearings in ships⁴. One particular example is that of "Gordon-Aerolite", a composite of unidirectional, unbleached flax yarn impregnated with phenolic resin and hot pressed. This was used in aircraft fuselages during World War II when materials supplies were restricted⁵. Cotton-polymer composites were reported to be the first fibre reinforced plastic used by the military for aircraft radar^{6,7}.

In the 1950's the body of the East German Trabant car was the first production vehicle to be built from natural Fibres, Cotton was used embedded within a polyester matrix⁸. These cars were still in production up until 1990, and can still be seen on the roads of Eastern European cities today.

Later, in the 1980's the first use of natural fibre and bio resin was used in combination to create the first all bio-composite automotive door panel. In the 90's, Daimler-Benz pioneered the use of natural fibres in commercial vehicles as part of the 'Belem' project based in the Amazon delta in South America. In this application, coconut fibres were used with latex in trucks for around a nine year period, with backrests, head restraints, bunk cushions and sun visors being produced, demonstrating the potential that indigenous fibres can have for a country and how they can be used in a commercial application in the automotive industry. This not only improved the quality of life for the individuals involved in this new application but it also became a commercial success and ensured its continuation.

Coconut fibres have been used in cars for more than 60 years in such applications as interior trim and seat cushioning. Estimated service life for these products is around 90 years – well exceeding the lifespan of the intended application⁹. Unlike plastic foam, the coconut fibres have good 'breathing' properties which is a distinct advantage for vehicle seats being used in countries where the climate is hot, as is the case in Brazil. Coconut fibres are also naturally resistant to fungi and mites and the remains of the fibres also make an effective natural fertilizer at the end of their lifetime⁹. In 1994, Daimler Chrysler started using flax and sisal fibres in the interior trim components of its vehicles. They continued investing in their application of natural fibres and in 1996 Jute was being utilised in the door panels of the Mercedes Benz E- Class vehicles. Daimler Chrysler as a company investing in environmental initiatives are a good example to cite here. In 2000, they spent around \$1.5bn on environmental initiatives of which \$870m was spent on environmentally friendly products and production processes resulting in a plethora of natural based components for their entire range of vehicles. German Car manufacturers are aiming to make every component of their vehicles either recyclable or biodegradable¹⁰.

Nowadays, there is an increasing trend for the use of natural fibres as a result of government legislation on environmental issues. This is particularly important in those countries where products from agricultural sources offer an attractive and cheap alternative for developing degradable materials¹¹. However, their potential use as a reinforcement is greatly reduced because of their hydrophilic (water absorbing) nature¹², and the lack of sufficient adhesion between untreated fibres and the polymer matrix¹³ resulting in poor impact resistance of the products. The issue of poor interfacial adhesion between fibres and matrix material is due to a mismatch in surface polarities – cellulose (polar) and polyolefins (non polar),

these issues have been addressed by the development of effective surface treatments¹⁴ for the fibres in both physical (Cold plasma and Corona) and chemical treatments (malaeic anhydride and organosilanes etc.). If a composite exhibits poor adhesion then it is going to be more susceptible to environmental attack and ultimately a reduced life span. As a result, considerable effort is currently being directed towards optimising the mechanical performance of fibre reinforced composites, and in particular their durability, through optimisation of the interfacial bond between the fibres and the polymer matrix¹⁵. Another issue in relation to poor impact properties is due to the high concentration of fibre defects imparted to the fibres in many cases during the mechanically intensive harvesting and processing stages which must also be addressed for improved product performance.

THE EUROPEAN AUTOMOTIVE INDUSTRY

The nature of the car industry (manufacturers, suppliers and legislation etc.) means it is necessary to look at the issue of these novel materials from a European perspective. The majority of examples quoted here relate to European based activities, clearly there are a number of other examples worldwide which warrant attention, however, this review covers developments within the European automotive industry predominantly. One of the most important sectors to have adopted natural fibres in recent years has been the European automotive. The second largest sector where these materials find use is in the construction industry¹⁶. It is also interesting to note that the situation in the United States (U.S.) is reversed. It is the construction sector which consumes the greater share of the natural fibre market at 64%, whilst the U.S. automotive industry has only a 16% share of the natural fibre market¹⁷. The United States automotive industry lags behind Europe by some 7 years.

A study conducted in 1999¹⁸ indicated that up to 20 kg of natural fibres could be used in each of the 53 million vehicles being produced globally each year. This means that for each new model of car there would be a requirement of between 1,000 and 3,000 tonnes of natural fibres per annum, with some 15,000 tonnes of flax being used in 1999 in the European automotive industry alone. To the natural fibre producer, the automotive market is attractive as a vehicle models platform life is for a minimum of 5 years but more realistically 7-8 years. This ensures a sustained period of demand for the natural fibres and helps to establish a period of credibility for the natural materials.

A study by the Nova Institute in 2000¹⁹ reviewed market possibilities for the use of short hemp and flax fibres in Europe. In this study, a survey of German flax and hemp producers showed that 45% of hemp fibre production went into automotive composites in 1999. One of the attractions of hemp, as compared with flax, is the ability to grow the crop without pesticide application. The potential for fibre yield is also higher with hemp.

Current well-established applications of natural fibres in automotive vehicles (Table 2).

The schematic of a generic vehicle, Figure 3, shows current applications from a range of different manufacturers. The type of natural fibre selected for manufacture is influenced by the proximity to the source of fibre, thus panels from India and Asia contain jute, ramie and kenaf, panels produced in Europe tend to use flax or hemp fibres, panels from South America tend to use sisal, curaua, and ramie.

The typical weight of natural fibres used within various parts of a vehicle are shown in Table 3:

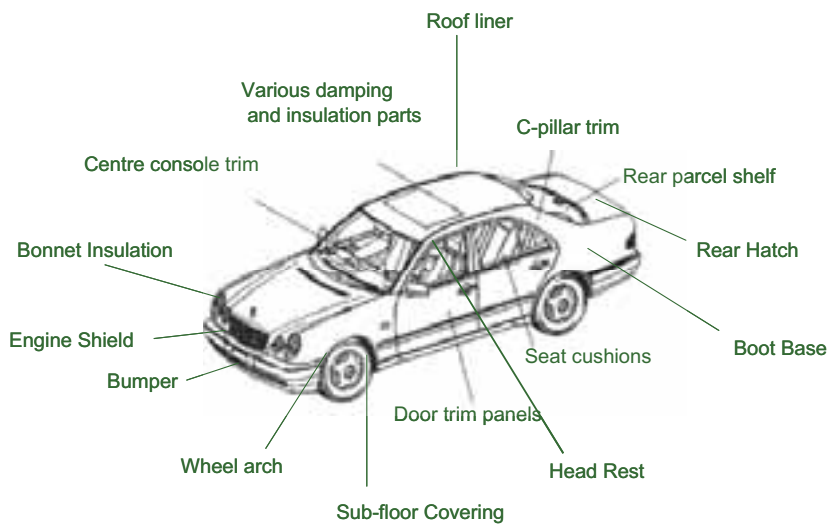
Virtually all of the major car manufacturers in Germany (i.e., Daimler-Chrysler, Mercedes, Volkswagen Audi Group, BMW, Ford and Opel) now use natural fibre composites in

Table 2. Vehicle manufacturers and use of natural fibre composites. ¹

AUTOMOTIVE MANUFACTURER	MODEL APPLICATIONS
AUDI	A2, A3,A4 (& Avant), A6, A8, Roadster, Coupe Seat backs, side and back door panels, boot lining, hat rack, spare tyre lining
BMW	3,5,7 series Door panels, headliner panel, boot lining, seat backs, noise insulation panels, moulded foot well linings
CITROEN	C5 Interior door panelling
DAIMLER-CHRYSLER	A, C, E and S-class models, EvoBus (exterior) Door panels, windshield, dashboard, business table, pillar cover panel
FIAT	Punto, Brava, Marea, Alfa romeo 146, 156
FORD	Mondeo CD 162, Focus Door panels, B-pillar, boot liner
LOTUS	Eco Elise (July 2008) Body panels, Spoiler, Seats, Interior carpets
MERCEDES-BENZ	TRUCKS Internal engine cover, engine insulation, sun visor, interior insulation, bumper, wheel box, roof cover
PEUGEOT	406 Seat backs, parcel shelf
RENAULT	Clio, Twingo Rear parcel shelf
ROVER	2000 and others Insulation, rear storage shelf/panel
SAAB	Door panels
SEAT	Door panels, seat backs
TOYOTA	Brevis, Harrier, Celsior, Raum Door panels, seat backs, Spare tyre cover
VAUXHALL	Corsa, Astra, Vectra, Zafira Headliner panel, interior door panels, pillar cover panel, instrument panel
VOLKSWAGEN	Golf, Passat, Bora Door panel, seat back, boot lid finish panel, boot liner
VOLVO	C70, V70 Seat padding, natural foams, cargo floor tray

applications such as those listed in Table 2. Ford uses from 5 to 13 kg (these weights include wool and cotton)²². The car manufacturer, BMW, has been using natural materials since the early 1990's in the 3, 5 and 7 series models with up to 24kg of renewable materials being utilised. In 2001, BMW used 4,000 tonnes of Natural fibres in the 3 series alone. Here the combination is a 80% flax with 20% sisal blend for increased strength and impact resistance. The main application is in interior door linings and panelling. Wood fibres are also used to enclose the rear side of seat backrests and cotton fibres are utilised as a sound proofing material.

Figure 3. Components on a generic vehicle, made from natural fibre composite materials²⁰



In 2000, Audi launched the A2 mid-range car which was the first mass-produced vehicle with an all-aluminium body. To supplement the weight reduction afforded by the all-aluminium body, door trim panels were made of polyurethane reinforced with a mixed flax/sisal mat. This resulted in extremely low mass per unit volume and the panels also exhibited high dimensional stability.

Recently, in the last few years, Volvo have started to use Soya based foam fillings in their seats along with natural fibres. They have also produced a cellulose based cargo floor tray – replacing the traditional flax and polyester combination used previously which resulted in improved noise reduction ²³.

Toyota has been using increasingly more natural fibres in their components since 1999²⁴, in the range of their vehicles such as in the Celsior, Brevis and Harrier. Kenaf fibres used in board production along with Polypropylene is the composite of choice for door trims, manufactured at Toyota’s Indonesian production facility. What is interesting to note in this case is that the three vehicle models mentioned above adopted the natural fibre components within a relatively short time frame of 4 years for the three models. Toyota also claim to have manufactured the first mass produced 100% natural automotive product in the world back in May 2003 namely the RAUM spare tyre cover which is comprised of Kenaf fibre and Polylactic acid or PLA as it is commonly known. Lactic acid-

based polymers (polylactides) are polyesters made from lactic acid, a compound found in both plants and animals.

Table 3. Natural fibre usage per component²¹

Component	Weight (Kg)
Front door liners	1.2-1.8
Rear door liners	0.8-1.5
Boot liners	1.5-2.5
Parcel Shelves	<2
Seat Backs	1.6-2
Sunroof shields	<0.4
Headrests	2.5

The present level of car production in Western Europe is about 16 million vehicles per year. This figure therefore equates to a current usage of 80,000 to 160,000 tonnes of natural fibre per year. German automotive manufacturers continue to lead the way, with Daimler-Chrysler for example, having a global natural fibre initiative program that benefits third world nations by developing products made from indigenous agricultural materials.

The Mercedes-Benz Travego travel coach, is equipped with flax reinforced engine and transmission covers. This was the first use of natural fibres for standard exterior components in a production vehicle and represents a milestone in the application of natural fibres. Exterior components pose interesting issues for the manufacturers, as in these applications the components must function as a protective cover for the vehicle and as a result the component must be able to resist a more aggressive environment (as compared to the interior applications) being exposed to both weathering effects and also chipping caused by debris making contact with the external surface.

Daimler-Chrysler made considerable investment in Research and Development in flax reinforced polyester composite for exterior or semi-exterior applications in recent years. A truck with flax-based, rather than glass-based, exterior skirting panels is now in production. Tests carried out by the Daimler-Chrysler Research Centre in Ulm, Germany, showed that these composite components stood up to impact without shattering into splinters, which is an important consideration in crash behaviour tests. They were also dimensionally stable and weather-resistant. Daimler-Chrysler suppliers found that switching from using glass fibres to natural fibres resulted in no problems in terms of the production equipment⁹ being able to use the same tools and machines and importantly at no additional cost to the manufacturer.

Daimler-Chrysler committed to producing a spare wheel well cover for the A-class vehicle in January 2002, this came into being in January 2005. The cover incorporates Abaca fibres in the exterior application of an under floor cover. It won the JEC award for innovation in May 2005 and also the Daimler Chrysler Environmental leadership award in November of the same year. The goals of the project were to create a functional safeguard component with equal characteristics to those of glass fibre products. The component also had to meet stringent test procedures which included – water crossing, kerbstone contact, shaking routes, heat, rock slides, and acoustic tests.²⁴

The benefits realised in the Travego coach include a weight reduction in the engine/transmission cover of 10% and a cost reduction of 5% over traditional materials. Fibres were typically purchased in 2002 for about 0.5-0.6 Euros/kg. This compares with approximately 1.5 Euros/kg for glass fibre rovings used in standard composite reinforcements. Natural fibres also exhibit numerous other advantages which have been reported widely in the literature over synthetic fibres^{25,26}.

One of the most recent developments within the automotive industry and announced in July of 2008, has been the release of the Lotus Eco Elise, (Figure 4). Renewable

Figure 4. Lotus Eco Elise (launched July 2008) with body panel, spoiler, seats made from natural fibres. Hemp plants growing shown in the background. (with permission)



materials such as Hemp, Eco wool, and Sisal have been utilised providing natural, biodegradable engineering materials. With the use of locally farmed Hemp (from East Anglia), the carbon miles to produce the Eco Elise are therefore reduced. Sustainable hemp technical fabrics have been used as the primary constituent in the high quality 'A' class composite body panels and spoiler. The hemp fibre has also been used in the manufacture of the lightweight lotus designed seats. The hemp material is used with a polyester resin to form

a hybrid composite, however, the intention is to use a fully recyclable resin in the future. Sisal, a renewable crop, has been used for the carpets in the Eco Elise, as it is a tough, abrasion resistant material.

Another development in the automotive industry announced in 2008 at the EcolnnovAsia 2008 event in October, related to the Mazda 5 car. In this application the manufacturer is using a bioplastic (namely PLA) in the interior consoles along with Kenaf and PLA in the seat covers. The manufacturer stated that 30% of the cars interior components were made from biobased materials.

Brake pads interestingly are one of the key components in the race to develop greener transport, with 80 million sets used in the UK every year. Since the use of asbestos was phased out in the 1980s, most have been formulated using man-made aramid fibres. They also incorporate significant amounts of heavy metal compounds. Around 20,000 tonnes of dust containing these materials are discharged into the environment as the pads wear each year. Now research into eco-friendly brake pads, backed by the Sustainable Technologies Initiative, has shown how a switch to natural fibres such as hemp, which can be grown in the UK, could offer a more sustainable solution. Researchers demonstrated how renewable fibres could reduce the reliance on synthetic materials and allow heavy metal constituents to be replaced with safer alternatives. The outcome is expected to provide up-to-date solutions to the global transport industry and its friction material supply base. Commercial development is going ahead, initially for the railway industry. The main end users, EFI, are particularly interested in exploiting the use of hemp in train brakes. Customers in Norway and other parts of Europe want to remove the use of sintered metal brakes that result in heavy metals getting into the environment. Interest is also expected from operators of underground and metro lines because of health concerns over airborne brake dust particles in enclosed spaces. The natural materials could cut production costs by a significant margin. Aramid fibre costs 20-30 times more than hemp fibre and it stands out as by far the most expensive ingredient that goes to make up a brake pad.

The two most important factors now driving the use of natural fibres by the automotive industry are cost and weight, but ease of vehicle component recycling is also an ever-increasing consideration to meet the requirements of the end of life vehicle directive. When you consider that 10million cars are scrapped in Europe each year (11m in the US), and

of those 96% are processed by shredder facilities, leaving 25% of the vehicles weight remaining as waste products in the form of plastics, fibres, foams, glass and rubber. The directive aims to 'depollute' all scrapped vehicles, avoid hazardous waste and reduce the amount of materials going to landfill sites to a maximum of 5% per car by 2015.

Figure 5. Eco-1 racing car



Racing Cars

The ethos for the Eco-1 racing car (Figure 5) was simple: 'Create a high-performance racing car that had a conscience'. Wherever possible, sustainable materials and manufacturing processes were used during construction. Eco-1 has tyres, bodywork, brake pads, lubricants and fuel made from natural, renewable materials. The chassis is made from steel and aluminium which can be recycled easily and efficiently. The tyres have a component which is

made from Potato or maize starch and are commercially available road legal tyres that offer very low rolling resistance. The hydraulic oil and the engine oil are a plant oil ester (which can also be used in a standard road car). The brake pads are made from CNSL (Cashew Nut Shell Liquid), Hemp and Jute, and the fuel to power the vehicle is derived from wheat. In total the racing car is 90-95% recyclable or biodegradable. Just because the materials the car is made from are friendly to the environment, it doesn't mean that performance has to be compromised. It is a car with a power-to-weight ratio of 350bhp per tonne, a car that does 0-62mph in four seconds, and that will go on to a top speed in excess of 125mph.

CONSTRUCTION INDUSTRY

The construction industry constitutes the second largest sector to employ natural materials in a range of products which include (but are not limited to):

1. Light structural walls
2. Insulation materials
3. Floor and wall coverings
4. Geotextiles
5. Thatch Roofing

We are also seeing a range of products such as sisal cement products – roof tiles and building blocks being produced in countries such as Tanzania and Brazil. Coir based products from India, which are strong, naturally termite and insect resistant, waterproof, flame resistant and carpenter friendly (excellent nail and screw holding properties) which make them ideal candidate materials in the construction sector.

LEISURE INDUSTRY

A range of products for the leisure industry have been publicised recently incorporating natural fibres. This section identifies just a few of these products.

Fishing Rods

Cellucomp have developed a fishing rod based on carrot fibres. The material is trademarked as CURRAN and is made from a high strength biofibre. The fibre used is nanoscopic in size which not only provides incredible strength, stiffness and toughness but also allows for a very smooth surface finish in the final product. The fibres have a stiffness of 130GPa, strength of upto 5GPa and failure strains of over 5%. The CURRAN material can also be utilised in a range of other sports equipment such as snowboards. The new "Just Cast" rods are around 50 per cent carrot - each made with around 2kg of the vegetables. But it is hoped that as the technique is developed, they will eventually be able to make products which are made from 100 per cent biological matter - carrots and other plants. Through a special process, nano fibres found in carrots are extracted and combined with high-tech resins enabling tough, durable components to be moulded to whatever shape, degree of stiffness, strength or lightness required. The company are already looking at using other vegetables such as turnips, swede and parsnips for other applications. It is interesting to note that carrots were one of the candidate materials considered by Henry Ford back in the early 1930's for use in vehicle body parts.

Audio Components

Eureka project E! 2819- Factory Ecoplast is combining natural fibres with thermoplastics to create new recyclable compounds for consumer products and audio components. Partners in the Eureka Factory Ecoplast project decided to join efforts to develop a palletised compound suitable for injection moulding and extrusion processes, combining two or more

material components in such a way that the resulting compound is better than any of the individual components alone. The new materials are suitable for use in the manufacture of a wide variety of products, including vacuum cleaner and lawn mower parts, storage boxes and even golf tees. Further tests of the project's new 'Eureka' speaker boxes show higher frequency acoustic performance on a par with market leaders.

Bicycles

The Museeuw bicycle incorporates flax fibres along with carbon fibres to produce the 'flax carbon hybrid race bike'. This bicycle was designed and built by the former world cycling champion Johan Museeuw. The bikes (3 different designs) are manufactured by hand and provide a unique combination of exceptional stiffness and tremendous absorption, providing a very pleasing ride (according to users) without any additional weight. Future developments include creating a wheel from 50% flax and 50% carbon fibre.

MISCELLANEOUS PRODUCTS

Included in this category are items such as grinding wheel discs with 1million units being produced each year under the trade name Plantex, in this instance hemp and polypropylene (PP) are being used to create the backing plates for these industrial products.

Cosmetic packaging is an area also seeing the adoption of natural fibres. In the USA, a lip stick casing made from Flax fibres and PP which has been on sale for 4 years selling 4million units per year.

Funeral Urns made from natural fibres and PLA which after a limited time wil naturally decompose leaving no physical residue behind.

Key events such as the 2008 Olympics hosted by China and held in Beijing (predominantly) presented an ideal opportunity to utilise natural materials on a global stage. This event alone used 80,000 tonnes of natural fibres, mainly in the buildings.

CONCLUSIONS

The use of natural fibres in a range of industrial applications has increased significantly over the last decade. The possibilities of utilising natural fibres are now being realised and as a result there are now numerous examples where natural materials have found application in a number of diverse sectors from automotive and construction industries, to packaging and leisure based products.

The recent surge of activity has been driven by an increase in western governments seeking polymer materials which are not reliant on crude oil; seeking lighter weight materials which can reduce carbon emissions by reducing vehicle weight; seeking natural insulation materials to improve energy efficiency of buildings; seeking carbon sinks such as forests (and forest products – timber) to lock up carbon dioxide; seeking recyclable or compostable materials which can reduce the landfill crisis.

An increase in consumer awareness on the subject of recycling and the impact that materials have on the environment have also played a key role in the adoption of these novel materials. A greater understanding of natural composite materials by researchers are also contributing to a greater interest and uptake in these natural based composite systems by industry that will continue to lead to more and more products entering the marketplace in the future.

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