Natural Fibre Composite

By: Sekhar Das

Natural Fibre Composite

By: Sekhar Das

1. Introduction

The first composite material known was made with clay and straw to build walls in Egypt 3,000 years ago. The success story of Genghis Khan is related with a composite bow. Genghis Khan began the Mongol invasions but it was the powerful composite bow which carried their civilization out of the steppe. The main advantage of composite bows over self bows (made from a single piece of wood) is their combination of smaller size with high power. Natural fibres have been using as a reinforcement material for composite till date. But after invention of glass fibre in 1938, glass fibre occupied a large amount of reinforcement material over natural fibre.

Later on, natural fibre lost much of its popularity. Other materials which were more durable like metals were introduced. The rise of composite materials began when glass fibre in combination with tough rigid resin could be produced on large scale during the sixties. During the last several decades there has been a renewed interest in the natural fibre as a substitute for glass, inspired by potential benefits of lower raw material price, weight saving, and 'thermal recycling' or the ecological advantages of using resources which are renewable.

Global concern for climate change, as reflected in Kyoto Protocol, pressure by different 'green groups' have led to enactment of Directive 2000/53/EC by the European Parliament on End-of life Vehicles. The directive stipulates that re-use and recycling of end-of-life vehicles must increase to 95% by 2015. Since 2000, steady growth of use of natural fibre composite in European cars has been observed. Similarly in USA, environmental concern has led to large scale use of "plastic lumber"---an NFC, as a substitute for wood.

2. Constituents of composites

1. Matrices
2. Reinforcement
3. Coupling Agents:
4. Fillers & Additives

Matrices
The role of matrix in a fibre-reinforced composite is to transfer stress between the fibres, and to provide a barrier against an adverse environment and to protect the surface of the fibres from mechanical abrasion. To protect fibre surface from abrasion, Matrix has only minor role in tensile load carrying capacity of the composite.

Reinforcement
Reinforcement materials are generally three types 1) Fibres 2) Whiskers 3) Particles
The main role of reinforcement to provide strength of composite, matrix is having lower stiffness than reinforcement so overall strength will be increased.

Coupling Agents
Following are the coupling agents:

a) To improve fibre-matrix interfacial strength
b) To protect the interface from environmental conditions such as moisture.

Fillers & Additives
Role:

a) To reduce cost
b) Increase stiffness
c) Reduce mould shrinkage
d) Control Viscosity
e) Impart fire-retardancy
f) Protection from UV rays
g) Processing aids.

3. General Classification of Composite Materials

Based on the nature of the matrix, composites can be grouped into categories

i) Polymer Matrix
ii) Metal Matrix
iii) Ceramic Matrix

Polymer Matrix Composites (PMCs)

The most common advanced composites are polymer matrix composites. Polymer matrix composites are light weight and high strength. These composites consist of a polymer thermoplastic or thermosetting reinforced by fibre. These materials can be fashioned into a variety of shapes and sizes. They provide great specific strength and stiffness along with resistance to corrosion. These are most common due to their high strength, lower cost and simple manufacturing principles.

Metal Matrix Composites (MMCs)

Metal matrix composites have a metal matrix, as the name implies. Examples of matrices in such composites include titanium, aluminium and magnesium. The typical fibre includes carbon and silicon carbide. Reinforcement of metals is mainly done to suit the needs of design. Example: the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion and thermal and electrical conductivities of metals can be reduced by the addition of fibres such as silicon carbide.

Ceramic Matrix Composites (CMCs)

Ceramic matrix composites have ceramic matrix such as calcium, alumina, alumina-silicate reinforced by silicon carbide. The advantages of CMC include hardness, high strength, high service temperature limits for ceramics, low density and chemical inertness. Ceramic materials have a tendency to become brittle and to fracture as they are naturally resistant to high temperatures. Composites successfully made with ceramic matrices are reinforced with silicon carbide fibres. These composites offer the same high temperature tolerance of super alloys but without such a high density. Usually most CMC production procedures involve starting materials in powder form. The brittle nature of ceramics makes composite fabrication difficult.

4. Which Natural Fibres are suitable for reinforcement Used:

Fibre is having higher stiffness than resin so incorporating fibre into resin, the composite stiffness will be increased. Various types of natural fibres are using for composite manufacturing but bast and leaf fibres are most suitable for composite used.

Classification of Natural Fibre based on plant

Fibre Name	Fibre Description
Seed fibre	Fibres collected from seeds or seed cases. e.g. kapok and cotton
Leaf fibre	Fibres collected from leaves. E.g. sisal, fique, banana and agave.
Bast fibre	Fibres are collected from the skin or bast surrounding the stem of their respective plant. Bast fibres have higher tensile strength than other fibres. Hence, these fibres are used for durable yarn, paper, fabric and packaging. Few examples

	are kenaf, flax, ramie, jute, industrial hemp, rattan and vine fibres.
Fruit fibre	Fibres are collected from the fruit of the plant, e.g. coconut (coir) fibre.
Stalk fibre	Fibres are actually the stalks of the plant. E.g. straws of wheat, barley, rice and other crops including grass and bamboo. Tree wood is also such a fibre.

According to Mclaughlin and Tait relationship between Tensile Modulus (E_f) and cellulose Volume Fraction (Vc) and Microfibril Angle (θ) is

$$E_f = EcVc \cos^2 \theta + (1\text{-}Vc)Enc$$

Ec and Enc are tensile moduli of cellulosic and non-cellulosic components (hemicelluloses, lignin)

Thus, Low θ→ Higher E_f → Stronger Fibre.
For Bast & Leaf Fibres, Vc ≈ 0.4-0.8, θ<10° & 15°-25°, Suitable as Reinforcement
Ramie is exception – Vc ≈ 0.8-0.9, θ<10°,
Suitable as Reinforcement
Coir – Vc < 0.4, θ =30°-45°, Not Suitable
Cotton– Vc = 0.4-0.8, θ =30°, Not Suitable
So, Reinforcing Fibres should have High Vc, Low θ

Fibre	**Density g/cm^3**	**Tensile strength* $10E^6$ N/m^2**	**E-modulus (GPa)**	**Elongation at failure (%)**	**Moisture absorption (%)**	**Microfibrillar angle (°)**
E-glass	2.55	2400	73	3	-	-
flax	1.4	800 - 1500	60 - 80	1.2 - 1.6	7	5-7
hemp	1.48	550 - 900	70	1.6	8	6-8
jute	1.46	400 - 800	20 - 55	1.8	12	7-9
ramie	1.5	500	44	3.7	12 -17	
coir	1.25	220	6	15 - 25	10	39-49
sisal	1.33	600- 700	38	2 - 3	11	10-22
banana	1.35	529-900	27-32	1-3	11	10-12
cotton	1.51	400	12	3 - 10	8.5	20-30

5. Advantage of Natural Fibre Composites:

1. Low specific weight, which results in a higher specific strength and stiffness than glass. This is a benefit especially in parts designed for bending stiffness.
2. It is a renewable resource, the production requires little energy, CO_2 is used while oxygen is given back to the environment.
3. Producible with low investment at low cost, which makes the material an interesting product for low-wage countries.
4. Friendly processing, no wear of tooling, no skin irritation
5. Thermal recycling is possible, where glass causes problems in combustion furnaces.
6. Good thermal and acoustic insulating properties

7. Less energy used than with traditional materials;
8. Lower cost.

6. Disadvantages of Natural fibre composite:

- Poor compatibility between fibre and matrix resins /polymers (Lower strength realization, higher resin consumption)
- High moisture absorption (Poor dimensional stability)
- Lower strength properties, particularly its impact strength
- Variable quality, depending on unpredictable influences such as weather.
- Moisture absorption, which causes swelling of the fibres
- Restricted maximum processing temperature.
- Lower durability, fibre treatments can improve this considerably.
- Poor fire resistance
- Price can fluctuate by harvest results or agricultural politics.

7. Major Areas of Application are:

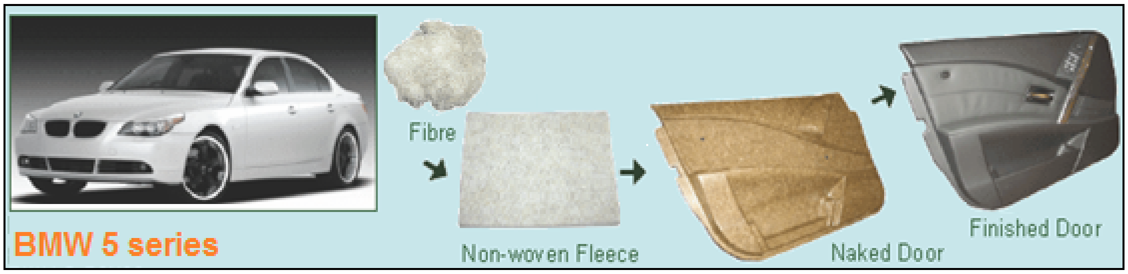
Automotive — 31%
Construction — 26%
Marine —12%
Electronic — 10%
Consumer Goods — 8%
Appliances — 8%
Miscellaneous — 4%
Aerospace — 1%

In car manufacturing industries have been using natural fibre composite for making different body parts of car.

Door systems: bolsters, arm rests, center inserts, upper door panels and full door substrates made from natural fibre composite blends.

Load Floors are located in the rear of the vehicle as these functional weight carrying components require strength and functionality. We utilize natural fibre and polypropylene to create load floor component substrates.

Package trays and back panels, these components made from a natural fibre substrate help to reduce interior road noise that flows through the back of the cab wall. Natural fibre components have the ability to incorporate attachments and clip attachments.
Fibre boards, panel, door shutters, paper, roofing sheets, plastering of walls, autoclaved cement composite.



8. Conclusions

The environmental and cost benefits connected with the use of natural fibre wide success. However, many limitations must be overcome in order to exploit the full potential of natural fibres. Natural fibres are not compatible with hydrophobic resins so natural fibre cannot form chemical bonds with hydrophobic resins. At first proper fibre surface treatment should be developed to enhance the compatibility with hydro phobic resins. There are several proposed techniques can be applied to increase compatibility 1)Physical Methods: Carona Treatment Plasma Treatment Heat Treatment 2) Chemical Methods : Alkali Treatment, Esterification, Treatment with Coupling Agents, Graft Copolymerization, Treatment with Polymeric Dispersion etc.

9. References

1. *http://en.wikipedia.org/wiki/Composite_material, July 2012*
2. *http://en.wikipedia.org/wiki/Natural_fibre, July 2012*
3. *Saira Taj, Munawar Ali Munawar, and Shafi ullah Khan 2007, Natural fibre-reinforced polymer composites, Institute of Chemistry,University of the Punjab, Lahore, Pakistan*
4. *Saheb DN & Jog JP. (1999) Natural fibre polymer composites: A review. Adv Polym.*
5. *Technol., 18, 351–63.*
6. *Chawla, K.K. 1987. Composite Materials. Science and Engineering. Springer-Verlag, New York.*
7. *Roe, P. and Ansell, M. 1985. Jute reinforced polyester composites. J. Mater. Sci. 20:4015-4020.*