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Natural fiber-mediated epoxy composites – A review

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ABSTRACT

With growing inclination towards the eco-friendly technology, natural fiber based polymer composite materials have been gaining a lot of momentum nowadays. The present review discusses the much research that has been carried out in the area of the epoxy-based composites reinforced with natural fibers. Influence of the various factors like the fiber content, fiber geometry, fiber size, surface treatment technique, and coupling agent on different properties like mechanical, thermal, behavior towards water absorption and others have been presented. It can be inferred that there is a need and scope for improvement of the surface properties of natural fiber using various methods like physical and chemical treatments, addition of coupling agents, etc. for the manufacturing of the composites having desired properties. These techniques not only modify surface morphology, but also improve other processing parameters like the hydrophilic character of fiber (which is desirable to be low), and hence improve several characteristics such as mechanical properties, thermal stability, water absorption and other considerations of the composites.

1. Introduction

Composite materials are not new to the world. In nature, wood is a naturally occurring composite consisting of cellulose fibers (reinforcement) in lignin (matrix); moreover, in a building system, the wall is a composite of cement and bricks. Fiber-built polymer matrix composites are finding applications in households and industries because they have more favorable properties such as high stiffness, greater strength, better fatigue performance, more corrosion resistance, low thermal expansion, low energy consumption during manufacturing and have non-magnetic properties [1–8]. Over the past decade, the use of bio-fibers as substitute for synthetic fiber (carbon and glass), as fillers in the development of polymer matrix composites has attracted much attention. The properties of bio-fibers like abundance, low density, low cost, renewable quality, high modulus, harmlessness, and biodegradability facilitates association with polymer to produce composite materials [9,10].

There is increased awareness about the properties of natural fiber based epoxy composites to meet engineering requirements. Epoxy resin and its composites have received considerable attention over the years for their use as structural materials at low temperature. For both industry and research communities, it is, therefore, a matter of concern to overview and assess the status quo and put efforts for more sustainable and feasible commercial exploitation and further development. The main objective of this review is to study the formulation, characteristics and performance of various cellulosic fiber mediated epoxy composites, hence to provide the fundamental basis for further research in the area and to enable the optimization of the composites for possible industrial uses. Numerous reports are available on natural fiber epoxy based composites and their characteristic analysis (Table 1).

2. Epoxy

The epoxy resin is a feasible polymer, which has effective strength, good toughness, and appreciable resilience. It has good resistance to moisture and chemical attack. It also has great electrical insulating properties and is devoid of volatile matter [11,12]. They can be cured at ambient temperature without any pressure by using a curing agent or may be heat cured. They can be bonded to nearly all materials like wood, glass, natural fibers, and metal [13,14]. They exhibit little or no shrinkage after curing. Properties of epoxy resin are shown in Table 2.

3. Natural fiber

Vegetable, animal and mineral fibers are part of the natural

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Table 1
Reported work on natural fiber reinforced epoxy composites.

Natural fiber	Characteristics	Reference
Cellulose fiber	Mechanical properties	[17]
Bamboo fiber	Wear properties	[18]
Sisal fiber	Tensile, wear and water absorption characteristics	[19]
Hemp fiber	Impact and flexural properties	[20]
Piassava fiber	Mechanical Characteristics	[21]
Cellulose fiber	Toughness and Impact strength	[22]
Recycle cellulose fiber	Flexural, fracture toughness and water absorption	[23]
Coir fiber	Tensile properties	[24]
Jute fiber	Flexural and inter-laminar shear strength	[25]
Flax fiber	Data related with Rosen Model	[26]
Wood dust	Mechanical characteristics	[27]
Wood dust	Analysis tensile and flexural strength using Taguchi Method	[28]
Kenaf fiber	Tensile and flexural strength	[29]
Ramie fiber	Mechanical strength	[30]
Kenaf fiber	Validate the tensile strength between experiment and theoretical using (Rule of Mixture)	[31]
Cellulose fiber	Thermal properties	[22]
Sugar palm fiber	Fickian diffusivity	[32]
Weave flax fiber	Water diffusivity	[33]
Flax fiber	Fracture and toughness	[34]
Palm tree fiber	Dielectric properties	[35]
Hemp yarn fiber	Study between experimental and numerical results	[36]
Silk	Energy and failure response	[37]
Silk	Crashworthiness characteristics	[38]
Hemp fiber	Fatigue behavior	[39]
Flax fiber	Damping behavior	[40]
Flax fiber	Fatigue behavior	[41]
Flax fiber	Crashworthiness characteristics	[42]
Flax fiber	Interfacial characteristics	[43]
Hemp fiber	Fatigue behavior	[44]
Flax fiber	Fire reaction characteristics	[45]
Natural silk	Absorption energy	[46]
Flax fiber	Crushing property	[47]
Hemp fiber	Rheological and thermal analysis	[48]
Banana fiber	Tensile and flexural strength	[49]
Tenax leaf fiber	Mechanical and thermal characteristics	[50]
Bamboo fiber	Wear and frictional characteristics	[51]
Flax fiber	Fatigue properties	[52]
Jute fiber	Tensile characteristics	[53]
Flax fiber	Tensile and compressive characteristics	[54]
Sisal fiber	Tensile and flexural properties	[55]
Betelnut fiber	Wear and abrasion characteristics	[56]
Agave fiber	Mechanical characteristics	[57]
Flax fiber	Crashworthiness properties	[58]
Phormium leaf fiber	Flexural and water absorption characteristics	[59]
Sugar palm fiber	Tensile characteristics	[60]
Arenga pinnata fiber	Mechanical properties	[61]
Agave fiber	Tensile and flexural characteristics	[62]
Kenaf fiber	Flexural characteristics	[63]
Fique fiber	Flexural properties	[64]
Recycled cellulose fiber	Fracture and flexural characteristics	[65]
Flax fiber	Tensile properties	[66]
Banana fiber	Visco-elastic behavior	[67]
Bamboo fiber	Tensile and elongation properties	[68]
Natural silk fiber	Crashworthiness properties	[69]
Sisal fiber	Impact and flexural characteristics	[70]
Coconut fiber	Adhesion properties	[71]
Kenaf fiber	Mechanical characteristics	[72]
Luffa fiber	Mechanical and thermal behavior	[73]
Kenaf fiber	Thermal properties	[74]
Coconut sheath fiber	Mechanical and thermal characteristics	[71]
Abaca fiber	Thermal study	[75]
Agave fiber	Water absorption study	[62]
Recycle cellulose fiber	Water absorption study	[65]
Bamboo husk fiber	Mechanical and thermal characteristics	[76]
Jute	Wear properties	[77]
Basalt fiber	Tensile and flexural characteristics	[78]
Nano cellulose	Thermal and mechanical study	[79]

fibers. Various sources for obtaining fibers are seed, leaf, stem etc. These fibers give a superior strength to a composite when reinforced with the polymer matrix. Huge availability of bio-fibers and ease in comfort fabrication has lured researchers to produce bio-fiber based composites for their research. Plants are producing two types of natural fibers: one is primarily fiber and another is secondary fiber. Fiber which is directly obtained from plant root is called the primary fiber while secondary fibers are the byproducts