Journal of Mines, Metals and Fuels, 71(6): 764-769; 2023. DOI: 10.18311/jmmf/2023/34491

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: www.informaticsjournals.com/index.php/jmmf

A Comprehensive Review on Kenaf Fiber Reinforced Polymer Matrix Composites for Non-Structural Applications

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Abstract

Due to renewable and environmental concerns, the creation of high-performance engineered goods created from natural resources is rising globally. Plant fibres are gaining popularity in polymer composites due to their environmental friendliness and lower cost than synthetic fibres. Because of its low density, Kenaf fibre offers superior specific characteristics than glass fibre as a reinforcement. Hence, development of composites for various applications plays a mojor role in industrial revolution. Kenaf plants, one of many distinct forms of natural resources, have been intensively exploited in recent years. As a result, this article provides an overview of recent advancements in the field of Kenaf fibre reinforced composites. Several essential challenges and future work proposals are highlighted, emphasizing the roles of material scientists and production engineers in ensuring the bright future of this novel "green" material through value addition to increase its use.

Keywords: *Polymer composites, Kenaf fiber, Green composites, Composite properties.*

1.0 Introduction

In comparison with their traditional isotropic equivalents, recent innovations have elevated the use of composite materials. Their major features, including enhanced ratio of strength to weight, reduced weight have fuelled this change, allowing for large weight reductions while maintaining appreciable properties. Composites are often made up of a polymer foundation induced with various synthetic and natural fibers.

To minimize the final product's density, composites are extensively using synthetic fibres[1,2]. Artificial fibres have recently lost favour with businesses and engineers owing to environmental and energy concerns[4-13]. Natural fibres provide several advantages, including environmental friendliness, reduced cost, reduced weight and acceptable mechanical and physical properties[14]. The benefits provided by naturally available fibers have resulted in them being emerged as potential substitutes for artificial fibers[15,16,19-25], and are commonly utilised in interiors of automobiles[26,27]. They do, however, have significant disadvantages, like lower resistance against absorbing water and mechanical properties compared to artificial fibres[28,29]. As a result, academics are experimenting with a range of approaches to overcome these issues[30,31]. One method is to treat the natural fibres[32]. Alkali treated fibers exhibit better properties compared to untreated fibers[33]. Natural fibres may be a feasible alternative to synthetic fibres in sacrificial structural applications[34-37].

Natural fibres come in a wide range of sources and variations. Figure 1 depicts the classification of natural fibres.

Natural fibre reinforced PMC is most typically made using

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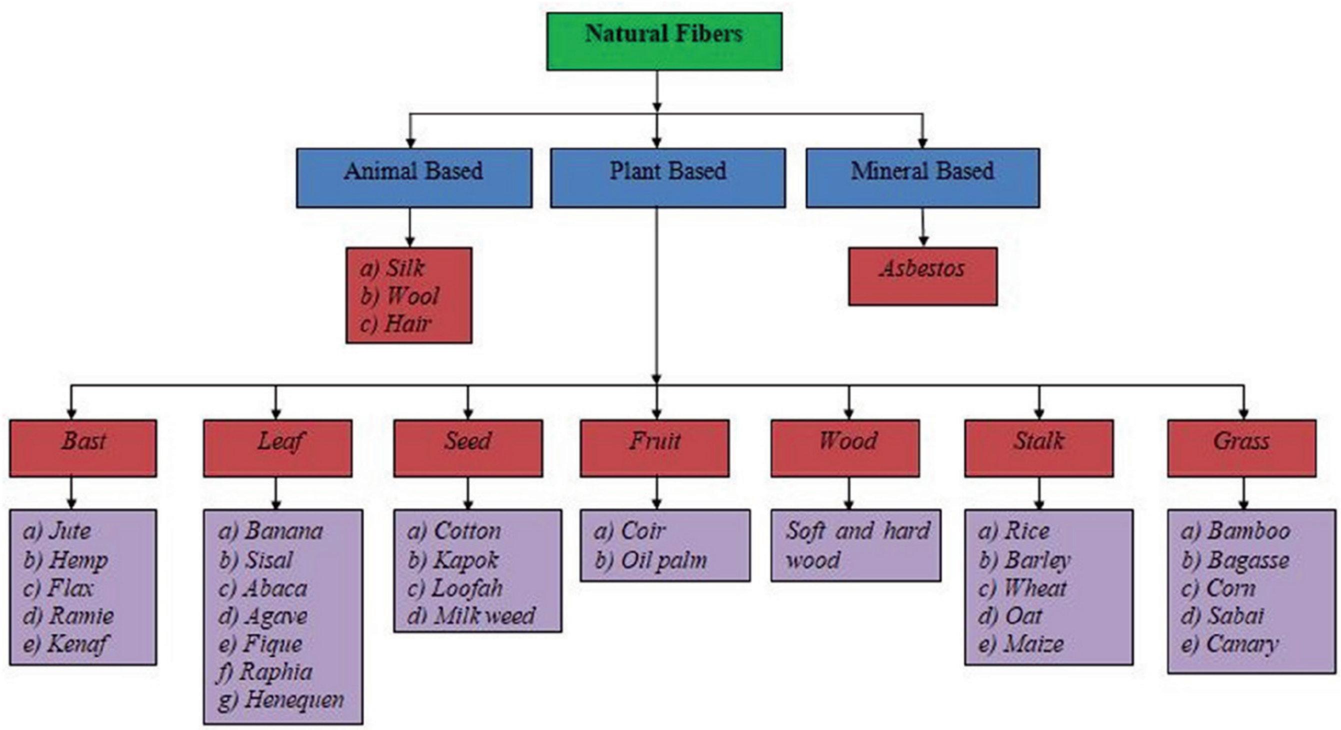

Figure 1: Fibers classification

plant-based natural fibres. Plant-based fibres are collected from many sections of the plant; Fig.2 shows the principal fibres derived from various portions of the plant.

Many researchers are interested in natural fibres as a reinforcing material in composites due to a number of benefits they offer such as low weight and cost, available with ease and exhibit acceptable strength[16-18]. Natural fibres are also known to be non-uniform having uneven cross sections, which distinguishes their structures from synthetic fibres.

2.0 Kenaf Fibers

Bast and core of the kenaf plant, also known as Hibiscus cannabimus L., are separated. The long fibers are extracted from bast region, which takes around 35 per cent of the weight of the dried stalk, whereas the short fibers come from the kenaf plant's centre[38]. The height of the plant varies from 1 m to 5 m, and yearly yield per acre of agricultural land can range from 600–10,000 kg of dry fibre. The kenaf plant's stem is divided into three sections: central, outer, and inner. Pith are polygonal parenchymatous cells that make up the core component[39]. The fibres from the stem's outer section have outstanding mechanical qualities and might be used in composites. Furthermore, kenaf has the advantage of being able to employ nearly 40 per cent of yield from stalk for production of fiber, which is nearly, double that of other natural fibers. As a result, it is quite inexpensive[40].

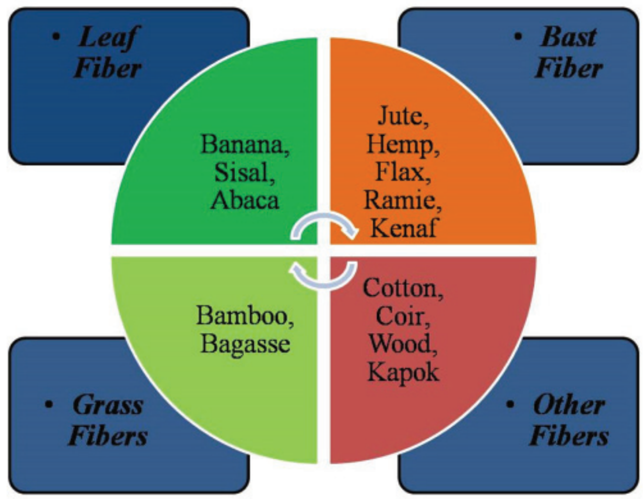

Figure 2 Popular natural fibres derived from various plant components

Natural fibre has a well-defined structure and components[41]. Plant-based natural fibres are made up of cellulose, hemicelluloses, lignin, pectin, and other components, and their characterisation is done on the basis of their contents. As seen in Fig.3, natural fibre has one thin primary wall and three thick secondary walls.

The main wall, which is deposited during cell formation, surrounds the secondary wall. The secondary wall has three layers, with the middle layer controlling the mechanical properties of the fibre[42]. When the fiber axis has parallel microfibrills, the fibre strength is found to be higher[43]. The fiber's characteristics are mostly determined by cellulose, which is the primary component[44]. Hemicellulose is a type of polysachrides with 5 to 6 carbon ring sugars that are hydrophilic in nature[45]. amorphous polymer network called lignin works as a chemical adhesive within and between fibres. It is made up of an uneven array of differently bound hydroxy- and methoxy-substituted phenylpropane units[46]. The amount of lignin and hemicelluloses in the fibre determines its toughness, which is proportional to each other. Simultaneously, the fiber's strength and stiffness are shown to rise up to a specific point[47]. D-galacturonic acid residues are abundant in pectins. Hemicelluloses, pectin polysaccharides, and the aromatic polymer lignin mix with cellulose fibrils to form a rigid structure that aids in plant cell wall reinforcement[48]. The chemical constitution and fibre sources in the plant dictate the majority of natural fibre properties. In order to determine natural fibre properties, a living plant's fibre function is crucial.

Kenaf's external walls mainly comprise of bast fibres called a macrofibrilm which consists of tube hollow in nature having four layers: one major cell wall layer and three secondary wall layers. The lumen is an open channel in the macrofibril's centre. In each wall layer, hemicellulose and lignin serve as a matrix for cellulose. The crystalline and amorphous parts of the microfibril are separated.

The qualities and performance (strengthening, thermal deterioration, etc.). The fibres were seen to degrade (through biological deterioration, moisture absorption, and UV degradation). according to their chemical compositions because kenaf fiber has more cellulose. It is more ecologically friendly and decomposable than the others. As a result, kenaf fibre is a common plant fibre used in composites and other industrial applications.

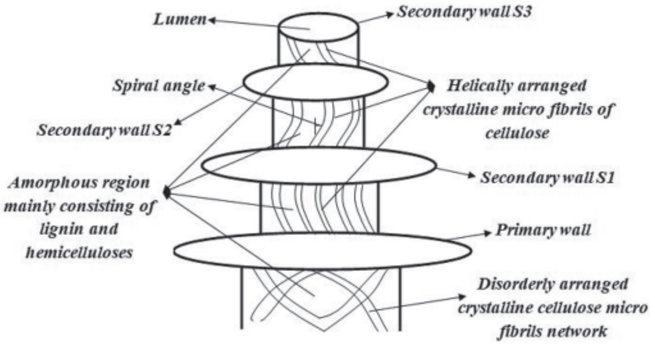

Figure 3 Natural fibre structure

3.0 Physico-Mechanical Properties

Kenaf fibre is the most powerful natural fibre that can be used to replace glass in composites. In comparison with glass fibers, which had specific tensile strength and tensile modulus of about 28.5 and 34.9 GPa, respectively, it displayed specific tensile strength and modulus up to roughly 832 MPa and 36.5 GPa. However, the physical and mechanical qualities of kenaf plant fibre are largely dependent on environmental conditions and processing procedure. It should be noted that kenaf possesses characteristics similar to glass fibre, making it an excellent candidate for FRPMC. The physical and mechanical properties are provided in Table 1[49-52].

Kenaf fibre and composites are three to two times less costly than glass fibre and have equal specific stiffness[53]. Thus, exhibiting potential in reducing the use of synthetic fibers[53]. Over 95% of the world's kenaf fibre is produced in India, China, and Thailand, making them the principal producers[58]. Kenaf production is estimated to be over 300.000 tonnes globally ("INFO: KENAF," n.d.).

4.0 Incorporation of Filler in Kenaf Based Composites

Several research on the addition of various types of fillers to kenaf fiber-based composites have been conducted. The major purpose of using nanofiller is aimed towards improve the interface between the nanosized building pieces and the polymer matrix, thereby boosting the composite's performance[60]. These fillers are essential for improving the physical and mechanical properties of composites[61]. Furthermore, by utilising these filler materials, water absorption may be reduced, improving the mechanical performance of natural fibre reinforced polymer composites[62]. The spaces between the fibres and the resin are filled with fillers, improving the interaction between the fibre and the matrix in most cases at a substantially cheaper cost/amount than fibre. As a result, it might also be used to reduce composite costs. However, homogeneous dispersion is a common issue with these fillers.

For filler, the maximum quantity is crucial; too much might produce clustering in the matrix during mixing, which has a negative impact on composite performance. Filler materials are accessible in both natural and synthetic forms. Before being applied to the fibre surface, these filler components are usually mixed with resin.

Waste management and disposal is a global issue for protecting the environment from pollution and depletion. There are various advantages to reusing waste material in the production of new commodities, including environmental and economic advantages. Researchers have not addressed the

Table 1 Physio-mechanical properties

Fiber	Diameter (µm)	Density (g/cm3)	Tensile strength (MPa)	Tensile modulus (GPa)	Ref.	Cost (USD/Kg) (Yahaya, Sapuan, Leman, & Zainudin, 2014)
Jute	25-250	1.3-1.49	390-800	13-27	(Sahu & Gupta, 2017)	0.35
Hemp	25-600	1.469	685	69	(Madeed-Al & Labidi, 2014)	0.6-1.8
Ramie	20-80	1.49	398-937	61.3-127.9	(Madeed-Al & Labidi, 2014)	1.5-2.5
Flax	24.9	1.49	499-1501	27.5	(Yan, Chouw, & Jayaraman, 2014)	1.5
Kenaf	39.9-89.9	1.21-1.39	294-929	21.9-53	(Sathishkumar et al., 2013)	1.3
Cotton	-	1.59	285-595	5.4-12.5	(Sahu & Gupta, 2017)	1.5-2.2
Kapok	21.9-64	1.46	44.9-64.1	1.72-2.54	(Madeed-Al & Labidi, 2014)	2.1
Coir	149.5-249.8	1.19	174.8	4-6	(Sahu & Gupta, 2017)	1.25
Oil palm	-	1.54	247.6	3.19	(Madeed-Al & Labidi, 2014)	-
Pineapple	50	1.52	169.5-1626	60-81.8	(Yan et al., 2014)	0.05
Sisal	100-300	1.3-1.5	500-1000	9.9-27.8	(Sahu & Gupta, 2017)	0.36
Palm	402-491	1	375	2.7	(Madeed-Al & Labidi, 2014)	-
Abaca	10-30	1.5	425-815	31-33	(Madeed-Al & Labidi, 2014)	0.71
Banana	95-245	0.75	161	8.5	(Yan et al., 2014)	0.1
Bamboo	240-330	0.9	440	36	(Sahu & Gupta, 2017)	1.77
Bagasse	200-400	1..25	96.5	6.5	(Sahu & Gupta, 2017)	-

topic of wood dust disposal or reuse in specifically. To improve the mechanical qualities of composite materials, various waste materials can be employed as fillers[63]. Fibers are employed as major reinforcing components to increase the composite's strength. However, using waste materials as filler, such as wood dust, can help to reduce weight and reduce dependency on natural fibres. To prevent pollution and resource depletion, wood waste is gathered and used to create a natural composite instead of synthetic fibres[64,65]. Agricultural byproducts such as bagasse, rice husks, and wood chips are the principal natural resources. Natural fillers are lighter, less costly, and substantially stronger than synthetic fillers.

5.0 Conclusions

The goal of this study is to provide a thorough examination of kenaf fibre reinforced composites and hybrids. According to the research, kenaf fibre is the most powerful natural fibre and potentially be used as substitute for composites incorporating fibers made of different types of glass. Kenaf fiber based composites exhibits better strength against tensile load and modulus compared to glass fibers. Addition of fillers is found to enhance the kenaf fiber reinforced composite's mechanical properties. Chemically modifying the kenaf results in enhanced bonding between the reinforcement and matrix thereby resulting in improved properties by almost 50%. It also helps to enhance the resistance to water absorption and thermo-physical properties. The kenaf fibre reinforced composites have shown promise in structural applications such as automobile components and construction RC beam reinforcement. Furthermore, natural fillers such as saw dust may be used to include sustainability into kenaf reinforced composites while also improving mechanical qualities.

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