

A Review of Examining the Mechanical Properties of Natural Fiber Reinforced Polymer Composites for the Automotive Sector

K. Perumal^{1,*}, Raja Kannan², Amala Justus Selvam², P. Senthilkumar³

Abstract

The need for lightweight, sustainable materials has increased due to the growing global population, environmental issues, and the fast growth of the automotive sector. Because of their excellent mechanical and physical qualities as well as their environmentally beneficial character, natural fiber-reinforced composites have become a viable option. Due to their ability to blend strength with lightweight properties, these composites are gaining increasing popularity across various industries, including aerospace, automotive, sports, medical, and personal protective equipment. Natural fibers serve as an advantageous choice for composite material applications due to their superior mechanical properties, economic viability, and sustainability. Examples of these fibers are jute, flax, hemp, and kenaf. This study examines the factors of fiber type, matrix type, fiber-matrix interaction, and environmental conditions that influence the mechanical and physical properties of natural fiber-reinforced composites. The study also highlights how processing methods can optimize composite performance for particular uses. By examining these crucial components, this thorough review seeks to provide a basis for upcoming studies and advancements in the field of biodegradable composites. The results show how natural fiber-reinforced composites can meet industry expectations for high-performance materials while lowering carbon footprints. The importance of these composites in promoting sustainable development across industries is highlighted by this investigation, which propels additional developments in environmentally friendly material research.

Keywords: Automobile sector, building, composites, mechanical and physical characteristics, natural fiber

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INTRODUCTION

The current trends automobile industry has seen an amazing change in the type of professional materials in its manufacturing. Composite materials were first introduced in the 1940s. Nowadays, the automobile industry is driven by materials our main pillar. The current automobile industry has moved towards utilizing alternative lightweight materials [1, 2].

Electrical resistance, fire resistance, high durability, resistance to chemicals, water, and corrosion, and a lightweight construction with a high strength-to-weight ratio are some of the remarkable properties of these materials. The automobile and aerospace industries are the primary industries that use fiber-reinforced composites in profitable applications [3]. The

reasonable shift over the recent years can be allocated to increasing demand for reducing vehicle weight to enhance fuel economy and minimum 250-ton barrel oil saving.

In the automotive industry, a composite material is created by combining two or more components that improve the properties of each individual piece. Recently built materials might be great for a variety of uses. For example, they are more affordable, lightweight, and robust [4, 5].

Fiber-reinforced composites consist of various types of fibers as reinforcements including carbon, glass and natural fibers. These are combined with resin, rubber, plastic or metal-polymer matrices [6]. Figure 1 shows composite material classification according to matrix and reinforcement types of flow chart.

The two main constituents of composite materials are the reinforcement and matrix. Fillers, compatibilizers, coupling agents, pigments, lubricants, surfactants, and solvents are a few more components.

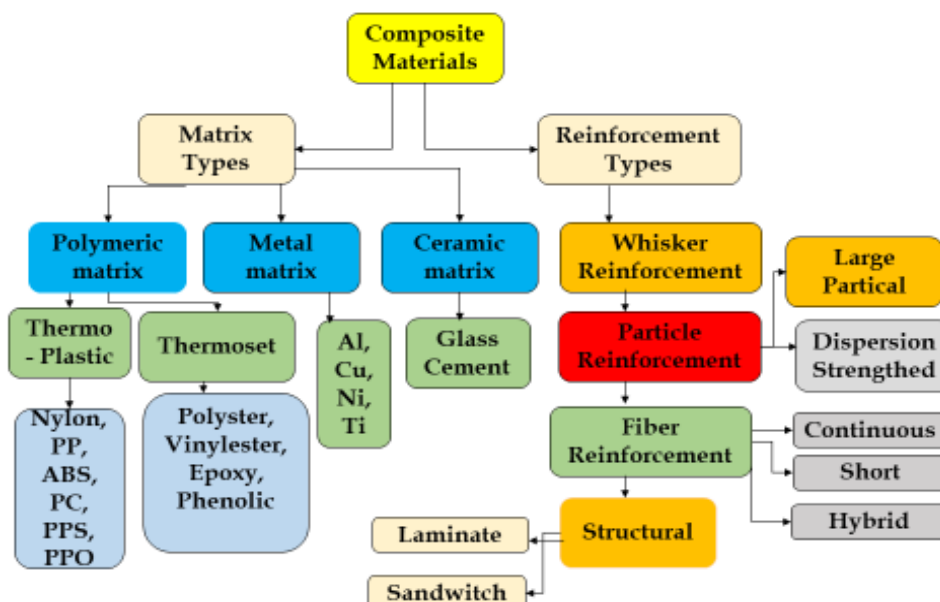


Figure 1. Composite Material Classification According to Matrix and Reinforcement Types.

NFRPC Stands for Natural Fiber Reinforced Polymer Composite

Three stages are distinguished in the matrix. One is a ceramic matrix made of metal, and the other is a polymer matrix. Two groups make up the polymer matrix classification. Thermoplastic is one, e.g., nylon, ABS, PP, PE, PPS, and other thermosetting matrices like polyester, vinyl ester, epoxy, and phenolic [7–9].

Because of its excellent mechanical qualities and inexpensive cost, synthetic fiber was once a key component of reinforced composites [10]. Glass fiber or carbon fibers are used in composites as reinforced composite materials [11].

All research on sustainable development currently focuses on environmental friendliness, and there is a lot of support and dispute over the automotive industry's need to switch from non-sustainable to ecologically friendly products Figure 2 shows Classification nature fiber [12].

In addition, Lower relative densities, great impact resistance, cost-effectiveness, high flexibility, low specific gravity, low equipment abrasiveness, reduced greenhouse gas emissions, process

friendliness, health hazards, recyclable, and CO₂ innocuousness are just a few of the many benefits that natural fibers have over synthetic ones [13–19].

In addition, natural fiber composites can have a higher fiber content, which gradually reduces the hazardous constituent polymer of the composite. Therefore, composites made from natural fibers are safe for the environment [20]. Natural fiber-based composites are extensively utilized in the automobile sector [21]. This is because they weigh less, which means they use less fuel and produce fewer toxic oil drums [22].

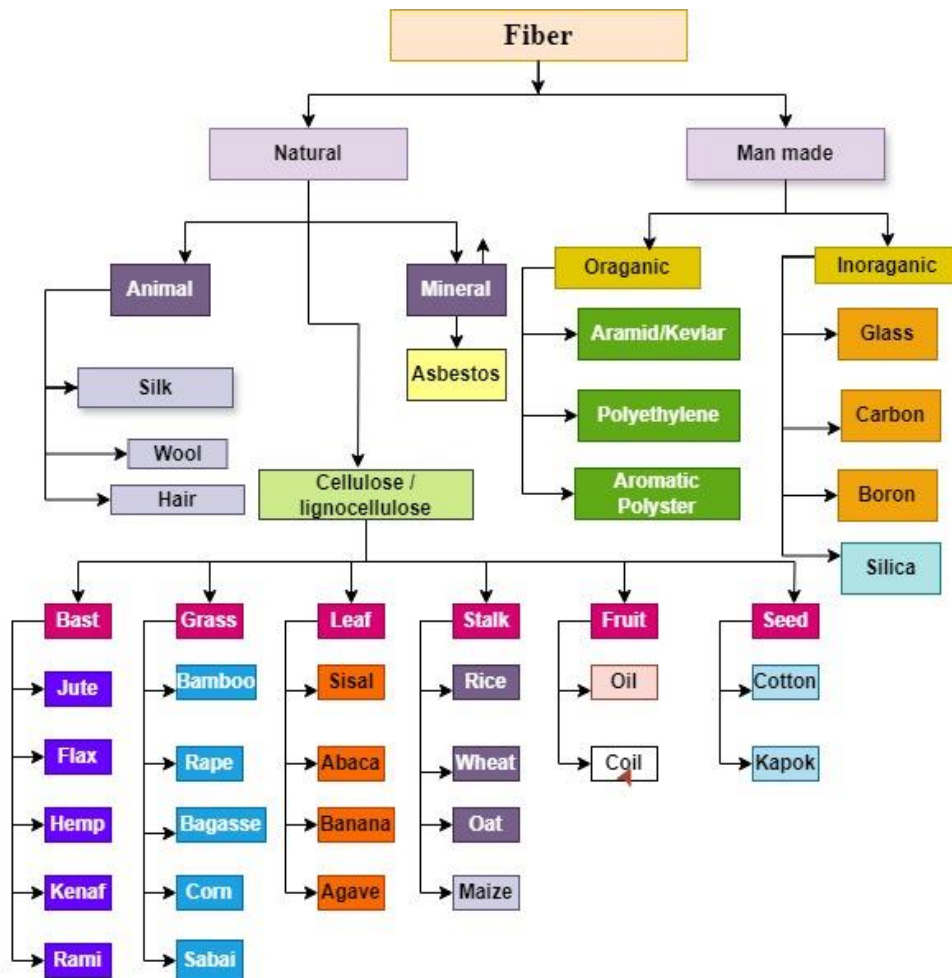


Figure 2. Classification Nature Fiber.

Even today, natural fiber reinforced composites are widely used in sporting goods, electronics, and protective clothing. Other things that may be made with natural fiber composites include laptop bags, bicycles, and tennis rackets [11].

Natural Fiber Sources

Natural fibers are cultivated from plant and animal. In this review, we focusing only plant based nature fiber. Fibers are classified in two groups. One is a primary plant and other one is secondary plant (Figure 3, Table 1).

PROCESSING TECHNIQUE

There are several techniques for creating natural fiber-reinforced polymer composites (NFRPCs), including resin transfer molding, injection molding, and hand lay-up techniques. Processing Method is displayed in Figure 4.

Numerous studies have shown that 80 C is the greatest temperature at which moisture can be extracted from natural fibers [19, 23, 24]. The most common method for combining fiber and matrix extrusion. According to a number of studies, the two most widely used molding processes for producing reinforced composites from natural fibers are compression molding and injection molding [25].

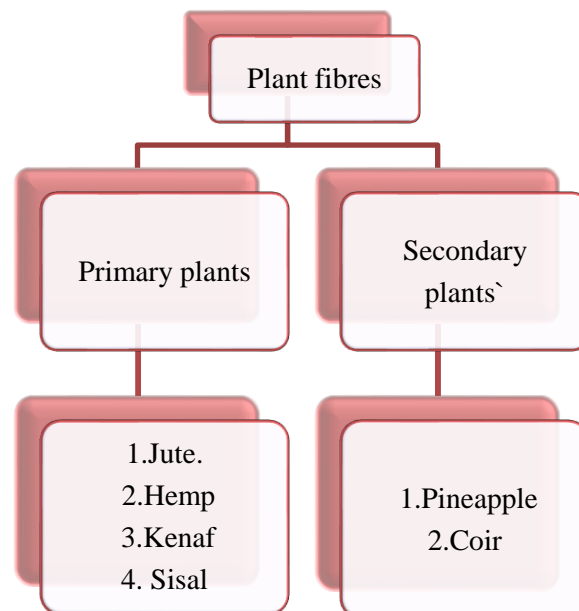


Figure 3. Classification of Plants.

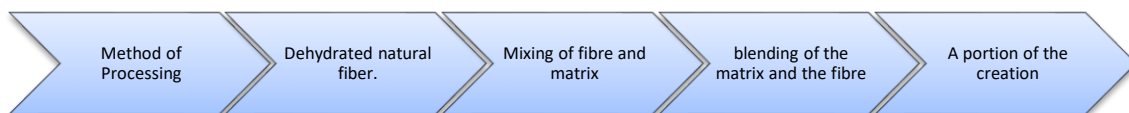


Figure 4. Method of Processing.

Table 1. Primary Fibre Sources: Manufacturing and Utilisation [1, 10].

S.N.	Fiber	Global Production (10 ⁶ Ton)	Application
1.	Flax fibre	.83	Products like tennis rackets, snowboards, window frames, decking, fences, and bicycle frames.
2.	Kenaf fibre	.97	Applied in mobile case manufacturing, insulation, bags, and packaging materials
3.	Hemp fibre	.1	Products like Work furniture, electronics, paper manufacturing, textiles, and rope production.
4.	Sisal fibre	.378	Products like construction to manufacture doors, panels, and roofing materials.
5.	Jute fibre	2.3	This category encompasses packaging, shutters, residential door frames, and textile applications.
6.	Coir fiber	.1	This category includes flush door shutters and enclosures for mirrors.
7.	Bamboo fiber	30	Associated with sectors in civil engineering and woodworking industries.
8.	Ramie fiber	.1	used in the manufacture of paper goods, furniture, clothing, fishing nets, industrial sewing threads, and packaging materials.

MECHANICAL PROPERTIES

Their mechanical properties make it much easier to use composites in a variety of industries, such as the automotive and housing sectors. The numerous studies on the mechanical characteristics of NFRPC are conducted in succession. The utilization of composite materials is greatly aided by their mechanical properties in numerous industries, such as the housing and automotive sectors. The many investigations into the mechanical properties of NFRPC are carried out one after the other [26–28].

The amount of lignin and hemicellulose also determines the characteristics of natural fiber [29]. Natural fiber with a high content of hemicellulose and lignin degrades faster and absorbs more moisture, which is not good for the fiber [30]. To achieve a composite with enhanced mechanical properties. It is crucial to have natural fibers that are high in cellulose and low in hemicellulose and lignin. The diameter and length of the natural fiber have an impact on the composites' mechanical qualities [9, 31, 32]. Compared to fibers with larger diameter, natural fibers with smaller diameter have a stronger impact on the mechanical properties. If the length of the fibers is smaller than the critical length, the stress transfer efficiency between the fiber and the matrix will be the lowest, resulting in insufficient mechanical properties [33]. The inclusion of fibers significantly influences the mechanical properties of composite materials [30, 34, 35].

By using advanced techniques including matrix and reinforcement fiber surface modification, the adherence between the fibers and the matrix was improved. To understand the mechanical properties of natural fibers and produce the necessary NFRPCs [37]. Table 2 shows assumptions about the mechanical characteristics of several plant fiber varieties. Reinforce dependent mechanical properties. Research has utilized cutting techniques, including matrix and reinforcement fiber surface modification, to improve the fibers' adherence to the matrix [38, 39].

Table 2. Natural Composites' Mechanical and Physical Properties.

Fiber from Plants	Young's Modulus (10^9 Pa)	Tensile Strength (10^6 Pa)	Density (g/cm^3)	Elongation (Percentage)
Flax	27.64–103	344–2000	01.43–1.54	1.24–1.34
Jute	26.54	393.3–773.6	1.34	1.6–1.9
Cotton	5.5–12.6	287–597	1.5–1.6	7–8
Fibre Hem	70.5	690.5	1.49	1.69
Coir	4–6	131–175	1.15	15–40
Fibre Abaca	12	430–760	1.5	3–10
Sisal	9–38	363–700	1.33–1.5	2–7
Bamboo	11–17	140–230	0.6–1.1	–
Kenaf	53	930	1.4	1.5
Banana	17.85	600	0.75–0.95	–
Ramie	24.5–128	400–1000	1.0–1.5	1.4–4.0

CONCLUSIONS

Natural fiber-reinforced polymer composites are generally preferred over synthetic fibers due to their many advantages, which include low specific gravity, high flexibility, low density, high impact resistance, low cost, lower abrasion resistance to equipment, lower health risks, process-friendly, low emissions of greenhouse gases, recyclability, carbon dioxide neutrality, and environmental compatibility. Natural fibers are highly resistant to moisture and have a low wettability; however, chemical treatment can overcome these NFRPCs can be manufactured by injection molding, compression molding and manual lamination processes. Because hemicellulose and cellulose's mechanical qualities are highly influenced by their size, they are necessary ingredients in polymer composites constructed of natural fibers. The diameter, length, composition, and manufacturing process are only a few of the many factors influencing a composite's mechanical properties. NFRPCs are likely to find significant use in the developing global industry, including protective garments, sports, civil engineering, automotive, and biological applications.

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