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A review on mechanical properties of natural fiber reinforced polymer (NFRP) composites

Ankit [a], MotiLal Rinawa [a,*], Prashant Chauhan [b], D.Suresh [c], Satish Kumar [d], R. Santhosh Kumar [e]

[a] Mechanical Engineering Department, Government Engineering College, Jhalawar, India
[b] Department of Physics and Material Science, Jaypee Institute of Information Technology Noida, India
[c] Department of Physics and Electronics Chaitanya (Deemed to be University), Hanmakonda, Warangal, India
[d] Lecturer Department of Mechanical Engineering, G B Pant Institute of Technology Okhla, New Delhi, India
[e] Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Andhra Pradesh, India

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A B S T R A C T

One of those innovations that led to their substantial growth in the field of engineering is natural fiber hybrid composites. Natural fiber-reinforced composites are used to replace synthetic fibers manufactured from boron, fiber glass, carbon fiber, etc. in a variety of application areas. Natural fibers, particularly in domestic uses in plants, animals, and regenerated material, are de-grading and durable compared to synthesized fibers. Strengthened polymers are common in natural fibers, such as cotton, sisal, coir, jute, flax, hemp, banana, flax, and more. Recently, for their excellent mechanical, chemical, and physical features many sectors have been added, such as vehicles, aerospace, marine, and buildings. Because of these properties, natural fibers have recently become an alternative approach for fiber-reinforced compo-sites for researchers and scientists. This paper explores the mechanical characteristics of natural fiber reinforced hybrid composites.

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1. Introduction

A composite material can be described as combining two or more materials with better characteristics than individual components used alone. Reinforcement can include either natural fiber or synthetic fibers in the Polymer matrix in fiber-reinforced polymer (FRP) composites. Natural fibers are getting more exposure than synthetic fibers as Synthetic fiber substitution in composites development. The key advantages are its high strength and rigidity combined with low density, which allows a weight reduction in the finished component in comparison to bulk materials. Today, natural fibers, due to their environmental advantages including biodegradability, are commonly used for synthetic fibers also have High Strength-Weight ratio, strong mechanical characteristics, low weight, and economic benefits. Plants like bananas, sisal, bamboo, kenaf, jute, bamboo and sugar cane can make natural fibers [1]. Natural fibers now have superior mechanical properties in the automobile, manufacturing and sports industries. Low weight natural fibers and safer alternatives to synthetic fibers. natural fibres. Natural fibers have certain limits, considering these benefits, High moisture absorption characteristics as low impact strength. The combination of various techniques will reduce these difficulties. The mechanical properties of the materials can be improved. Many researchers have been focused more into developments of natural fibers and their mechanical properties [2]. Natural fibers are also intensively studied as replacement for synthetic fibres. They are also potentially under investigation. The substitution of traditional and plastic materials with natural Fiber composites will also become a reality and help to create a sustainable economy. An ideal natural fibre is fully bio-degradable and consists of only short cycles of renewable plants under regulated conditions. Natural fiber composites are considered as a suitable alternative for glass composites in a variety of applications in terms of mechanical strength and a lower price in various research papers on fibers extraction and chemical treatments, fiber matrix adhesion or processing conditions. In fact, by using coupling agents, the fiber length is established and Rather interesting characteristics are attainable in conjunction with the best possible matrix. The demand for energy for manufacturing is much lower compared

* Corresponding author.
E-mail address: rinawa.iitd@gmail.com (M. Rinawa).

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to synthetic fibers and a recovery of energy can be achieved [3]. Today, natural fibers like sisal and jute fibers replace glass and carbon fibers because of their easy availability and their expenses [4]. In the growing world energy crisis and environmental risks, Natural fibers are chosen to enhance as an tool that can minimize wear, during care and respiratory discomfort and serve as an alternative for artificial fibre composites [5]. Mechanical properties of natural fibre-reinforced composites were stated by many writers. But less effort has been made on reinforced polymers from natural fiber. This article offers an overview of natural fiber polymers along with their mechanical properties.

2. Natural fiber composites

Polymer can usually be categorized into thermoplastics and thermosetting in two groups. Thermoplastic materials dominate at present as bio-fibre matrices; the thermoplastics most widely used for this purpose are the most commonly used thermocouple are polypropylene (PP), polyethylene and polyvinyl chloride (PVC); phenolic, epoxy and polyester resins [6].

The fibers of plants are categorized in Bast, Leaf, Seed, Fruit, Wood and grass. Fig. 1 shows the natural fibers and matrices typically used for polymer composites [7].Some of natural fibers have physical properties in Table 1. These fibers are low cost and high-specific fibers equivalent to synthetic fibres.

Table 2 Presents the areas in which natural fibers have distinct advantages over the synthetic fibre most widely used, i.e. Fiber glass [10].Table 3.

3. Effect on mechanical properties of filler material

A. Alavudeen et al [12] researched the mechanical characteristics of woven banana fibre, kenaf fibre, and hybrid fiber composites of banana and kenaf. Owing to the hybridisation of kenaf and banana fibers, the mechanical strength of woven bananas and kenaffibers is reduced. The capacities of tensile, twisting, and effect in the tissue hybrid banana/kenaffibers are higher than in the individual fibres. SLS treatment seem to enhance mechanical strength further by improving interface connection. In order to comprehend fiber/matrix adhesion debonding, morphological studies of fractured mechanical test samples were carried out with the help of electron-tron microscopy (SEM).

M. Ramesh et al. [11] studied the mechanical properties of reinforced polyester composites in sisal, jute and glass fibre. The incorporation of fiber glass into a blend of jute fibers contributed to maximum tensile Strength. Similarly, the sample of jute and sisal composites has also been shown to maximum bending power and maximum impact strength for the sisal composite fiber.

A. Gowthami et al. [13] developed sisal natural fiber composites with and without silica by using 100% biodegradable sisal fibers as reinforcement in the polyester matrix. The findings showed that the tensile strength and tensile modulus of silica composites are 1.5 and 1.08 times higher than that of silica-free composites. The impact strength of sand composites is 1.36 and 1.8 times higher than that of silica-free and plain polyester composites, respectively.

Amar Patnaik et al. [14]examined the three body abrasive wear and mechanical properties of particulate-filled epoxy glass composites. The purpose of their work was to research the abrasive wear behavior of randomly focused glass fiber (RGF) reinforced with epoxy resin filled with Al2O3, SiC and pine bark dust. Dry sand/rubber wheel abrasion tests (RWAT) were conducted at a test

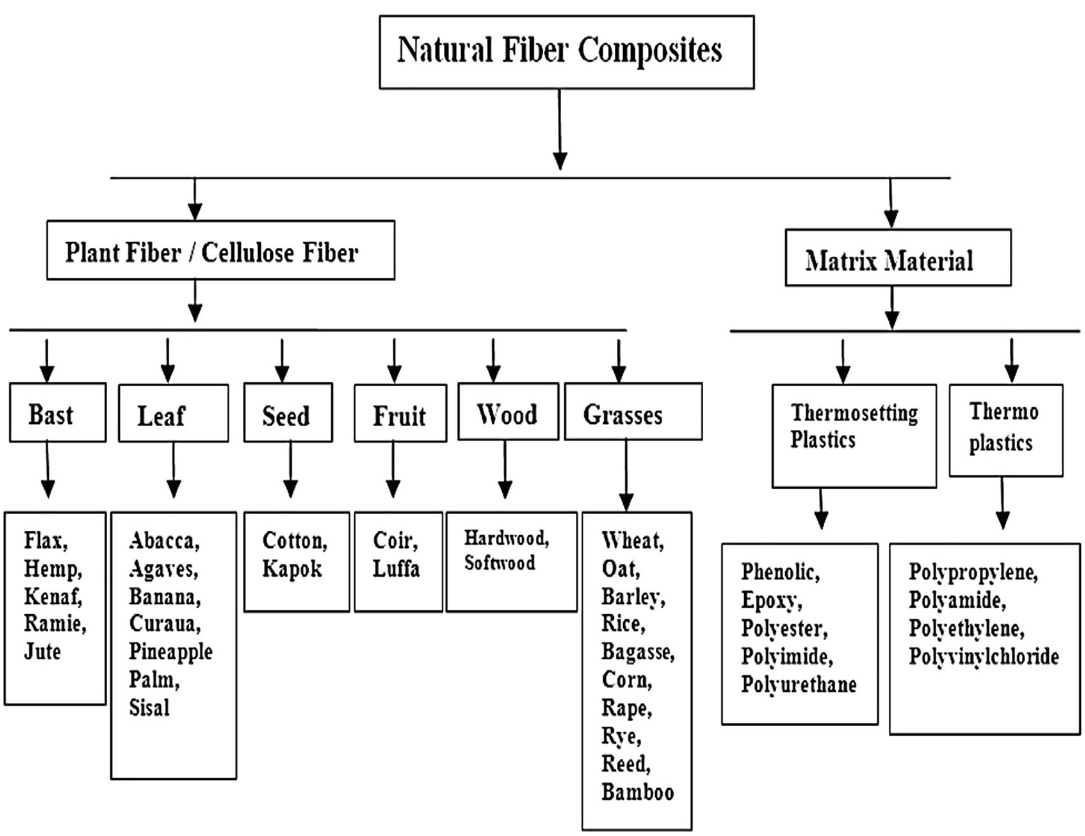

Fig. 1. Commonly used natural Fibersand matrices for polymer composites (Source:[7]).

Table 1
Physical properties of natural fibers.

Fibres	Tensile Strength (MPa)	Young's modulus (GPa)	Elongation at break (%)	Density (g/cm3)	References
Abaca	400	12	3–10	1.5	[8]
Bagasse	350	22	5.8	0.89	[8]
Bamboo	290	17	–	1.25	[8]
Banana	529–914	27–32	5.9	1.35	[9]
Coir	220	6	15–25	1.25	[10]
Cotton	400	12	3–10	1.51	[10]
Curaua	500–1150	11.8	3.7–4.3	1.4	[8]
Flax	800–1500	60–80	1.2–1.6	1.4	[10]
Hemp	550–900	70	1.6	1.48	[10]
Jute	410–780	26.5	1.9	1.48	[11]
Kenaf	930	53	1.6	–	[10]
Pineapple	413–1627	60–82	14.5	1.44	[9]
Ramie	500	44	2	1.5	[10]
Sisal	610–720	9–24	2–3	1.34	[11]

Table 2
Comparative advantages of natural fibers over synthetic fibers.

Properties/Factors	Natural fibres	Glass fibres (synthetic)
Density	Low	Twice that of natural fibres
Cost	Low	Low, but higher than NF
Renewability	Yes	No
Recyclability	Yes	No
Energy consumption	Low	High
Distribution	Wide	wide
CO2 neutral	Yes	No
Abrasion to machines	No	Yes
Health risk when inhaled	No	Yes
Disposal	Biodegradable	Not biodegradable

Table 3
Applications of fibers.

Fiber	Applications
Jute	Covered Door Panels, and Seat Backs
Sisal	In the interior door linings, panels, and door panels
Bamboo	Modular house construction
Coir	Car seat covers, mattresses, doormats, and rugs
Hemp	Carrier for covered door panels, Racing Bicycle, and Cases for musical instruments
Flax	In the interior door linings, panels, door panels, Package trays, door panel inserts, Racing Bicycle, Cases for musical instruments, and Green wall panel

speed of 100 rpm. Tests were carried out at loads of 50 and 75 N, varying the abrading distance from 200 to 600 m. Experimental findings of abrasive wear experiments showed that composite wear was sensitive to abrasive distance variance and less sensitive to sliding velocity.

Hemalata Jena et al. [15]studied the impact of cenosphere-filled composite bamboo fiber. They also re-ported that the impact properties of bio-fiber reinforced composites are highly affected by the inclusion of cenosphere as filler and laminate. In the case of a laminated composite, the impact strength is increased by the addition of a filler up to a certain limit, beyond which it is reduced by additional addition. The findings indicate the sensitivity of the im-Pact properties to the concentration of the fillers. Increase in lamina from 3 to 7, the effect strength is increased and the strength is decreased when the lamina is further increased to 9.The maximum impact intensity of the 7 composite layers with 1.5 wt% of the cenosphere is 18,132 KJ/m2. There is also evidence of a decline in the density of composites, which also relies heavily on the quality of fillers and fiber.

Girisha, C. et al. [16] studied the mechanical properties of chemically treated fiber composites of arecanut husk and tamarind fruit. They found that the treated fibers showed better results compared to untreated fibers. They also noted that the strength of hybrid composites increases with an increase in the volume fraction of fiber in hybrid composites. In the investigation, the fruit husk fibers and the tamarind fruit fibers were reinforced with the Epoxy matrix and the composites were created by hand-crafted technician.The experiment showed that the overall mechanical properties of all hybrid natural fiber composites were 40–50% of fiber reinforcements.

Zamri et al. [17] have studied the mechanical characteristics of reinforced, water-absorbing polyester jute/glass. Composites were exposed to various water conditions and were tested for the three different water conditions, the purified and marine water, the acidic and water sites for three weeks and the impact on the flexural and compression properties of the different water environments were also studied in this analysis. The Jute Composite was found to not be suitable for underwater use.

AjithGopinath, SenthilKumar.M, Elayaperumal A [18] experimented with mechanical Jute propertiesPolyester and epoxy reinforced fiber compositesresin.In this analysis, the jute epoxy was disclosed.Better mechanical characteristics displayed. The care-Time required for the composite of jute polyester relatively short of jute-epoxy time. The pullFor jute epoxy more strength and flexural characteristicsthat makes it more suitable than the jute polyesterAuto applications instead of jute-polyestercomposites.

The hybrid effect studied in M R.Sanjay, B. Jogesha[19]Jute/E-Glass fiber composites are manufacturedBy method of hand layup. The hybrid has been discoveredComposite is stronger than the jute material.Composite made of glass fiber individually. The TheTheIntegration of fiber glass into composites of jute fibreImprove mechanical characteristics and lead toIncreased use of natural fibers in different areasRequests. Requests.

The literature describing above shows that fillers can be changed by adding a filling stage to the matrix during composite preparation, both physical and mechanical characteristics. The addition of composite filler is to boost mechanical and tribological characteristics.

4. Effect of process parameters on mechanical characteristics

Berhanu et al. [13] investigated the impact of the percent weight of polypropylene reinforced jute fiber and observed that mechanical properties enhanced as the percentage of jute weight resurrected to 40%.

S. Raghuraman et al. [14] have concluded that the composite is of a maximum tensile strength of 97,71 MPa, with 50 percent sisal fiber and 50 percent resin combination. The burst load of reinforced sisal-glass composite is also strong (10.285 KN). The breaking loads of reinforced sisal-glasser composite have been detected to be 1,10 times greater than reinforced sisal-coir-glass composite fiber and 1,33 times greater than reinforced composite coir-glass fiber. The coir-glass fiber enhanced compound elongation is found to be higher than that of other compounds, and thus may have more ductile property in nature.The hybrid with composite has high bending strength (138.87 MPa) and a good impact strength (1429 KJ/m2, respectively), with 40 percent sisal coir-glass and 60 percent resin.

Zamri et al. [15] have studied the mechanical characteristics of reinforced, water-absorbing polyester jute/glass. Composites were exposed to various water conditions and were tested for the three different water conditions, the purified and marine water, the acidic and water sites for three weeks and the impact on the flexural and compression properties of the different water environments were also studied in this analysis. The Jute Composite was found to not be suitable for underwater use.

Onal et al.[16] studies the properties of glass/carbon hybrid specimens, such as tensile and flexural strength, with each stratum layer before and after impact. The carbon fire at the end surfaces has been found to increase bending strength and also enhance the tensile properties of hybrid.

SathishPujari et al. [18] investigated the comparison and potential of the mechanical and physical properties and the chemical composition of the jute & banana fiber compounds. With this composite technology, it is possible to use and apply the cheaper products in high-performance applications. The useful properties of two different materials, low-cost processing, flexibility etc, are used in different areas of engineering, in high-level applications such as the recreational and sports products, the ship-ping industry, aerospace and other applications.Thus the composite is the most desired technology in an increasingly rising trend with this context.

Tara Sen et al. [20] have reviewed how composites apply in structural facilities, primarily with the aid of artificial fibers to increase the strength of the structure and have not discussed the issue of the susceptibility of these raw materials used for the reinforcement of the structure. The need for raw materials needed for structural reinforcement to meet global demand is increasing rapidly in the sense of an expandable world population and with increasing buying capacity.

The effects of hybridized bananas and kenaffiber reinforced hybrid composites have been tested experimentally by the company, Samivel et al. [20] and found that the hybrid composites gave greater water resistance than the hybrid composites. The effect of hybridization on the mechanical property of the coir-glass hybrid laminate was investigated by Jayabal et al.[21] and found that coir fiber (natural) is faster than glass fibers and that inexorable poration of extreme ply-glass fipers enhance the mechanical properties of coir laminates.

The influence of the number of layers and fiber directions on the mechanical behavior of composites were explored by Hind Abdellaoui et al. [21]. The findings show that by increasing the number of layers, the mechanical comportements of laminated materials have improved. For composite with five layers the maximum properties were obtained. Composites have high mechanical properties at the direction of the 0 grade fiber and the direction of cutting at 0 grade. The results indicate a certain discrepancy between the module measured and forecast (Young modulus, shear modulus, Poisson coefficient).Possibly because of the fibers' perfect relation with the matrix in the assumptions. This discrepancy.

The efficient process for improving the mechanical properties of Jute/Poly Lactic acid composites has been developed by Yoshihiko Arao et al. [22]. Results indicated that hydrolysis deletion is important to improve overall efficiency. With PLA, it increased its module, but reduced the absolute tensile strength, without any hydrolystic alteration.

The theoretical dynamic study of reinforced concrete slab unthe free and simply supported state was discovered by Ahmed and Mohammad et al. [24]. They showed that the help has an impact on the modal characteristics, because the values are high simply supplied. The modal properties are therefore accurate for experimental research free of charge.

The dynamic properties of the glass/epoxy enhanced hybrid composite under free conditions, with different appearance and ply orientation were analyzed by Ratnaparkhi et al. [23]. by experimental and FEA simulation. The result showed that the growth in the aspect ratio causes the natural frequency to increase and the ply orientation to decline by [45/−45] and [30/60].

Literature has concluded that the composite production has had a significant effect on the composite properties. By creating the compositions using different methods, mechanical characteristics such as tensile, flexural and impact strength can be adjusted.

5. Applications of natural fiber composites

There are many businesses, such as the automotive, manufacturing, energy and aircraft industries that are driven by, say, society and governments to manufacture environmentally friendly products and reduce their dependence on fossil fuels as seen in the Table 3[24]below.

As reinforcement in different matrices, natural fibers replace synthetic fibers. The prepared composites can effectively replace wood, as well as in numerous other technological fields, such as car parts. Seventy years ago almost all resources were extracted from natural textiles for the production of commodities and various technological goods. Textiles, ropes, linen and even paper, including flax and hemp, were made from natural local fibres. Any of them continue to be used today. The first composites for the manufacture of vast numbers of boards, tubes and pipes for electronic purposes were used already in 1908. (paper or cotton to reinforce sheets, made of phenol or melamine–formaldehyde resins). Aerospace seats and fuel tanks, for example, were made in 1996 from natural fibers with a limited amount of polymer binders. Due to its impressive properties such as biodegradability and high specific properties, the past decade has seen various applications of natural fiber composites.A development is currently taking place primarily in the automotive and packaging industries in the use of natural fibers as enhancements in technological use (e.g., egg boxes). Textile waste is used for years in the automotive industry to enhance the plastics used in automobiles, especially in Trabant. Natural fibers are commonly used around the world in composite applications. Natural fiber composite materials are therefore used for many vehicle parts.These are mostly based on polypropylene or polyesters, with fibers including flax, hemp and jute added. In future vehicles, cassava nut oil and hemp can be shaped in this way. Even golf clubs can be constructed around jute fibres, and cocoon hair tennis rackets can be stiffened. Bicycle frames can derive their strength from any other acceptable plant of 2000. The high-tech revolution in the use of natural fibers could result in the substitution of synthetic substances.A new generation of bio-based composites for a number of applications is now being developed in a broad range of products which utilizes natural fibers and bio-based soy resins [25].

For many structural applications, natural fiber composites have been used because they have high basic strengths and anti-metal modules. These developments range from household to more important and sophisticated fields such as aircraft and satellites. Natural fibers are expected to be a growing market in composite materials [26].

6. Conclusions

The use in polymer composite enhancements of natural fibres, natural fiber development and characterisation, surface refitted fibers with different fillers and the change in properties of natural fiber composites were examined from the perspective on their role and expectations. Comparing natural fiber with glass fiber reinforced composites revealed that in industrial applications natural fibers were superior. Furthermore, it gives way to economic growth in rural areas through the use of natural fibers in different engineering and construction industries.Bio-composites have different benefits for synthetic fiber such as lower fibre, eco-friendly and lower density coefficient. This makes them more famous and has already generated enormous scientific knowledge.

The research findings show that the properties of reinforced polyester composites found in yutefiber can be improved. But very few study has carried out on composites and properties reinforced by jute/glass fibre. The literature showed that the modal method for evaluating the dynamic properties of the composites did not provide much detail. Application for automotive industry for weight and cost reductions will be built for a suitable hybrid of a known stacking series, leading to the investigation of mechanical and dynamical characteristics of epoxy hybrid composites reinforced with jute/glass fibre.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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