PHYSICAL AND MECHANICAL PROPERTIES OF NATURAL FIBER REINFORCED POLYMER COMPOSITES WITH POTENTIALS FOR WIND TURBINE BLADE APPLICATIONS: A REVIEW

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Graphical Abstract

Abstract:

The wind turbine blade, which is currently being developed with carbon and glass fiber-filled composites, is a key part of the wind turbine system used in the production of wind energy. Present-day realities have necessitated the need for the replacement of these materials, which are costly, scarce, non-biodegradable, and non-eco-friendly, with natural fibers, which are more available and eco-friendly. This study gives an overview of the wind energy industry, wind turbine blades, and the production systems associated with it in particular. It describes the attributes of natural fibers, their composites, hybrids of natural fibers, their defects, and their possible application in the development of wind turbine blades.

Key Words: Natural fiber, Wind turbine blades, Energy, Composites, Ecofriendly materials

1.0 INTRODUCTION

In more recent times, and concerning global energy transformation, renewable energy has become a better option in exploitation and consumption and of which among the renewable energy sources, wind energy stands out as significant (Onea et al., 2020;

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Abbas et al., 2020; Gonzalez et al., 2010; EWEA, 2009; He & Li, 2020; Saeed et al., 2020). Also in recent times, wind energy has been reaching its potential as its use has been growing exponentially with its only possible obstacle as stated by Sayigh (2020) to be political and not technical. The rapid growth of wind energy technology in capacity was estimated by Milborrow (2020) to be about 600GW in 2018 just as studies have predicted that in the overall energy supply, the portion of renewable energy will see an increase by 49% (14%-63%) through 35 years (2015-2050) (Gielen et al., 2019). The cause of this substantial increase was attributed to the exploration of its characteristics which are unique to other sources of renewable energy. Exploration of this energy source, just like oil, has not been limited to land only but has also extended offshore.

This high rate of development of the wind energy industry has brought about a simultaneous growth in the size of the systems used to harness this source of energy (IRENA, 2019) and also a gradual decline in the cost of generation. This relationship is expressed in the graph shown in Figure 1. This shows that considering renewable energy sources, wind energy has the potential to be the cheapest, even though geothermal (the rising of steam near the surface) has in some cases proven to be cheaper or in places where the geography supports the economic development of hydro energy generation systems.

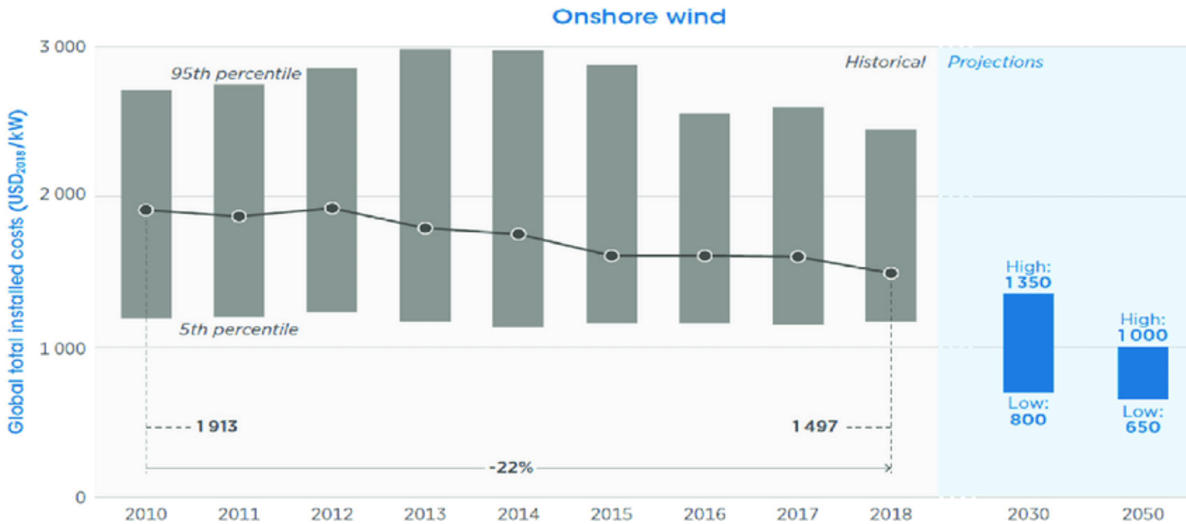

Figure 1: Installation cost of the wind energy system (past, present, and projected) (IRENA, 2019)

The wind is a resource that varies, and for it to be harnessed, a wind turbine is used which is fixed at the base and exposed to different forces, torques, and atmospheric conditions (Dhiman et al., 2020). Made of many components, the wind turbine blades are a core part of the wind turbine in their complexity. Wind turbines are energy converters, converting energy from a natural source in its kinetic form into mechanical energy which is applied to an electrical generator where the mechanical energy is converted to electrical energy. The two available types of wind turbines used for wind energy harvesting include the vertical and horizontal axis wind turbines. Their designations depend on their modes of operations in terms of the direction of rotation of the blades on the turbines. The development of wind turbines is an expensive process and is partly because of their size, and therefore they should be able to have a considerable period of operation before their decommissioning or failure. In other to meet these demands, the design of large turbine blades should be according to industrial standards and concepts as in Figure 2. The increasing need for this clean source of energy has mandated businesses concerned with harnessing wind energy to venture into harsh environments and therefore materials and design must meet these new conditions in terms of performance.

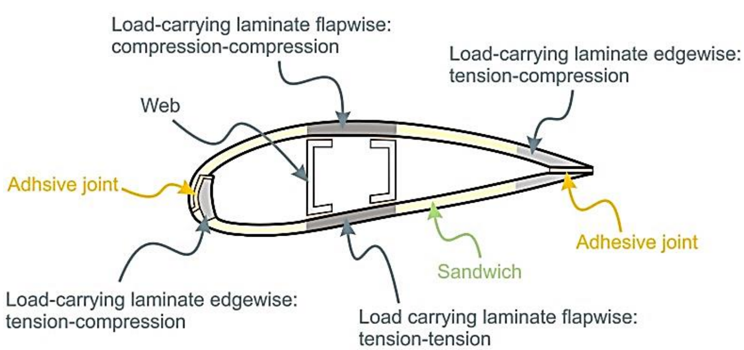

Figure 2: Cross-section of a wind turbine blade

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The importance of blades regarding the performance of wind energy harvesting systems can never be overemphasized. However, the blades are exposed to complex forces which are most of the time, irregular, and such conditions can bring about failure which is disastrous even though the maintenance of these systems can be very expensive (Ying et al., 2020). Figure 3 highlights the forces acting on the wind turbine system.

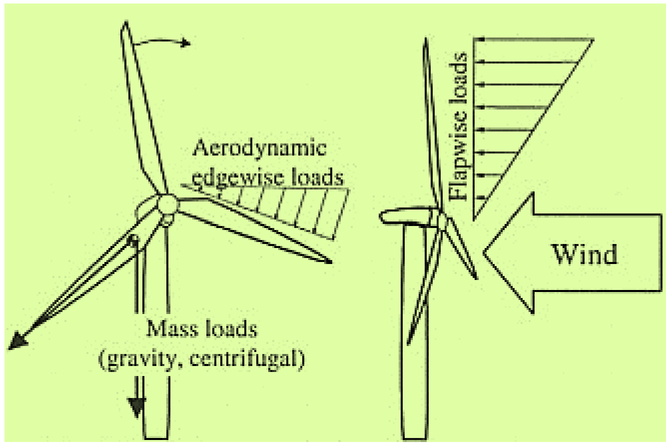

Figure 3: Forces acting on wind turbines

Although many forces act on the entire wind turbine system as shown in Figure 3, principal to the wind turbine blade are the centrifugal force (due to the rotating blade as a mass), gravitational forces (due to the weight of the blades), direct lateral or flap wise (due to the action of wind on the blades), and aerodynamic forces (due to wind action in respect to the blade geometry). Summarily, the principal forces on a wind turbine blade in operations induce tensile, flexural, and fatigue stresses on the blade. Therefore, materials specified for application in developing wind turbine blades must possess good tensile, flexural, and fatigue strength and must also be light in weight. Generally, there are many other criteria considered for the development of wind turbines, but the main criteria of consideration for materials used for the development of the blades for wind turbines are mainly their mechanical strength, stiffness, weight (density), and fatigue properties.

The blades of a wind turbine among other parts have the highest cost with respect to development and installation and are usually developed from composites material, mainly fiber-reinforced composites. Their role in energy production is critical even though their susceptibility to damage is just like any other components developed from these composites. Engineers are exploring innovative designs for these blades which will take advantage of the commendable properties of new materials. The current materials used for the development of these wind turbine structures (blades) have been challenged by ongoing studies of the possibility of replacing them with materials that have the same or better properties such as less expensive, less demanding during production, low weight, high reliability, biodegradable and ecofriendly. The engineer designing the blade must focus on the materials systems which are of lower cost, less weight, easy to process, recyclable, more performance, and longer life. Also, recent developments in wind turbine technology have not only increased in size but also the exploration of offshore environments. This implies that a strong criterion for the selection of materials for wind turbine blades includes the environmental compatibility of the material. Like in the case of offshore environment or any other humid environment, the water absorption or corrosion characteristics are an important consideration.

There has been rapid development in wind turbine blade technology, thereby giving it the ability to span to greater lengths. As of 2009, the length of wind turbine blades was reaching up to 180m (Thomsen, 2009) and is currently surpassing it exceedingly. The need to substantially bring down the leveraged cost of producing energy from this source has driven the size increase in these energy harvesting systems. Gravitational forces due to the weight of these materials have become the main consideration in the design of these systems due to the increasing weight which is brought about by the increase in size. The structural stiffness of the blades, which makes sure that there is a clearance between the tip of the blade and the tower to avoid a collision, has been receiving increasing attention due to its importance because longer blades undergo more deflection. From the material standpoint, the design also has to consider the stiffness-to-weight ratio of major importance (Mishnaevsky, 2020).

Typically, some parts of the wind turbine like the blades and nacelles are made of composite materials even though metals are used to make other load-carrying parts like the tower and the generator (Mishnaevsky, 2020). Composite materials have been an excellent choice for the development of wind turbines because of their good mechanical properties coupled with their low weight (Kalkanis et al., 2019). Fiber-reinforced polymer composites are examples of these composite materials that are used for the development of wind turbine blades of which different properties can be obtained by the variation of the fiber and polymer. Although the need for high-performance materials has skewed the industry towards synthetic fibers like carbon fiber and glass fibers, the current clamor for eco-friendly materials and low-weight materials has made the wind turbine blades experience an increase in the use of natural

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composite for the development of these wind turbine blades. Even though synthetic fibers have proven to be advantageous in their mechanical properties like high strength-to-weight ratio, they are also not eco-friendly and recent studies on natural fibers have proven the possibility of replacing these synthetic fibers with natural fibers. Natural fibers are gotten mainly from plants and are of low densities compared to synthetic fibers. Although with a compromise of lower mechanical properties, their use has proven to be viable in the development of wind turbine blades.

In other to support the ongoing shift from the development of wind turbine blades with synthetic fiber, this study gives an overview of the physical and mechanical propertis of natural fibers-based materials, having potential for applications in the development of wind turbine blades.

2.0 MATERIALS FOR DEVELOPING WIND TURBINE BLADES

2.1 Current materials for wind turbine blade manufacture

In recent times, in the wind energy industry, material selection, mostly for polymers and fibers used for systems development (e.g. wind turbine blades) is of major economic value. Blades size (length) and cost has been on the rise. This is necessary because the efficiency of the wind turbine output is directly proportional to the size (length) of the wind turbine blade. But the mechanical properties of the materials currently in use restrict the maximum size of the wind turbine blade. It is such that, considering the density of a material, the weight of the wind turbine blade due to its size, induces stress on the system beyond the load bearing capacity of the material., and so, failure. Some materials like Kevlar, carbon fiber, etc. may have commendable density and good mechanical properties, but the cost of such materials may outweigh their advantages. To address this situation, there must be a focus on materials that are less expensive and possess the ease of processing without compromising the performance and reliability of the wind turbine blades.

Many studies have shown the performance of several materials and their potential for use in the development of wind turbine blades. Brondsted, et al. (2005) and Gardiner (2012) reported on thermoset composites materials and thermoplastic composites materials respectively with commendable mechanical performance. Also, natural fiber composites have been reported as well. Important also is the trending hybrid fiber composite material which is a combination of two or more fibers as reinforcements for the development of wind turbine blades.

In composite materials, the fiber is the mechanism that carries the load longitudinally and it determines the strength of the composite material. The fibers may either be chopped, short or continuous, or in elongated crystals structurally. Many fibers exist, but those that are common in the market and have found application in the development of wind turbine blades include; glass fiber which may be E or S, carbon fibers which may be IM and HS, etc. Hybridization of these two materials (carbon fiber and glass fiber) can be very profitable in that there is a combination of the good performance and the good processability of the carbon fiber and glass fiber respectively. Being used as reinforcement materials, glass fibers and carbon fibers are synthetic fibers having the drawback of being non-biodegradable and non-recyclable after their service life. Another major drawback is their hazardous nature during processing which makes them injurious to health. Recently, research focus has been shifting more to the exploration of the natural fiber reinforced composites from the traditional monolithic materials (Samuel et al., 2022a; Samuel et al., 2022b; Alabi et al., 2022; Samuel et al., 2022c; Samuel et al., 2022d). The composition of composite materials constituents (e.g., polymers and fibers) used for the development of wind turbine blades are usually varied to achieve improved performance or properties.

Also, just like other ductile materials, carbon fiber composites which are linear elastic materials tend to highly notch sensitive due to their failure to distribute the concentration of stresses. In cases of composites with hybrid fiber reinforcement, when a failure in the layer with low elongation occurs, a significant drop in its vertical stress, and this kind of loss in strength is intolerable for materials used for the development of wind turbine blades so, therefore, there is the requirement for pseudo ductility. Swolfs (2019) also recommended using Carbon fiber for reinforcing materials used for this application in place of the current trend of glass fiber which is of higher density, although the challenges of using carbon fiber as reinforcement were noted as its difficulty in impregnation because of their small fiber diameter and therefore smaller interface spacing, misalignment sensitivity due to their anisotropy and greater stiffness, and lastly their sensitivity to impact damage due to their brittleness although this becomes less considerable in operation but of high consideration during transportation and installation.

Pradeep et al. (2019) investigated the material properties like good fatigue strength, less weight, high strength, and good stiffness which addresses challenges like cyclic loading, gravitational forces, wind forces, and stability, and recognized that the reinforcement of composites with nanomaterials brought about more acceptable mechanical properties. In their study, they noted that Carbon Nanotube Fibers (CNT), which are within the allotropy of carbon, have the aspect ratio of its nanostructure to exceed 1,000,000 which is excellent, and for the wind turbine blades, the exceptional properties of the cylindrical carbon molecules position it to be a better choice. Pradeep et al. (2019) also stated that the manufacturing industry has compulsorily explored materials like natural bio-composites and thermoplastics which are eco-friendly and this refocus has been made favorable by the advances in technology. Since low density and high strength are very important criteria, materials that are reinforced with carbon nanotubes are

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a better choice for the composite structure. Also, these carbon nanotubes could be hybridized with natural fibers for the manufacture of these composites with even more improved properties. This hybridization makes it possible to manufacture wind turbine blade materials that are more robust with lesser weight and importantly, eco-friendly.

2.2 Mechanical Characteristics of Natural Fiber

2.2.1 Natural fibers

Considering the significant characteristics of natural fibers like their low cost, availability, eco-friendliness, bio-degradability, non-abrasiveness, and good mechanical properties, there has been an increase in the use of these fibers as reinforcement for the manufacture of these blades for wind turbines (Pradeep et al., 2019). Natural fibers that are commonly used include bast fibers (hemp, jute, flax, kenaf, roselle, ramie, rattan), leaf fibers (abaka, henequen, pineapple, banana), seed fibers (kapok, cotton, doum palm nuts), stalk fibers (rice and bamboo), fruit fibers (coir and tamarind) and stem fibers (sisal and crown) while particulates include (groundnut shell, seashell, and jack fruit). Natural fibers are usually extracted from different parts of the plant. Some of these natural fibers have exhibited excellent mechanical properties. Over the years, many authors have studied the behavior of these natural fibers. Some of the results of the studies are presented in Table 1.

Table 1: Mechanical Properties of some selected natural fibers

Fiber	Density (g/cm^3	Tensile Strength (MPa)	Author
Coir	1.2	175-220	Dittenber et al., 2012; Islam et al., 2015
Cotton	1.5-1.6	287-597	Dittenber et al., 2012; Omar et al., 2010
Flax	1.4-1.5	345-1500	Baley et al., 2014; Yükseloğlu et al., 2016
Hemp	1.48	550-900	John et al., 2008; Suardana et al., 2011
Jute	1.3	393-800	John et al., 2008; Kumar et al., 2017
Kenaf	1.4	930	Dittenber et al., 2012; Saba et al., 2015
Ramie	1.5	220-938	John et al., 2008; Teja et al., 2017
Sisal	1.33-1.5	400-700	Dittenber et al., 2012; Naveen et al., 2018
Wood pulp	1.5	1000	Holbery et al., 2006
Cellulose Earbamate	1.5	365	Ganster et al., 2006
Crystalline Cellulose	1.6	7700	Moon et al., 2011; Klaas et al., 2005
Cordenka Rayon	1.8	883	Ganster et al., 2006
Lyocell	1.4	553	Ganster et al., 2006; Zhang et al., 2018
Viscose	1.3	338	Ganster et al., 2006; Reinhardt et al., 2013

The tensile properties of natural fiber are on average more than 500MPa. Although some of these natural fibers like cotton, flax, kenaf, and wood pulp showed a commendable tensile strength of 800MPa, 1145MPa, 930MPa, and 1000MPa respectively. This shows that to a large extent, their mechanical properties can be comparable with that of some synthetic fibers. Athijayamani et al. (2009) presented the properties of some of these natural fibers in which the average density of these natural fibers was found to be 1.4g/cm^3 and the tensile behavior of flax fiber reached a value of 1035 MPa.

As there have been increased exploration of wind energy resource, environments with very harsh conditions are also being explored. These conditions necessitate the application of high-performing materials such as those developed from bio nanocomposites which are also ecofriendly. The study by Kausar (2020) focused on these set of materials for such applications and noted that the future will focus on greener and more ecofriendly materials as they will contend for important properties such as lightweight, high efficiency coupled with their characteristics of being readily available, thereby sustainable and inexpensive. Plants-based materials are referred to as green composites. Sustainable materials have been developed by the combination of various polymers (synthetic and natural) and also eco-friendly nanofillers. These green polymeric nanocomposites possess the properties (exclusively) of the polymers that are sustainable and the reinforcement that is eco-friendly. These green nanocomposites which have nanofillers as reinforcements are eco-friendly, and are applicable in the energy production industry. Initially, petroleum-based polymers which

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were in use and their composites were very hazardous to the ecosystem but incorporating these eco-friendly nanofillers have proved to be a useful alternative for these non-environmentally friendly materials. Including materials such as cellulose nanofibers which are ecofriendly and inorganic nanofillers in some of these synthetic polymers can improve the material performance and also pave the way for further development (Kumar, 2019). It was observed that high-performance materials may be obtained from developing materials such as hybrid plastics which are made of a blend of natural and synthetic polymers and bio-nano composites. Even though it was also noted that developing materials (green composites or nanocomposites) gotten completely from natural sources portends lower cost and more eco-friendliness but the tradeoff of structural and mechanical properties as compared to synthetic materials was not detailed. The achievements of these eco-friendly (green materials) are dependent on different considerations which include the expected physical properties, ease of fabrication, and also the techniques of processing of which the increasing size of the present and future wind turbine blades makes these properties balance more complicated.

2.2.2 Natural Fiber Composites

Some recent studies have been concerned with the application of natural fibers for the development of polymer composites. Ng et al. (2019) studied the mechanical properties of Kenaf/Polypropylene and it presented 12.74 MPa to be the tensile strength of the composite and its flexural strength was 29.34 MPa with a tensile and flexural modulus of 0.56 and 2.30 respectively. Also, Ng et al. (2019) in their study of the mechanical properties of Pineapple/Polypropylene composite showed that the tensile strength of the composite was 17.07 MPa, while it had a tensile modulus of 0.58 with flexural strength and modulus of 45.25 MPa, and 2.75 respectively. Yallew et al. (2020) in their studies showed that Hemp/Polypropylene composites have a tensile strength of 56.51 MPa, Jute Polypropylene has a strength of 41.48MPa and Sisal/Polypropylene composite has a strength of 75.84MPa this shows a good prospect of the possible application of natural fiber as reinforcement for the development of wind turbine blades. Figure 3 shows the mechanical attribute of some natural fiber composites. Jute also shows excellent performance, even though, generally, most of the natural fiber composites are of a good performance. The reinforced material possesses better mechanical properties than the virgin matrix.

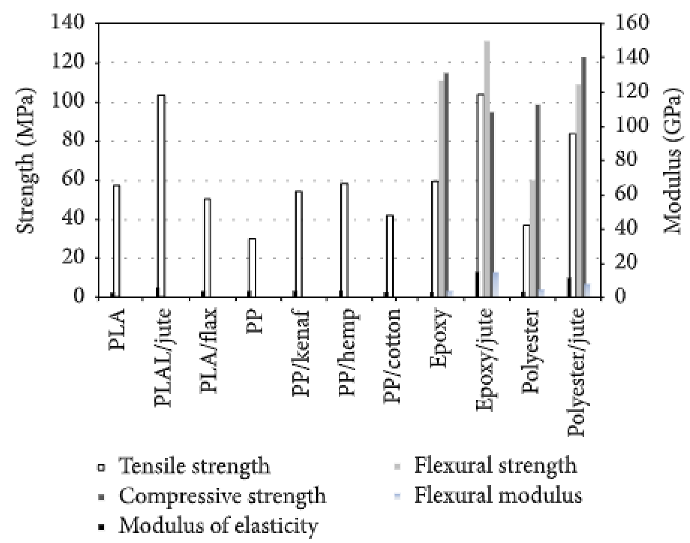

Figure 3: Mechanical properties of some selected Natural fiber composites (adapted from Mohammed et al., 2017)

Noteworthy is that the mechanical properties of epoxy and polyester-based composites have proven to perform better than the other polymers. Also of importance is the strength of the bond (adhesiveness) between the fiber and the matrix (polymer) which has a strong influence on the mechanical properties of the natural fiber/polymer composites.

Table 2: Mechanical Properties of some Natural fiber composites

S/N	Composite	Tensile Strength (MPa)	Flexural Strength (MPa)	Reference
1	Sisal/Epoxy	83-410	290-320	Cao et al., 2007; Rong et al., 2001; Gupta et al., 2016
2	Sisal/PE	65.5	99.5	Prasad et al., 2011
3	Sisal/ B/E	64	75	Tragoonwichian et al., 2008
4	Flax/Epoxy	104-280	311	Beg et al., 2008; Kishor et al., 2013

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5	Flax/VE	111-248	128	Xie et al., 2010
6	Flax/UP	61-304	91-198	Mwaikambo et al., 2002
7	Flax/PP	40-321	74-146	Maldas et al., 1993; Darshil, 2013
8	Hemp/Epoxy	105-165	126-180	Laly et al., 2003; Bledzki et al., 1999
9	Hemp/PP		127	Sain et al., 1993
10	Hemp/PLA	62-83	101-143	Bledzki, et al., 1999; Ickering et al., 2003
11	Kenaf/PLA	82-233	126-254	Goda et al., 2006; Mallick, 1993
12	Kenaf/PHB	70	101	Sawpan et al., 2011
13	Kenaf/PP	52	60	Bledzki et al., 2010
14	Jute/UP	50	103	Rachini et al., 2012
15	Jute/PP	74	112	Rowel et al., 1997
16	PALF/ UP	53	80	Hasur et al., 2004
17	Banana/Epoxy	34	128	Islam et al., 2019
18	Rattan	13	131	Islam et al., 2019

2.2.3 Natural Fiber Hybrid Composites

According to Swolfs (2018), fiber-hybrid composites are composites that have more than one fiber type in a matrix, giving them more design freedom. It was also noted that even with the commendable advancement in recent years, more effort is needed to comprehensively understand these hybrid fiber composites even though there have been commendable research efforts on fiber hybrid composites with pseudo ductility. Although toughness is a major challenge for some of these composite applications, especially wind turbine blades, most composites possess properties such as good strength and commendable stiffness but are not ductile of which fiber hybridization has been a way out of these challenges. Ductility is a required characteristic needed for most engineering applications as it is a determinant of the failure pattern of components, systems, or structures made of such materials. The more ductile a material is, the more its failure can be detected before any damage. Swolfs (2018) prescribed pseudo ductility as a way out to non-ductile fiber hybrid composites. Although a clear definition of pseudo ductility was not given by the authors, it was described as the strain difference between the final failure strain at the same stress level but on the extrapolated linear elastic region. Pseudo ductility described by Swolfs could address some key drawbacks of composite materials as regards their use in the development of wind turbines, as the materials used show little or no warning upon failure leading to serious safety concerns and hence suboptimal design relative to more ductile materials. Many hybrids have focused on the blending of natural fibers with synthetic fibers. In this form of hybridization, the superior mechanical properties of the synthetic fiber are duly harnessed (Mochane, 2019). Just like in the study of Akil et al. (2014) in which glass fiber was blended with high modulus jute. The result of the hybridization was a composite of highly improved mechanical (tensile and flexural) properties. This was majorly due to the presence of glass fiber which also was instrumental in the reduction of the water absorption properties.

More also is the hybridization of two natural fibers to form a composite material. This also has the potential of improving the properties of the resulting material and also reducing cost. This kind of hybrid material has itself given rise to the interest in biodegradable composite in which both the fiber (reinforcement) and the polymers (matrix) are biodegradable.

Some of these hybrid composites are presented in Table 3 in which their possible behavior in service as applied to the conditions of the wind turbine blade is discussed. The reference to the studies in which the mechanical properties of the composites were obtained for the assertions made are presented.

Table 3: Selected materials and their possible behavior with respect to an application for the development of wind turbine blades

S/N	System	Composite	Highlights	Reference
1	Synthetic-natural fibers hybrids	Glass-jute fiber hybrids	-Proves to be more suitable for the development of wind turbine blades than the non-hybridized natural fiber composite as the mechanical properties are improved and better. -With reduced moisture absorption, it can find offshore applications. As it would be able to withstand such humid environments. -The material degradation characteristics of the composite (which is usually a setback caused by the natural fiber are reduced. Making it suitable for application in even harsh and adverse environments. -There is a good balance with respect to its cost and performance.	Akil et al., 2014

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		Carbon-flax fiber hybrids	-Possible to replace the synthetic fiber-reinforced composite that is currently in use as it possesses very good mechanical properties when compared with each other.	Kureemun et al., 2018
		Carbon-jute fiber hybrids	-With improved mechanical properties, this can successfully replace carbon fiber in the development of wind turbine blades.	Ramana et al., 2017
2	Natural-natural fiber hybrids	-Kenaf-jute fiber hybrids -Kenaf-hemp fiber hybrids	-Has lower water absorption characteristics and better mechanical properties than the non-hybrid composites of kenaf, jute, or hemp. This property makes it a possible material for wind turbine blades but in areas where the environment is less humid. -This hybrid material also portends a cost-effective solution for the development of wind turbine blades coupled with its commendable water-resistant property.	Maslinda et al., 2017
		-Seaweed-sugar palm fiber hybrids	-Composite materials of this hybrid fiber have its mechanical and water resistance properties minimal and are also very cost-effective. -Practically the composites absorb less water and have the potential for offshore wind turbine blade development. -The important mechanical characteristics, which are the tensile and flexural strength are slightly increased than the non-hybridized composite of these fibers.	Jumaidin et al., 2017
3	Natural fibers-Ceramic hybrids	-Oil palm fibers-clay hybrid	-This material has a considerable improvement in its mechanical properties than the non-hybrid oil palm fibers. -With low cost and good mechanical properties, it can be used in the development of the wind turbine blade.	Essabir et al., 2016
		Pinecone fibers-clay hybrid	-Also has a low cost of development and has a property such that with every increase in loading, the tensile modulus increases as well. Make it possible application in wind turbine blade development.	Arrakhiz et al., 2013
		-Kenaf fibres- oil palm nanofiller -Kenaf-montmorillonite (MMT) and organically modified montmorillonite (OMMT)	-Possesses good mechanical properties when compared to the non-hybrid composite of each fiber of kenaf and palm fibers. -Also considering its low cost, it is considerable for the development of wind turbine blades.	Saba et al., 2016

It is clear that the synthetic-natural hybrid composites possess superior performance and therefore superior potential as possible materials for the development of wind turbine blades. But the low cost of these natural-natural fiber hybrid composites, hybrid nanocomposites, and their other characteristics should be a drive for further research to modify these natural hybrid composites for better performance. This will not only present an eco-friendly material but also a material that can compete in mechanical properties with purely synthetic composites or synthetic-natural hybrid composites.

2.3 Water Absorption Properties

A major setback for these natural fiber-reinforced polymer composites is their water absorption due to the presence of compounds such as pendant hydroxyl and polar groups of the fiber. That is to say, the moisture absorption resistance of these fibers is poor (high) and that is due to the presence of these hydroxyl groups. This phenomenon leads to a poor bond between the hydrophobic polymer and the hydrophilic fibers. And this poor resistance to water absorption will negatively affect the mechanical properties

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of these natural fiber polymer composites. This could according to Marta et al. (2017) affect the mechanical properties by the plasticization of the polymer matrix or inadequate adhesion (de-bonding) at the phase of interaction between the fiber and the matrix. For the development of these composite materials with good mechanical properties, the water absorption and hydrophilic nature of the fiber must be reduced through modification, chemically. This chemical treatment can be carried out with sodium chloride, alkalis, peroxide, etc. (Mohammed et al., 2015). As described earlier, the wind energy industry is exploring extreme environments like offshore and so, exposure to a very humid environment like offshore or swampy areas is an important material design consideration. The materials must show very low water absorption properties so as not to degrade to a point of failure upon exposure to these environments. And also, a means of mitigating this water absorption challenge of the materials is through hybridization. Table 4 presents the water absorption properties of some natural fiber reinforced polymeric composites.

Table 4: Moisture absorption properties of some composites

S/N	Composite	Water Absorption (%)	Reference
1	Jute/glass fiber/polyester (JGC*)	7.63-9.05	Akil et al., 2014
2	Kenaf/magnettie20–40/polyester INI (0.10–13.79 MPa) treated fiber/polyester	6.5-12.24	Xia et al., 2016; Xia et al., 2016
3	Epoxy/(coir/jute/coir)	11.2-15.3	Xia et al., 2016
4	Epoxy/(20% kenaf/Kevlar)	3.15	Yahaya et al., 2015
5	Epoxy/kenaf/PET (70/15/15)	2.089-3.988	Terzi et al., 2018
6	INI-treated fiber reinforced composite	6.2-7	Xia et al., 2015

3.0 CONCLUSION

With the growing demand for wind energy, the challenge has been to make efficient use of our scarce resources. There have been great improvements in material development although, with an increasing shift from the use of synthetic fibers, there have been great prospects in the use of natural fibers for wind turbine blades manufacture. The mechanical characteristics of these natural fiber composites proposed for wind turbine blades have been promising.

Declaration

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Code availability: Not applicable
Ethics approval: Not applicable
Consent to participate: Not applicable
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