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MECHANICAL CHARACTERISATION OF FLAX AND SISAL FIBER REINFORCED POLYMER COMPOSITES FOR WIND TURBINE BLADES

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ABSTRACT

The wind turbine is a device that converts kinetic energy from the wind, into electrical power. Among all the parts of a wind turbine such as blades, hub, gear box, nacelle, and tower; nacelle and wind turbine blades are generally made up of glass fibers and carbon fibers, for better strength, low weight, and corrosion resistance. The main limitations of these materials are the availability, non biodegradable, health hazardous and their fabrication cost. Hence, the aim of this research is to replace these materials with natural fibers.

In this research work, application of natural fibers reinforced polymer composites in wind turbine, requirements to the composites, their properties, constituents, manufacturing technologies, and defects will be reviewed; promising future directions of their developments also will be discussed.

KEYWORDS: Multiaxial Reinforcement, Natural Fibers, Polymers, Synthetic Fiber, Wind Turbine Blades

INTRODUCTION

A wide variety of sources, including coal, oil, coke, natural gas and nuclear materials, have been used to generate energy. The consumption of energy has increased, due to the increasing population and civilization. At the same time, the ecological awareness has become the major environmental issue, in the global marketplace. In today’s scenario, the major threat for the environment is the ecological imbalance, which is increasing due to the toxic waste disposal. This issue has led to the increased interest in renewable and sustainable energy sources. The only concern for the sustainable development is minimum pollution and reduction in energy consumption [2]. The increasing interest in the direction of using renewable energy, has led to the development of wind energy concept. The wind energy is a prominent renewable energy source and is a solution of the global energy problem. Wind turbines or mills have been established to convert the kinetic energy of the wind, into mechanical or electrical energy [3].

The majority of wind turbines fundamentally consists of three rotor blades and rotates around a horizontal hub, and convert the wind energy into the mechanical energy. The development of wind turbines for the production of power is a promising area. The rotor blades are considered as one of the key components of the wind turbine [1]. The wind turbine efficiency majorly depends on the aerodynamic shape and length of blade, the angle of the blades, as well as the materials used to manufacture the blades. Moreover, the wind turbines generate power, according to the speed of the wind, but not according to the demand. The fundamental criterion for the selection of materials, for the wind turbine blades is that, the material must possess high strength and high stiffness, low density and good fatigue strength. The strength of the blade must be satisfied so that, the blade can withstand the load acting on it without fracture and stiff enough so that, it cannot strike the tower during extreme loading conditions. The high fatigue strength of the blade means that, it can with stand time-varying loads throughout its intended period of life. The wind turbine industries are focusing on the development of lightweight, cost-effective and environmental friendly materials, for the production of wind turbine blades. The selection of suitable blade materials plays an important role, which determines the ultimate efficiency of wind turbine blade.

Wind Turbine

Vertical axis wind turbines (VAWTs) has both advantages and disadvantages, but generally they have not been commercially successful than the horizontal axis wind turbines (HAWTs). This is largely due to the reduced performance and dependability of most VAWTs. However, there are practical applications for VAWTs and new research and technology is improving their performance [4, 5].

Horizontal Axis Wind Turbines (HAWTs), on the other hand, are very advanced, reliable, and economically good. They come in many sizes and shapes, but they are all descendents of the old windmills, used to grind grain or pump water. Today these machines are proving: as they are used throughout the world, producing clean, reasonable, and sustainable electricity. Modern horizontal axis wind turbines produce electricity which is70-85%, whenever the wind is over 7-8 mph.

Wind turbines are classified by their size, or "capacity" (how much electricity they can produce). They can be small (< 100 kW), intermediate (100-500 kW), or large (500 kW - 5 MW). Small wind turbines are used for homes, farms, and remote sites, where electricity is hard to come by. They can be connected to the electric grid, but often they are just connected to a battery bank instead. Intermediate wind turbines are often used for schools or in hybrid systems with diesel generators that are used to powering remote towns and villages. Large wind turbines are used to produce electricity, which goes to the electric grid and then we can use this electricity in our homes, schools, and businesses places [4, 5].

DEVELOPMENT OF WIND ENERGY IN INDIA

The wind energy installation is mainly concentrated in Tamil Nadu, Karnataka, Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh, and Rajasthan. Tamil Nadu has always been the leader among Indian states in the installation of wind energy. It has installed a capacity of 7,277 MW wind energy, which is 35% of India’s total wind energy installation. Maharashtra is closely following Tamil Nadu with 4,099 MW of installed wind energy. Gujarat, Rajasthan and Karnataka contribute in increasing the share of wind energy in India. All these states have installed more than 2000 MW wind energy. Wind energy has contributed more than 19,500 MW, in the total installation. This is the reason, now the government has increased the target of annual capacity,, up to 2500 MW.

Small Wind Turbine

Smaller scale turbines for residential use are available. They are approximately 7 to 25 feet (2.1–7.6 m) in diameter and produce electricity at a rate of 300 to 10,000 watts, at their tested wind speed [31, 33].

Small Wind Turbine Technology Opportunities in India

There is a need to invent a long-term vision of the Indian industry, to produce small wind turbines that are accepted for common household appliances, in the same way that Invertors and air-conditioning systems are being used today. By virtue of their compelling economics, these new turbines are achieving high market potential, especially in the areas with lower housing densities and sufficient wind resources.

We all need to realize that, large wind turbines are now in their seventh or eighth generation of technology development, while small wind turbines are yet to develop commercially in India. Achieving these goals will require continuous advances in small wind turbine technology, progressive improvements in small turbine manufacturing, and efficient installation techniques.

For its part, the Indian industry should try harder for an innovative and simple design, so as to reduce the cost of the electricity generated by small wind turbines, in comparison with foreign small wind turbine suppliers [9]. Globally, the installation cost of a typical 1 to 6-kW residential wind turbines is about Rs. 1.5 lakhs ($3,500) per kilowatt (smaller systems being relatively more expensive). These turbines produce about 1,200 kWh per year.There is a need to bring down the installation cost to somewhere between Rs.50, 000 – Rs.75, 000 ($1,200 to $1,800 per kilowatt) with raised energy productivity level, to 1,800 kWh per installed kilowatt. If these goals are met, the 30-year life cycle cost of energy will be in the range of Rs. 2/ kWh ($0.04 to $0.05/kWh), which is lower than, virtually all-residential electricity tariffs in the country today [10].

The engineering challenges presented by the interrelated disciplines of aerodynamics, structures, controls, electrical conversion, electronics, and corrosion prevention are formidable. Thus, there is a need for adequate research cooperation between the private and public sectors, to develop the small wind turbine technology indigenously.

To support industry in addressing technology barriers, four models of Private and Public sector collaboration are proposed [11, 12].

- Research conducted at national laboratories such as C-WET, Chennai and universities with input from members of the industry.
- Applied research projects conducted at the facilities of a small wind turbine companies with support from the government through competitive procurement [19, 28].
- Applied research projects involving companies, universities, and national laboratories.
- Privately funded research and development [25, 27].

The opportunities, which are likely to be presented by improved technology, can be achieved through the cooperative activities discussed in this roadmap, for the small wind turbine industry. Work by industry members, research institutes, state and local governments, and MNES can help in the contribution of small wind turbines, to the electricity generation mix [14, 29].

Natural fibers are defined as, substances that are obtained from plants, animals, minerals or from geological processes, which are biodegradable over time [21]. They can be spun into filaments, threads or ropes and can be woven, knitted, matted or bound. Since natural fibers are obtained from natural sources, they do not need any formation or reformation. The commercially important natural fibers are those cellulosic fibers, obtained from the seed hairs, stems, and leaves of plants; protein fibers obtained from the hair, fur, or cocoons of animals and the crystalline mineral asbestos [34, 35].

METHOD OF FABRICATION

Multiaxial reinforcements are, fabrics made up of multiple plies of parallel fibers, each laying in a different orientation or axis - hence the term 'multi-axial'. These layers are typically stitched and bonded (usually with a polyester thread), to form a fabric. Many industries are using multiaxial reinforcement, to increase the properties [37].

Usually hand Layup process has been used, for the fabrication of Natural Fibers such as, Flax and Sisal [28]. Figures below show that, multiaxial reinforced for the fabrication of materials having different angles, for each layer of fibers enhance the mechanical properties of the composites [34].

Table 1: Details of Ply Construction 1

Layers	Angle	Fiber Specification	Ply Weight in Grams
Layer 1	0°/90°	Sisal	26.84
Layer 2	0°/90°	Flax	24.16
Layer 3	0°/90°	Sisal	26.84
Layer 4	0°/90°	Flax	24.16
Layer 5	0°/90°	Sisal	26.84

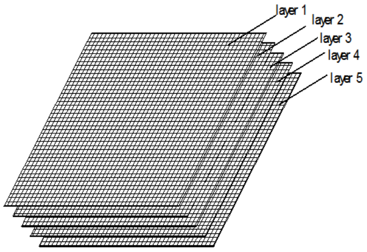

Figure 1: Ply Construction 1

Figure 1 consists of 40% of 5 layers of flax and sisal fibres and remaining is epoxy. Table 1 shows direction of each fibre and its percentage in terms of weight.

Table 2: Details of Ply Construction 2

Layers	Angle	Fiber Specification	Ply Weight in Grams
Layer 1	0°/90°	Sisal	26.84
Layer 2	+45°/-45°	Flax	24.16
Layer 3	0°/90°	Eglass	33.72
Layer 4	+45°/-45°	Flax	24.16
Layer 5	0°/90°	Sisal	26.84

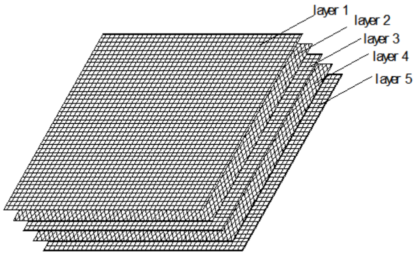

Figure 2: Ply Construction 2

Figure 2 consists of 35% of 5 layers of flax and sisal and 5% of E-glass fibres and remaining is epoxy. Table 2 shows direction of each fibre and its percentage in terms of weight.

EXPERIMENTATION

Tensile Test

For tensile test ASTM standard D3039 is selected. The most common specimen for ASTM D3039 has a consistent rectangular cross segment, 25 mm (1 in) wide and 250 mm (10inch) long and 3mm thickness [15].

Figure 3: Tensile Test Specimen

Figure 3 Tensile test specimen L= Length (250 mm); W= Width (25 mm); t = thickness (3 mm); P = Load The tensile test can be conducted on Universal Testing Machine. For testing the specimen, gauge length can be determined with the help of Vernier Caliper. The specimen is fixed between the upper cross head and middle cross head of the UTM. After the crosshead has been fixed, proper range of loading can be selected (0-300KN). As the load increases, deformation increases uptill the specimen fails or fractures.

Bending Test

For bending test ASTM standard D790 is selected. The most common specimen for ASTM D790 has a consistent rectangular cross segment, 25 mm (1 in) wide and 125 mm (10inch) long and 3mm thickness [14, 18].

Figure 4: Bending Test Specimen

Figure 4 Bending test specimen L= Length (125 mm); W= Width (25 mm); t = thickness (3 mm); P = Load. The bending test measures the ductility of the materials. The cross sectional area of the specimen can be measured with the help of a vernier caliper. The specimen will be placed over the supports as the loading comes exactly at the center of the specimen. The load will be applied very slowly, until the specimen fails.

Impact Test

The Charpy impact test, also known as the Charpy V-notch test, is a standardized high strain rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent ductile-brittle transition [9, 7, 11]. It is widely applied in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. Impact Test was carried out by using Charpy impact test machines. The specimen size is 64mm X 12.7mm X 3mm.

Figure 5: Impact Test Specimen

RESULT

Table 3: Result for Specimen 1 and 2

Properties	Epoxy+Flax+Sisal (Specimen 1)	Epoxy+Eglass+Flax+Sisal (Specimen 2)
Density (g/cc)	1.158	1.28
Impact Energy (kJ/m^2)	22	51.5
Tensile strength(MPa)	39.22	56.9
Youngs modulus(GPa)	2.366	3.351
Flexural strength(MPa)	61.87	89.2
Flexural modulus(GPa)	3.48	5.57

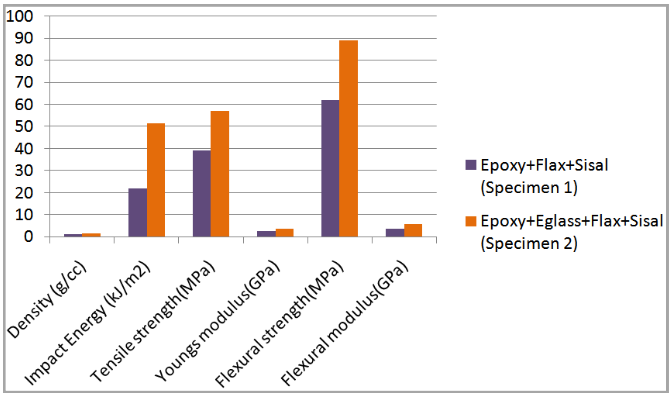

Figure: 6

From the above results it is observed that the natural fibre inforced polymer composites material properties can be still improved with adding small amount of E-glasss fibre with it.

CONCLUSIONS

The generation of energy is very essential for human survival and social development, but the generation of energy without polluting the environment is the biggest challenge of the twenty-first century. This problem can be solved by utilizing sustainable energy sources. Wind energy is the greatest example of sustainable energy source. Wind energy is clean, environmentally friendly and inexhaustible, and can act as an alternative to fossil fuels. The fundamental concept of using sustainable energy lies in the fact that, it can reduce greenhouse gases and pollution. It is true that, wind power is the fastest growing alternative energy system, but the materials used for wind turbine components are not environmentally attractive.

As the modern wind turbines are designed for an estimated life span of 20 years, a large structure needs to be disposed into the environment in the future, after the end of the service life. The materials used for wind turbines are still non-biodegradable in nature. For this reason, scientists and engineers constantly focus on replacing the existing material system of wind turbines, with bio-degradable materials. Natural fiber reinforced composite form one such class of materials, which not only possess superior mechanical properties but are also bio-degradable in nature. Natural fiber reinforced composites can be a potential candidate, where they can replace the conventional material systems of the wind industry. These materials can be introduced in the manufacturing of various sections of a wind turbine.

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