JOURNAL OF AERONAUTICAL MATERIALS
ISSN: 1005-5053
Vol. 44, Issue-01, 2024
pp. 153-160

HYBRID COMPOSITE MATERIALS FOR WIND TURBINE BLADES AND THEIR FEASIBILITY STUDY – AN EXPERIMENTAL APPROCH

Dr. Sujesh G
Associate Professor, Department of Aeronautical Engineering, Jawaharlal College Of Engineering And Technology, Palakkad, India.

Abhijith D Giri, Arathi Menon, Nanditha K P, Vinayak S Menon
Research scholar,Department of Aeronautical Engineering, Jawaharlal College Of Engineering And Technology, Palakkad, India.

Abstract: The approach attempts to find a suitable hybrid composite material for the wind turbine blade that combines a polymer matrix with a natural fibre matrix and uses more renewable resources as a matrix. One of the most abundant natural energy sources is wind power, which is harvested by erecting windmills in open spaces, typically distant from populated areas. Finding the best balance between cost and efficiency is the main challenge here. Using hybrid composite material blades in place of the antiquated wind turbine blades is one method to do this. This has balanced strength and stiffness as its key benefit. In order to ensure that the blades revolve in a specific direction, wind turbine blades are built in accordance with pre-made mathematical formulas. Utilising novel materials such as hybrid fibres transforms the way that production is done today and opens up new avenues for improvement, including reduced wear, lower environmental impact, and increased efficiency. In this work, specifics of such materials and their characteristics have been covered.

Introduction:

Science and technology are advancing at a rapid rate every single day. Renewable energy sources are on the rise, and composite materials and reinforcements are one of the fields that are advancing in this direction. Two or more distinct materials are squeezed together to create composite materials.

The two major components of composites are the matrix and the reinforcement. The process's ultimate goal is to create a material that is more desirable or has hybrid features as compared to the base materials. Everyday items like concrete, mud bricks, and fiberglass in eyeglass frames are examples of composites. Typically, matrix is a homogeneous polymer substance.

The matrix's function is to provide shape, toughness, and type, as well as to protect fibers from harm caused by structural stresses, harmful chemical reactions, and uneven stress distribution. In situations of compressive loading, the matrix also stabilizes the composite to prevent buckling .Depending on the kind of phase present, composite materials are further divided into a number of groups. Polymer matrix composites, metal matrix composites, carbon matrix composites, and ceramic matrix composites are the four different types of matrix materials. The fibers that make the reinforcement provide the composite material rigidity. Particle reinforced composite, fiber reinforced composite, and structural reinforced composite are the three categories of reinforcements.

Buildings, bridges, race car bodies, and other structures are built using composite materials. By making modifications at the nanoscale level, composite structures are being improved even further. These materials are referred to as hybrid composites. At the molecular level, hybrid composites are made up of two elements: an organic component and an inorganic component. Carbon aramid reinforced epoxy and glass reinforced epoxy composites are the most popular kind of hybrid composites.

Energy is the ability to do tasks. Currently, the most common type of energy used worldwide is electricity. Since it comes from primary energy sources like wind, solar, thermal, etc., the electricity we use is categorized as a secondary energy source. There are various ways to use the natural resources that are at our disposal to produce power.

The primary source is thermal energy, which is powered by fossil fuels like coal and natural gas. The urgent requirement is to switch from non-renewable to renewable energy sources. The best and most effective solution for the change is thought to be wind turbines. Windmills transform mechanical energy from wind. To turn wind energy into electricity, massive windmills are erected in wide-open places. With an average capacity of 2.5 to 3 MW, an onshore wind turbine may produce more than 6 million kWh annually, and this number will only increase. However, every system has advantages and disadvantages. Mechanical failure, excessive stress, creep development, and numerous other reasons all contribute to wind blade failure. Previous wind turbine blades were built of a single material and had a high failure rate and low lifespan. As a result, composite materials, a new class of materials, were tested in an effort to replace the existing turbine blades and were successful.

As we read this paper, experiments are being done to enhance the composite material by adding more materials like natural fibers, aramid fibers, etc. to increase the properties of the composite material. Therefore, it appears that the application of advanced and hybrid composites in this field has a lot of potential.

Materials currently used in wind turbine blade.

Today's wind turbines all include blades, which are primarily built of composite materials. The matrix in the composites currently in use is often a thermosetting matrix (almost 80% of commercially utilized composites employ thermoset), which is based on polyester. Epoxy resin has now supplanted polyester resin in a number of applications. Although they offer an intriguing alternative to thermoset matrices, thermoplastic matrices are rarely used. Due to their adaptability and range of qualities, glass fibers and carbon fibers top the list of the reinforcements that are most frequently utilized. Glass fiber-reinforced plastics (GRP) are the composite material kinds that are most frequently employed in the wind turbine industry. GRP rules the market because it offers the necessary qualities at a reasonable price. In contrast to carbon fibers, which have lower damage tolerance, ultimate strain, and compressive properties, glass fibers are more frequently used. They are also significantly more expensive. The creation of these turbines is now being done using newer, better materials that have improved qualities. The report goes on to detail some of these materials and their features.

Materials Used for sample preparation.

The fiber serves as the primary component of hybrid composites. In order to accomplish this, we choose natural fibers such as bamboo, aloe vera, banana fibers, sisal, and bagasse (fibres from sugarcane).Each fiber is chosen in accordance with specific findings. For instance, bamboo fibers have the potential to provide thermal insulation, allowing them to survive hot and humid environments, while sisal has the best mechanical and physical characteristics. The fibers that were used in this are listed below:

• Bamboo fibres: Bamboo composite materials display an elastic behavior up to the ultimate failure point and do not yield like steel. In general, bamboo composite reinforcement displays low stiffness when compared with traditional construction materials. The thermal conductivity of untreated outer and inner bamboo was almost the same. This suggested that bamboo material has good thermal insulation.

• Aloe Vera Fibre: This is a native plant of Africa, botanical name of Aloe vera is Aloe barbadensis miller called the lily of the desert. In the native language it is called as Katrazhai , in coastal areas of south India are major producer of aloe vera . It is a 90% water content plant. It has many medicinal values like increasing the collagen content of the skin to heel wound and acts as a necessary ingredient for many cosmetic products. Recently researchers started using aloe vera fiber as reinforcements in Fiber reinforced composites. This fiber usage and its mechanical strength characteristics are still in the research stage. 22 Department of Aeronautical Engineering, JCET

• Banana fibres: Organic banana fibre is used to make various eco-papers like tissue, filters, and currency paper. Being natural, heat resistant, having good spinning ability and high tensile strength, it is used for making yarn, fabrics, and garments. It can be blended with other fibres. Eco-friendly bags are made from banana fibre.

• Sisal fibres: Agave sisalana is the botanical name of sisal, in the native language it is called as Talai narilai, is the produce of Eastern countries. In India it is largly produced in states of Odisha and Maharashtra. Sisal fiber has outstanding durability and minimal maintenance and exhibits minimum wear and tear. It is a tough fiber.

• Jute fibres: Jute is a long, soft, shiny bast fiber that can be spun into coarse, strong threads. It is produced from flowering plants in the genus Corchorus, which is in the mallow family Tiliaceae. The primary source of the fiber is Corchorus olitorius, but such fiber is considered inferior to that derived from Corchorus capsularis. "Jute" is the name of the plant or fiber used to make burlap, hessian, or gunny cloth.

Preparation Of Laminates:

The simplest and oldest open molding technique for creating composites is hand lay-up. Dry fibers in the form of woven, knitted, stitched, or bond fabrics are first manually inserted in the mold before the resin matrix is applied to the reinforcing material with a brush. The wet composite is then rolled using hand rollers to assist a consistent resin distribution, ensure an improved contact between the reinforcement and the matrix, and achieve the appropriate thickness. The laminates are then allowed to cure in typical air conditions. This procedure is typically broken down into four steps: preparing the mold, gel coating, lay-up, and maintaining the Integrity of the Specifications.

Table 1: Arrangement Of Natural Fibres

S.No.	SAMPLE NAME	LAYER 1	LAYER 2	LAYER 3	LAYER 4	LAYER 5
1	SAMPLE A	GlassFibre	BananaFibre	GlassFibre	BambooFibre	GlassFibre
2	SAMPLE B	GlassFibre	Jute Fibre	GlassFibre	SisalFibre	GlassFibre
3	SAMPLE C	GlassFibre	Aloe Vera Fibre	GlassFibre	BananaFibre	GlassFibre
4	SAMPLE D	GlassFibre	Bamboo Fibre	GlassFibre	Jute Fibre	GlassFibre
5	SAMPLE E	GlassFibre	SisalFibre	GlassFibre	AloeVera Fibre	GlassFibre

Figure 1: Prepared samples

Laboratory Testing:

Mechanical characterization of designed laminates are carried out in one of the rapidly expanding test centre in South India ,Delta Inspection and Research Centre which is an ISO 9001:2015 accredited organization. Through persistent effort and dedication to quality, Delta Lab has attained a single position in the following areas: Chemical Analysis, Mechanical Tests, Building Materials Testing, Metal Ferrous and Non-Ferrous, Aluminium, Copper, Nickel, Lead & Zinc Base Alloys, Bitumen and its Products, Rubber & Polymer. The Delta lab is furnished with high-tech digital tools and instruments with low resolution. They are overseen by a group of knowledgeable experts who support the testing industry.

Table 2: Mechanical Characterisation

SL NO:	CHARACTERISTICS	SAMPLE A	SAMPLE B	SAMPLE C	SAMPLE D	SAMPLE E
1	TENSILE STRENGTH (MPa)	192.586	231.602	165.39	181.379	213.507
2	FLEXURAL STRENGTH (MPa)	1865	2035	1265	1276	1365
3	IMPACT VALUE (J)	7.5	8.3	6.5	7.0	6.7
4	BARCOL HARDNESS (BHU)	48	43	45	44	47
5	WATER ABSORPTION (%)	1.67	0	13.33	9	0.25

From the above observation SAMPLE B shows superiority in all perspective of mechanical characteristics. So for the application for wind turbine manufacturing SAMPLE B can be considered depending on strength to weight ratio.

Table 3: Strength – Weight Ratio

Sl No	**Material**	**Tensile Strength (Mpa)**	**Density (G/cm^3)**	**Strength To WeightRatio**
1	ALUMINIUMALLOY	342.6	2.81	121.921
2	GFRP	301.1	1.54	195.514
3	STAINLESSSTEEL	501.5	8.001	62.68
4	SAMPLE B	268.4	1.774	151.294

From this table it can be seen that the value of strength-weight ratio of Sample B is better than Stainless Steel and Aluminium Alloy. Considering the fact that our sample is a natural composite it can be concluded that Sample B is a good option for replacing conventionally used materials especially Aluminium Alloy.

A sophisticated procedure called hygrothermal analysis is used to assess how heat and moisture affect an engineering structure. The temperature, relative humidity, and moisture content of the materials used to build the structure are only a few of the variables that are considered in this research.

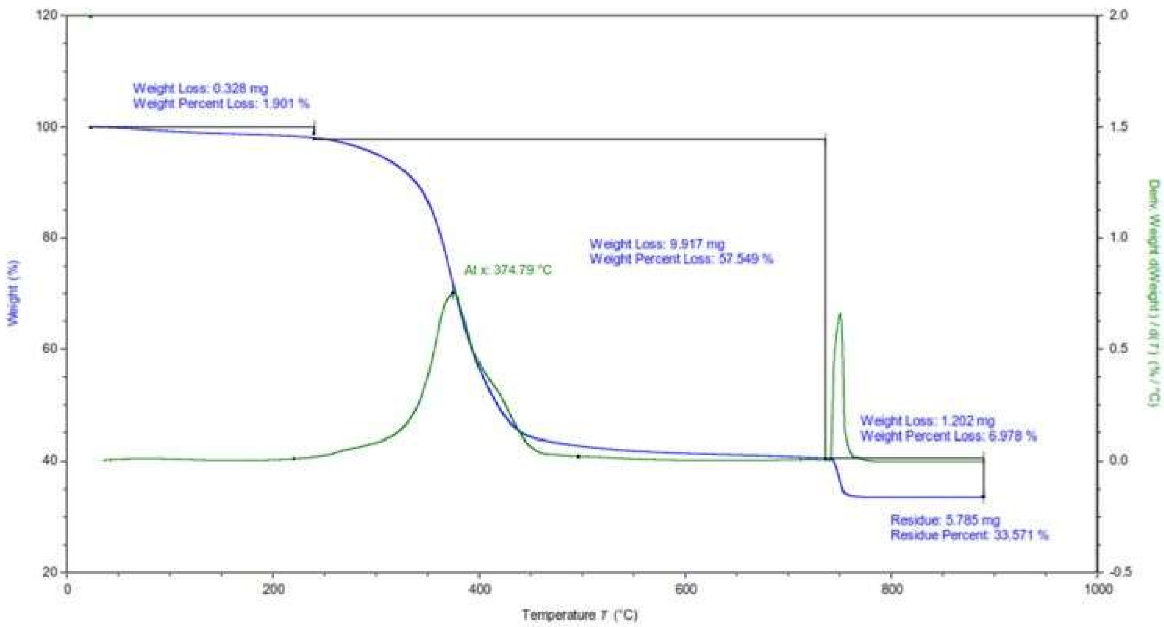

Fig 1: Hygrothermal Analysis

A total of 17.32mg of sample B was taken for the Thermogravimetric Analysis. From the graph, it is clear that at 250°C there is a weight loss of 1.901% (0.328mg).On reaching a temperature of 374.79°C the weight loss is 57.549% (9.917mg).On applying further temperature and reaching 750°C there is a weight loss of another 6.978% (1.202mg). So till 750°C, a total of 66.428% of Sample B was decomposed (11.492mg). By reaching a temperature range of 900°C a residue of 33.571% (5.785mg) was found. Thus we can conclude that the sample used is very much temperature resistant and will only decompose at much higher temperatures.

Conclusion:

Wind energy appears to be a step in the right direction as environmentally friendly solutions become more and more necessary and the energy crisis becomes more and more obvious. Therefore, it is even more crucial for us to continue pushing the envelope in our industry. When assessing the efficiency and performance of this system, better materials should be used in the manufacturing of the wind turbines. Although the glass fiber composites already in use are functioning reasonably well, carbon, aramid, and basalt fibers provide far more encouraging outcomes. As the demand for sustainable materials increases, natural fibers are being used more frequently. However, hybrid composites win the prize since they bring the best of both worlds together. They most certainly represent the future. In this research different types of hybrids natural and glass fiber-reinforced polymeric composites are prepared. And their mechanical strength, thermal capability, environmental stability, and failure morphology were studied using various experimental testing methods.

References:

[1] S. S. P. Reddy, R. Suresh, M. B. Hanamantraygouda, and B. P. Shivakumar, "Use of composite materials and hybrid composites in wind turbine blades," *Mater. Today Proc.*,vol. 46, pp. 2827–2830, 2021, doi: 10.1016/j.matpr.2021.02.745.

[2] C. M. Meenakshi and A. Krishnamoorthy, "Experimental and finite element analysis on the mechanical performance of hybrid fiber reinforced epoxy composites," *Int. J. Mech. Prod. Eng. Res. Dev.*, vol. 9, no. 4, pp. 1195–1202, 2019, doi: 10.24247/ijmperdaug2019124.

[3] C. M. Meenakshi, A. Krishnamoorthy, A. Abishek, S. Fehath Basha, A. George Vinser, and G. Hari Haran, "Study on failure morphology and water absorption behavior of naturalfiber reinforced hybrid composite laminate," *Int. J. Recent Technol. Eng.*, vol. 7, no. 6, pp. 14–17, 2019.

[4] C. M. Meenakshi and A. Krishnamoorthy, "Study on the effect of surface modification onthe mechanical and thermal behaviour of flax, sisal and glass fiber-reinforced epoxy hybrid composites," *J. Renew. Mater.*, vol. 7, no. 2, pp. 153–169, 2019, doi: 10.32604/jrm.2019.00046.

[5] C. M. Meenakshi, S. Sucharitha, and V. Srinivasan, "Variation in heat deflection behaviour of alkali treated and untreated hybrid fibre reinforced composites," *Int. J. Eng. Adv. Technol.*, vol. 8, no. 6 Special Issue 2, pp. 765–767, 2019, doi: 10.35940/ijeat.F1277.0886S219.

[6] G. R. Kalagi, R. Patil, and N. Nayak, "Experimental Study on Mechanical Properties of Natural Fiber Reinforced Polymer Composite Materials for Wind Turbine Blades," *Mater. Today Proc.*, vol. 5, no. 1, pp. 2588–2596, 2018, doi: 10.1016/j.matpr.2017.11.043.

[7] N. Manisaran, G. Santhan, C. M. Meenakshi, and A. Krishnamoorthy, "A comparative study on the effect of hygrothermal exposure over the mechanical strength of glass fiber and hybrid fiber reinforced polyester composites," *Asian J. Chem.*, vol. 31, no. 3, pp. 687–689, 2019, doi: 10.14233/ajchem.2019.21790.

[8] T. Batu, H. Lemu, and B. Sirhabizuh, "Study of the Performance of Natural Fiber Reinforced Composites for Wind Turbine Blade Applications," *Adv. Sci. Technol. Res. J.*,vol. 14, no. 2, pp. 67–75, 2020, doi: 10.12913/22998624/118201.

[9] M. K. Bin Bakri, E. Jayamani, and S. Hamdan, "Processing and Characterization of Banana Fiber/Epoxy Composites: Effect of Alkaline Treatment," *Mater. Today Proc.*, vol.4, no. 2, pp. 2871–2878, 2017, doi: 10.1016/j.matpr.2017.02.167.

[10] C. M. Meenakshi and A. Krishnamoorthy, "The mechanical characterization of mono andhybrid fiber reinforced composites using experimental and finite element analysis

methods," *Int. J. Mech. Prod. Eng. Res. Dev.*, vol. 9, no. 3, pp. 189–196, 2019, doi: 10.24247/ijmperdjun201920.

[11] G. Das and S. Biswas, "Physical, Mechanical and Water Absorption Behaviour of Coir Fiber Reinforced Epoxy Composites Filled with Al2O3 Particulates," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 115, no. 1, 2016, doi: 10.1088/1757-899X/115/1/012012.

[12] N. Saba, M. T. Paridah, K. Abdan, and N. A. Ibrahim, "Physical, structural and thermomechanical properties of oil palm nano filler/kenaf/epoxy hybrid nanocomposites," *Mater. Chem. Phys.*, vol. 184, pp. 64–71, 2016, doi: 10.1016/j.matchemphys.2016.09.026.

[13] S. Sathish, T. Ganapathy, and T. Bhoopathy, "Experimental testing on hybrid composite materials," *Appl. Mech. Mater.*, vol. 592–594, pp. 339–343, 2014, doi: 10.4028/www.scientific.net/AMM.592-594.339.

[14] G. Carra and V. Carvelli, "Long-term bending performance and service life prediction ofpultruded glass fibre reinforced polymer composites," *Compos. Struct.*, vol. 127, pp. 308–315, 2015, doi: 10.1016/j.compstruct.2015.03.049.

[15] X. Jiang, H. Kolstein, and F. S. K. Bijlaard, "Moisture diffusion in glass-fiber-reinforced polymer composite bridge under hot/wet environment," *Compos. Part B Eng.*, vol. 45, no.1, pp. 407–416, 2013, doi: 10.1016/j.compositesb.2012.04.067.

[16] T. D. Jagannatha, G. Harish, and C. Author, "Mechanical Properties of Carbon/Glass Fiber Reinforced Epoxy Hybrid Polymer Composites," *Int. J. Mech. Eng. Rob. Res*, vol. 4, no. 2, 2015.

[17] R. Eires, J. P. Nunes, R. Fangueiro, S. Jalali, and A. Camões, "New eco-friendly hybrid composite materials for civil construction," *ECCM 12 - Eur. Conf. Compos. Mater.*, 2006,[Online]. Available: http://hdl.handle.net/1822/5894

[18] S. Kumarasamy, M. S. Zainol Abidin, M. N. Abu Bakar, M. S. Nazida, Z. Mustafa, and A. Anjang, "Effects of High and Low Temperature on the Tensile Strength of Glass FiberReinforced Polymer Composites," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 370, no. 1, 2018,doi: 10.1088/1757-899X/370/1/012021.

[19] Z. Al-Hajaj, B. L. Sy, H. Bougherara, and R. Zdero, "Impact properties of a new hybrid composite material made from woven carbon fibres plus flax fibres in an epoxy matrix," *Compos. Struct.*, vol. 208, pp. 346–356, 2019, doi: 10.1016/j.compstruct.2018.10.033.

[20] D. Chandramohan, T. Sathish, S. Dinesh Kumar, and M. Sudhakar, "Mechanical and thermal properties of jute/aloevera hybrid natural fiber reinforced composites," *AIP Conf.Proc.*, vol. 2283, no. October, 2020, doi: 10.1063/5.0024976.