Hybrid Composites Manufacturing and Testing of Wind Turbine Blades

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ABSTRACT

Composite materials are made from two or more different compressed materials. Composites mainly consist of two parts i.e., matrix and reinforcement. The major challenge in the field of composite materials is less efficiency at a high cost, increase in weight, high stress and creep formation, non-degradable when compared with green composites, high heat dissipation, etc. The process aims to identify a suitable Hybrid Composite Material For The Wind Turbine Blade using more renewable resources as a matrix for the composite material and its mixed layer line up with polymer matrix with natural fiber matrix. There is a wide scope of composite material in automotive, aerospace, wind energy, electrical, sports, domestic purpose, civil construction, medical chemical industries, etc. Composite materials have a great potential for application in structures subjected primarily to compressive loads. Composite materials have attractive aspects like relatively high compressive strength, good adaptability in fabricating thick composite shells, low weight, low density, and corrosion resistance. Composite materials have good mechanical, electrical, and chemical properties, due to which we can use composite materials in many various industries. Various parts of automobiles and aerospace are manufactured with composite materials due to their good properties. Composite materials are used for domestic purposes like furniture, window, door, mating, civil construction, etc. In the marine, chemical industries, and sports, we can use composite material for better performance of the parts. With the help of a review, we conclude that composite materials have wide advantages & applications in various industries; we can make better lifestyles with the help of composite materials.

Keywords- Hybrid composites, reinforcement, Matrix, Laminates, VARTM, Hygrothermal Analysis, Thermogravimetric Analysis.

INTRODUCTION

Composite materials are made from two or more different compressed materials. Composites mainly consist of two parts i.e. matrix and reinforcement. The ultimate aim of the process is to produce a material with higher desired qualities or hybrid properties compared to base materials. Matrix is generally a homogeneous polymer material. Composite materials are further separated into various categories depending on the type of phase present. There are four types of matrix materials namely polymer matrix composites, metal matrix composites, carbon matrix composites, and ceramic matrix composites. Reinforcement is the fibers that provide stiffness to the composite material. There are three classes of reinforcements namely, particle reinforced composite, fiber reinforced composite, and structural reinforced composite. Further advancements are being made to improve the structure of composites by making adjustments at the nanoscale level. Those are called hybrid composite materials. Hybrid composites comprise two elements at the molecular level, the inorganic part, and the organic part. The most common hybrid composites are carbon aramid-reinforced epoxy and glass-reinforced epoxy composite.

A. Hand Lay-up Method

Hand lay-up is the simplest and oldest open molding method for fabricating composites. At first, dry fibers in the form of woven, knitted, stitched, or bond fabrics are manually placed in the mold, and a brush is used to apply the resin matrix on the reinforcing material. Subsequently, hand rollers are used to roll the wet composite to ensure an enhanced interaction between the reinforcement and the matrix, to facilitate a uniform resin distribution, and to obtain the required thickness. Finally, the laminates are left to cure under standard atmospheric conditions. Generally, this process is divided into four steps: mold preparation, gel coating, lay-up, and during maintaining the Integrity of the Specifications.

In the Hybrid composites, the main component is the fiber. So for that, we are selecting natural fibers like bamboo, aloe vera, banana fibers, sisal, and bagasse (sugarcane fibers). Each fiber is selected based on certain findings. For example, sisal provides the best mechanical and physical properties while bamboo fibers provide thermal insulation capability to withstand hot and sultry conditions. The fibers used in this are given below:

Bamboo fibers: 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 Katrazhai, in coastal areas of south India are major producers 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 also 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.

Banana fibers: Organic banana fiber 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 fibers. Eco-friendly bags are made from banana fiber.

Sisal fibers: Agave sisalana is the botanical name of sisal, in the native language it is called Talai narilai and is produced in Eastern countries. In India, it is largely produced in the states of Orissa and Maharashtra. Sisal fiber has outstanding durability and low maintenance and exhibits minimum wear and tear.

Jute fibers: 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 the 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.

B. Preparation Of Laminates

The laminates were prepared using the hand lay-up method as it is simple and less costly the steps are as follows:

- First, take 2 synthetic fibers with dimensions 1m*1m and apply the releasing agent (polishing wax) on one side of both synthetic fibers.
- Now, a mixture of hardener and resin is taken in a 10:1 ratio, mixed thoroughly, and applied to the synthetic fiber.
- Now place a glass fiber of dimension 300 mm*300 mm above the synthetic fiber and apply the epoxy hardener mixture.
- Similarly, take the natural fiber and glass fibers and repeat the above process up to the required.
- Now place the synthetic fiber above the composite and leave it to dry.
- In a similar way prepare the other samples too.
- After drying up, remove the synthetic fiber and we will get the required samples.

C. Laboratory Testings

We have done some of our testing at Delta Inspection and Research Centre, Chennai. The remaining test is done in Micro Lab, Chennai.

Delta Inspection and Research Centre, an ISO 9001:2015 certified Laboratory is one of the fast-growing test centres in South India. Delta Lab has achieved a single position in 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, etc. through its constant effort and commitment of quality. Delta Lab is equipped with sophisticated digital equipment/instruments with minimum resolution. They are managed by a team of competent professionals who support the field of testing. They are committed to delighting our customers with our competency and quick service. They assure you of their best service with high quality promptly.

Micro lab emerged over these years into a national multiple specialty test house accredited as per ISO 17025 by NABL. The micro lab has grown with knowledge acquisition from clients and Third-Party Agencies (Lloyds, TUV, BV, NPCIL, BHAVINI). So much to this, our certification is unquestioned in the industry, and that is because we value testing. Micro lab assumes a partner status with MNCs, OEMs, and R&D teams of a range of industries such as Automotive, Plastics, Rubber, Paints, Civil, Chemical, Metals & Heavy metals, Water, Ores, and Minerals. Micro lab's specialization also touches on Accelerated Weather Testing, Failure Analysis, Fatigue & Fracture Toughness.

Table 1: Results Of Mechanical Characterisation

SL.NO	CHARACTERISTICS TEST	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

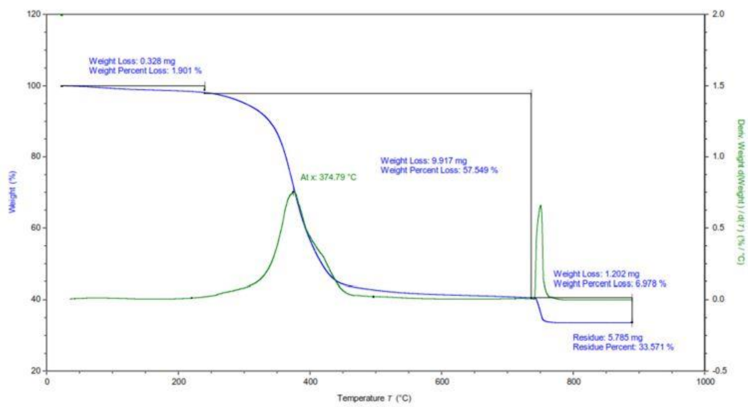

Fig 1: Hygrothermal Analysis

A total of 17.32mg of sample 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.

Table 2: Hygrothermal Analysis

ID	Test Obervation
1	0.94 %
2	0.88 %
3	1.57 %
4	1.22 %

D. Calculations

$$\text{Poisson's Ratio} = \frac{\text{Transverse Strain}}{\text{Lateral Strain}} \quad (1)$$

$$\text{Young's Modulous} = \frac{\text{Longitudinal Stress}}{\text{Longitudinal Strain}} \quad (2)$$

$$\text{Poisson's Ratio} = \frac{1.38983}{4.52715} = 0.307$$

$$\text{Young's Modulus} = \frac{231.598}{0.231} = 1.002 \text{ MPa}$$

E. Designing

The table below depicts optimized twist angle and chord length values for 10 different sections of 1.17 m blade length.

Table 3:Blade Design Dimensions

Sr No:	Position(m)	Chord (m)	Twist angle (Deg.)
1	0.00	0.076	0.00
2	0.09	0.126	15.97
3	0.21	0.100	10.9
4	0.33	0.083	7.72
5	0.45	0.070	5.55
6	0.57	0.061	3.98
7	0.69	0.053	2.80
8	0.81	0.048	1.87
9	0.93	0.043	1.12
10	1.05	0.039	0.51
11	1.17	0.036	0.00

The required dimensions mentioned above were taken for the design of the blade and these dimensions are taken from an international journal which is titled 'Simulation of Micro Wind Turbine Blade in Q-Blade' which is published in the International Journal for Research in Applied Science & Engineering Technology (IJRASET) by Mr. Shubham Raut, Mr. Shubham Shrivas, Mr. Rohan Sanas, Mr. Navjyot Sinnarkar and Prof. M. K. Chaudhary, "Trinity academy of engineering", Department of Mechanical Engineering Savitribai Phule Pune University, Pune, India.

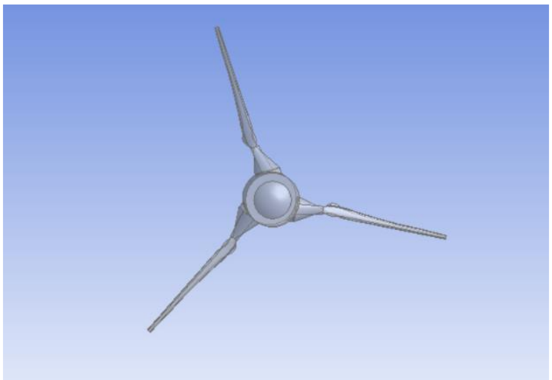

Fig 2 :Top View Of 3 Blade Models With Hub.

Fig 3: Isometric View Of The Blade.

CONCLUSION

The present research work is an extensive study from material selection to finite element analysis and new product development using hybrid fiber-reinforced polymeric composite materials. All the new and current technologies like Computer-Aided Design, Rapid Prototyping (3D Printing), Advanced Manufacturing like VARTM, and Finite Element Analysis (FEA) are used. Due importance is given to understanding the impact of environmental factors on composite life and strength, which happens to be the main factor of consideration in the case involving natural fibers in composite manufacturing. This research has extended to product development, which is a real need for economic and industrial development.

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. Experimentally predicted mechanical strength values are compared with the finite element analysis results.

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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 natural fiber 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 on the 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 and hybrid 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 of pultruded 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 Fiber Reinforced 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.