STM JOURNALS

Journal of
Polymer & Composites

ISSN: 2321-2810 (Online)
ISSN: 2321-8525 (Print)
Volume 12, Special Issue 3, 2024
DOI (Journal): 10.37591/JoPC

http://engineeringjournals.stmjournals.in/index.php/JoPC/index

Research JoPC

Experimental Analysis of Wind Turbine Blade (Hawt) With Recycled Carpet Waste Polymer Composite Material

Rakshapal Singh Rajawat[1]*, Rajneesh Kumar Singh[2]

Abstract

The term "carpet" is often used interchangeably with "rug," but there is a technical distinction. Rugs are generally smaller and can be easily moved, while carpets are typically larger and cover a significant portion of the floor. Carpets are commonly used to enhance the comfort of indoor spaces, provide insulation, and contribute to the overall design and atmosphere of a room. Polymer composite materials also known as polymer matrix composites (PMCs) are a type of composite material where polymers (plastics) serve as the matrix material. My current project involves creating a wind turbine blade (HAWT) out of carpet waste polymer composite material and analysing its features. The banana-hemp-glass fibre reinforced composite material used in this experiment are made by hand lay-up. Tensile, flexural, and impact strengths are thoroughly investigated and provided. The following conclusion has been formed based on the findings obtained by horizontal axis wind turbine (HAWT) using hybrid composite material blade with modified aerofoil design of lift boosting techniques. The parameters derived from the result. When the tower height and inlet velocity of the rough surface blade were raised, the actual power of the wind turbine was determined to be optimal.

Keywords: Composite material, Mechanical properties, Wind blade, RPM, Performance

INTRODUCTION

Recycled carpets are crafted using fibers and materials sourced from various recycled sources. This can include post-consumer materials such as plastic bottles, discarded textiles, or post-industrial waste from manufacturing processes. Sustainability Focus: The production of recycled carpets emphasizes sustainability by reducing reliance on virgin materials, conserving natural resources, and decreasing the carbon footprint associated with carpet manufacturing. Design Variety: Recycled carpets come in a diverse range of styles, colors and textures, offering consumers a wide selection while maintaining a commitment to environmental responsibility. The design options cater to various aesthetic preferences and functional needs. Durability and Performance: Manufacturers strive to maintain or enhance the durability and performance characteristics of recycled carpets compared to traditional options. This ensures that the carpets meet quality standards while promoting a longer product lifespan. Circular Economy Principles: The use of recycled materials in carpet production aligns with the principles of a circular economy. These carpets contribute to closing the loop on resource usage by reusing materials, reducing waste and promoting a more sustainable approach to manufacturing. Consumer Appeal: With an increasing focus on sustainability, consumers are showing a growing interest in environmentally friendly products. Recycled carpets appeal to eco-conscious consumers who seek flooring options that align with their values and

***Author for Correspondence**
Rakshapal Singh Rajawat

[1]Research Scholar, Mechanical Engineering, Nims University Rajasthan (Jaipur), India
[2]Assistant Professor, Mechanical Engineering, Nims University Rajasthan (Jaipur), India

Received Date: March 21, 2024
Accepted Date: May 04 2024
Published Date: July 09, 2024

Citation: Rakshapal Singh Rajawat, Rajneesh Kumar Singh. Experimental Analysis of Wind Turbine Blade (Hawt) With Recycled Carpet Waste Polymer Composite Material. Journal of Polymer & Composites. 2024; 12(Special Issue 3): S259–S265.

contribute to a healthier planet. Industry Innovation.

The introduction of recycled carpets encourages innovation within the flooring industry. Manufacturers explore new technologies and processes to enhance the recyclability of materials, improve production efficiency, and reduce environmental impact. Regulatory Compliance: Recycled carpets often align with or exceed environmental standards and regulations. This compliance reinforces the commitment of manufacturers to responsible practices and can contribute to the overall sustainability goals of businesses. Recycled carpets represent a positive step towards sustainable living and responsible consumption. As awareness of environmental issues grows, the adoption of recycled materials in carpet production reflects a broader commitment to balancing the need for functional and aesthetically pleasing products with environmental stewardship. The introduction of recycled carpets is a testament to the industry's responsiveness to global environmental challenges and the ongoing pursuit of eco-friendly solutions.

A study by Miliket al. [1] examined the mechanical characteristics of a reinforced composite composed of the two most abundant plant fibres in Ethiopia, Nacha and Sisal. To improve the fiber-to-fiber interfacial contact, it underwent further treatment with 5% NaOH and residue removal. Chen, J. et al. [2] study focused on the primary recycling technologies and the repurposing of recycled goods. More work is still needed to advance current recycling technologies from the laboratory to commercial manufacturing. The widespread usage of thermoset composites in wind turbine blades has made their recycling a critical problem that requires attention. The majority of the FRP waste recycling and reuse technologies are still in the laboratory stage and are extremely limited at the moment. In Park, H. et al. [3] study a structural design employing natural flax fibre composite was completed for a 1-kW-class horizontal axis wind turbine blade. A comparison is made between the flax/epoxy composite blade's structural design outcomes and the glass/epoxy composite blade design outcomes. With an emphasis on tensile, flexural, and impact behaviours, Venkatasudhahar et al.[4] work includes the creation and characterization of five layered carbon-jute-banana fibre reinforced composites, a novel epoxy hybrid composite. Using a traditional manual lay-up process, six distinct hybrid composites were created in a woven mat with varied symmetrical laminate stacking sequence. Materials that improve a composite's properties when added are known as filler (P. Divya Vani et al. [5]). A study was conducted to determine how filler materials affected the mechanical properties of hybrid composite by varying the filler content.This work examines the construction of a new set of composites made of glass fibre reinforcement, epoxy resin, and sawdust particulate fillers, as reported by M. Sabareeswaran et al. [6] The current study's findings support the idea that adding wood flour glass fibre can improve these qualities. In comparison to combinations of (0%+30%), (5%+25%), (10%+20%), and 15%+15%, the composites made with 25% of WAS and 5% of TS powder-reinforced epoxy composites demonstrated superior tensile, compression, and flexural properties, according to research by Pasha, N. et al. [7]. Banpurkar, R. Prof. et al. [8] looked into the design process and history of wind turbine blades. Aerodynamics is a key consideration in the design of wind turbine blade, and it is also the primary cause of smaller major losses in energy production and operational efficiency. However, to be able to obtain good material qualities, more producers are turning to epoxy with regard to developing a trustworthy technique for creating and evaluating HAWT, the project will be successful. Pradeep A.V. [9] investigated the state-of-the-art materials used in wind turbine blade construction. Additionally, in an effort to lighten the material and boost its strength, research was done to determine the advanced properties of materials related to wind turbine blades. Without a doubt, wind energy provides green energy, according to research by Kalkanis, K. et al. [10]. This does not mean that manufacturing, maintenance, and decommissioning have no environmental impact. The company's expansion plans for the future underscore the necessity of optimisation in every aspect, with the primary tool being their entire life cycle.

MATERIAL FABRICATION PROCESS.

Banana Musa plants produce bananas, a tropical fruit. Banana flesh is soft and tasty, and they have a thick peel that protects their elongated, curving shape. Raw banana fiber carpet is shown in Figure 1.

Journal of Polymer & Composites
Volume 12, Special Issue 3
ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

They are a popular and healthful snack due to their rich vitamin, fibre, potassium, and other critical mineral content. Hemp is a form of Cannabis sativa plant that is utilised commercially and industrially shown in fig. 2. Hemp contains extremely low levels of the hallucinogenic chemical THC (tetrahydrocannabinol), as opposed to its near relative marijuana. Hemp is used to make a wide range of products, including paper, textiles, food (such as hemp seeds and oil), biodegradable plastics, and even building supplies. Glass carpets are constructed of layers of woven or nonwoven glass fibres embedded in a binder substance, which is typically polyester or epoxy represented in fig. 3. Typically, microscopic glass strands spun or drawn from molten glass are used to create the carpet. These fibres are well-known for their toughness, strength, and resistance to chemicals and water. In this experiment, glass, hemp, and banana fibres were combined to form hybrid composite materials. Glass fibres were laminated with HY911 hardener and epoxy resin (epoxy 758). The base plate was cleaned of rust using abrasive paper. The surface was then cleaned twice with a thinner solution and allowed to dry. After curing, the surface was covered with silicone gel. The surface was allowed to settle for a few minutes prior to moulding. The hardener and epoxy resin are mixed in a 10:1 ratio. After combining, the curing period and pot life were 20 minutes, as depicted on the laboratory chart. This inspection is necessary to guarantee that the resin does not cure within the curing pot. A stopwatch was used to constantly monitor the pot mixture. The natural fibres were initially dried in the sun for three to five hours. The first laminate was constructed by layering glass and banana fibres on top of a foundation plate and applying epoxy resin. This laminate was made by hand-laying two layers of banana fibre and three layers of glass fibre. The manufactured laminate can only be 300 × 300 × 4 mm in dimension. We fill the second and fourth layer of each laminate with natural fibres, while the top, middle, and bottom layers are comprised of glass fibre. Similarly, hemp-glass and banana-hemp-glass fibre laminates with epoxy resin are made using the same hand lay approach. Then, with use of a weight press, the three sets of hybrid laminate were cure for 12 hours while loaded. Banana, hemp and glass and their fabricated mixture are shown in Figure 4 and Figure 5.

Figure 1. Raw Banana fiber carpet [12].

Figure 2. Raw Hemp fiber carpet [12].

Figure 3. Glass fiber carpet [12].

Figure 4. Fabricated banana-glass fiber composite laminate [12].

Figure 5. Fabricated hemp-glass fiber composite laminate [12].

EXPERIMENT MODEL

According to the measurements of the turbine blade considered with reference to NACA 2415-il – NACA 2415 listed in table 1, an aerofoil is prepared demonstrated in fig. 6. To make the top and bottom layers, three layers of woven roving are stacked on top of each other. After 14 to 16 hours of curing, the top and bottom constructions should be quite strong. After that, the GFRP laminates are removed from the mould. The primary components of the experimental setup are the rotor blade, shaft, support block, and flap.

Table 1. Properties of NACA airofoil [11].

Airofoil naca2415-il – NACA 2415	
Chord (mm)	100
Radius (mm)	0
Thickness (%)	120
Origin (%)	0
Pitch (degrees)	0
Halo (mm)	0
Halo (mm)	0
Line thickness (%)	100
X grid (mm)	15
Y grid (mm)	15
Paper width (mm)	280
Paper height (mm)	200

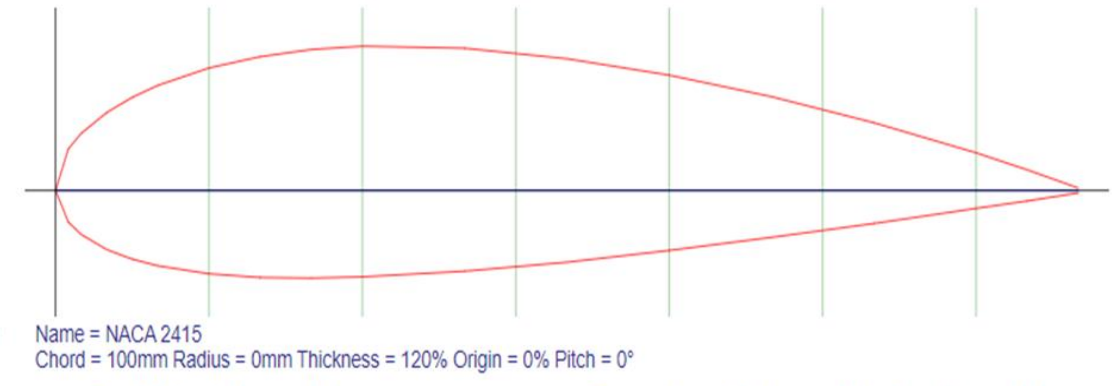

Figure 6. NACA 2415 airofoil [11]

SPECIFICATION OF BLADE

Length of blade = 0.3
Twist angle = 10 deg.
Cord length = 5.2 cm
Camber area = 2.4 cm
Camber position 2.2 cm from Leading Edge
Blade thickness = 0.7 cm
Blade twisting 11 Degree
Number of blades = 3
Blade nomenclature = NACA Aerofoil type

METHOD

According to the Bet'z Limit theory in the form of kinetic energy that maximum power developed is (0.59) times the total kinetic energy of the wind flow before it strikes to the rotor blade of the wind turbine. This factor is known as Bet,z coefficient and denoted by Cp. Therefore above equation may be written as

P (theoretical maximum power) = Cp (1/2ρAVi^3)
= Cp K.E. (Available in the wind stream)
Theoretical power of wind turbine is,
Power air =1⁄2 ρAvi3
Actual power, Power actual = 1⁄2 ρ AVa (vi^2-ve^2)
Where, ρ = Density of the air =1.2 kg/m^3
vi = Inlet velocity at the blade in m/s
ve = Exit velocity at the blade in m/s
A = Swept area of rotor blade in m^3
Va =Average Velocity in m/s
Coefficient of Power,cp = Actual power/Theoreticl power
Putting the value of b in the original equation of power coefficient,
We get, cp = Actual power/Theoretical power
cp = va/vi(1-b^2)
cp= (vi+ve)(1-b^2)/2vi
cp = 1/2 (1-b^2)(1+b)

EXPERIMENTATION CASES

To find out the power analysis of wind turbine a working model was developed. Experiment was carried out on the working model at the different wind speed and tower height. In the experiment, we used the blade at various times, locations, and wind speeds

Date of experiment	Place of experiment
24/05/2023	Dewas (M.P)
28/05/2023	Dewas (M.P)
30/06/2023	Dewas (M.P)

- Wind turbine rotor blade with a rough surface
- Blades of wind turbines with varying heights

RESULT

Natural and artificial fibre reinforced hybrid composite materials are becoming increasingly popular because to their eco-friendly, recyclable, biodegradable, and user-friendly properties. Many researchers are researching in this subject to create hybrid composites that can replace metals and alloys in engineering and technology without compromising weight resonant capabilities or cost. In the current work, banana, hemp fibres are hybridised with glass fibre to create ready hybrid composite laminates. The examination samples are then prepared from the composite laminates in accordance with ASTM standards, and the materials are tested under tensile, flexural, and impact loading situations utilising a UTM and an impact testing machine. Table 2 displays findings of the examination into the mechanical properties of the tried composite sample. In this section a detail parametric study is carried out on the basis of different types of samples.The material properties of different samples are listed in table 2.

Table 2. Shows the mechanical properties discovered using ASTM standards [12].

Sample	Tensile strength (MPa)	Testing-UTM	Flexural strength (KN)	Testing-UTM	Impact strength (Joules)	Testing- UTM
Banana-glass fiber	39.3	ASTM	0.52	ASTM	5.33	standard

composites		D638		D790		ASTM A370
Hemp-glass fiber composites	37.4	-	0.29	-	5.34	-
Banana-hemp-glass fiber composites	29	-	0.53	-	8.68	-

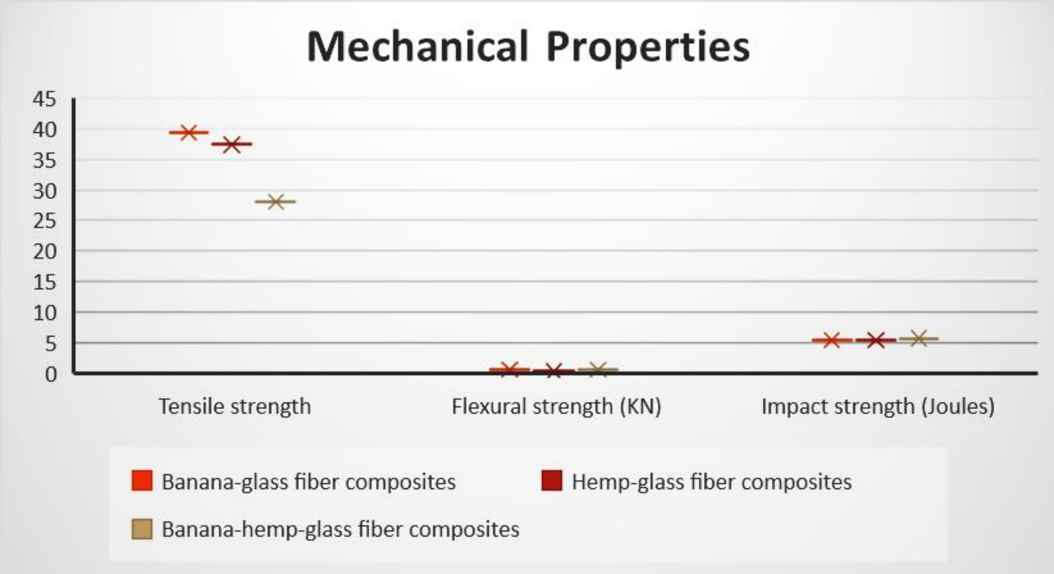

Figure 7. Comparison of mechanical properties of different fiber composites.

Power analysis of a wind turbine using hybrid polymer composite at varying tower heights is listed in table 3. Power analysis is calculated on the basis of tower height. The results obtained based on the observation for different cases of rotor blades with rough surface sare listed below in table 3. When the tower height increase from ground level to 8.8 m. Then wind velocity varies from 4.8 m/sec to 6.6 m/sec. which RPM varies from 35 rpm to 52 rpm, and actual power varies from 0.0798 watt to 0.5428watt. The actual power and wind turbine were found optimum for rough surface blade. The variation of RPM and power at different tower heights and inlet velocities is shown in Figure 8.

Table 3. Power analysis.

Tower height(m)	**Inlet Velocity(m/s)**	**Outlet velocity(m/s)**	**$V_1^2 – V_2^2$(m/s)**	**R.P.M**	**Actual power (W)**
6.4	4.8	4.6	1.88	35	0.0798
6.8	5.4	4.5	8.91	40	0.2800
7.4	5.6	4.2	13.72	45	0.3828
8.2	6.2	3.8	24	48	0.50351
8.8	6.6	3.6	30.6	52	0.5428

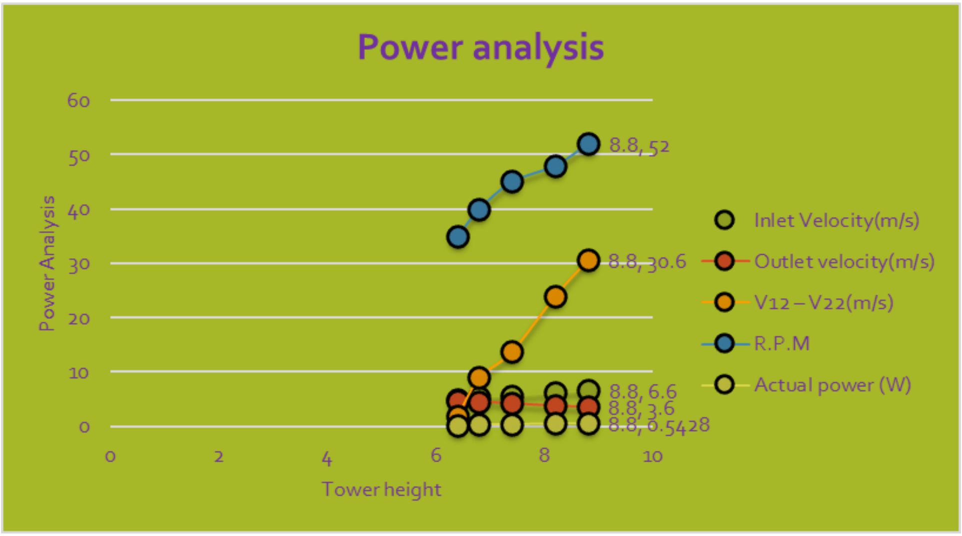

Figure 8. Power analysis.

CONCLUSION

Banana-glass fibre hybrid composites had better tensile strength (39.3 MPa vs. 37.4 MPa) than standard hemp-glass fibre reinforced composites. Composites reinforced with banana-hemp-glass fibres have a maximum flexural strength of 0.53 kN, which is higher than the 0.52 kN of banana-glass fibre composites.

- The hybrid composites' impact strength ranges from 5.33Joules to 8.68Joules.
- Following results were reached using data from horizontal axis wind turbines (HAWT) equipped with aerofoil blades and advanced lift-increasing techniques.
- The tower height and input velocity of the rough surface blade were found to be the optimal values for the parameters derived from the actual power of the wind turbine. As tower height and inlet velocity have increased, so too has the wind turbine's power.
- Hybrid composite blades are inexpensive and have a maximum lifespan of ten to fifteen years.

Declaration of Interest

No potential conflict of interest was reported by the author(s).

Acknowledgement

We acknowledge the support of mechanical engineering department Nims University Rajasthan Jaipur in conducting this study.

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