

SHORT ABSTRACT

Thesis title - Development of Bio-Composite Blades for Straight Darrieus Wind Turbines

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In the present modernized world, with the increase in energy demand, conventional energy sources are not only towards the depletion stage but also causing serious adverse effects on the environment. The escalating environmental concerns and the urgent need for sustainable energy solutions have intensified the quest for renewable energy sources. Among the various renewable sources, wind is the most viable and practical form, generating a large amount of usable electricity. However, the conventional materials used in the construction of wind turbine blades such as glass/carbon fiber reinforced polymers (FRPs) have raised serious environmental concerns due to their non-biodegradable nature and reliance on fossil fuels during manufacturing. To address these challenges, the development of bio-composite materials represents an environmentally friendly alternative for wind turbine blades. These composites possess several advantages over conventional composites, including a low carbon footprint, better recyclability, and possible improved mechanical properties.

The research aims to investigate the mechanical properties of bio-based composites developed from natural material (bamboo) for wind turbine blade application. Different bamboo species are selected from the North-Eastern region of India and the developed composites are tested for mechanical strength. The elastic material properties of the bamboo composite is evaluated using representative volume element (RVE) homogenization technique. These material properties are utilized for determining the static strength of bamboo composite turbine blades on two standard airfoils. The model is developed in ANSYS and detailed structural analysis is done to get the optimum layup. Free and forced vibration of the bamboo composite blade is also studied. A three-dimensional model of the straight Darrieus wind turbine is modelled to study the real-time interaction between the blade and the surrounding airflow and finally a prototype of the bamboo blade is fabricated. The results of the experimental investigated demonstrated that the developed bamboo composite has a high specific strength of $245 \text{ MPa.m}^3/\text{g}$ compared to glass composites with specific strength of $239 \text{ MPa.m}^3/\text{g}$. Further it is observed that the non-symmetric blade with angle-ply layup showed better structural performance in terms of stress and deflection. The bamboo composite blade have 70.98% and 1.11% less stress and deflection values compared to the glass composite wind turbine blade. The natural frequency values of bamboo composite blades are higher which represents stiffer blades with reduced risk of structural failure. The value of maximum stress from the fluid-structure interaction is 32.26 MPa which is less than the allowable safe stress limit of 96.14 MPa obtained from the experimental results.

It is concluded that bamboo has a high strength-to-weight ratio, which is a crucial factor in designing efficient wind turbine blades. Bamboo is also an attractive substitute for replacing traditional composites like carbon and glass fiber composites in the construction of blades because of its remarkable mechanical properties, low cost, quick growth rate, and availability. Moreover, the density of bamboo is very less compared to traditional glass/carbon fiber composites, which can withstand the mechanical stresses and large deflections associated with wind energy production. The application of bamboo composites in wind turbine blades is a novel and sustainable solution for enhancing the environmental friendliness and efficiency of wind turbine systems.