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Intelligent and Data-Driven Reliability Evaluation Model for Wind Turbine Blades

Daniel Osezua Aikhuele, University of Port Harcourt, Nigeria*
https://orcid.org/0000-0001-9274-4530

Ayodele A. Periola, Bells University of Technology, Nigeria

Elijah Aigbedion, Bells University of Technology, Nigeria

Herold U. Nwosu, University of Port Harcourt, Nigeria

ABSTRACT

Wind energy is generated via the use of wind blades, turbines, and generators that are deployed over a given area. To achieve a higher energy and system reliability, the wind blade and other units of the system must be designed with suitable materials. In this paper, however, a computational intelligent model based on an artificial neutral network has been proposed for the evaluation of the reliability of the wind turbine blade designed with the FRP material. The simulation results show that there was a reduction in the training mean square error, testing (re–training) mean square error and validation mean square error, when the number of training epochs is increased by 50% such that the minimum mean square error and maximum mean square error were 0.0011 and 0.0061, respectively. The low validation mean square error in the simulation results implies that the developed artificial neural network has a good accuracy when determining the reliability and the failure probability of the wind turbine blade.

KEYWORDS

Artificial Neutral Network, Failure Probability, Fatigue Reliability, FRP Material, Wind Turbine Blade

1. INTRODUCTION

Wind, which is a limitless and a clean energy source (renewable in nature), is one of the oldest alternative source of energy. It has been described by energy researcher as one of the most reliable energy resources ever discovered (Pfaffel et al., 2017), a renewable green energy and harmonious to environment, since it neither consumes fossil fuel nor makes dirty atmosphere (Jiang et al., 2017; Oyedepo, 2012).

This renewable green energy which can be realized via the use of wind blades which can be connected to a turbine and a generator, is deployed over a given area for the purpose of generating electrical energy (Periola & Aikhuele, 2021). In generating the electrical energy, the wind blades of the system are made to turn by the forces of nature (wind), such that it generates a kinetic energy which then fires the turbine to generate the electrical energy output via the generator. The wind blades and the turbine used in the system, are deployed in arrays which usually covers a large geographical area (Aikhuele et al., 2019). This is done with the aim of intercepting the wind at a significant number of points thereby generating a significant electrical energy output. In this manner, wind renewable

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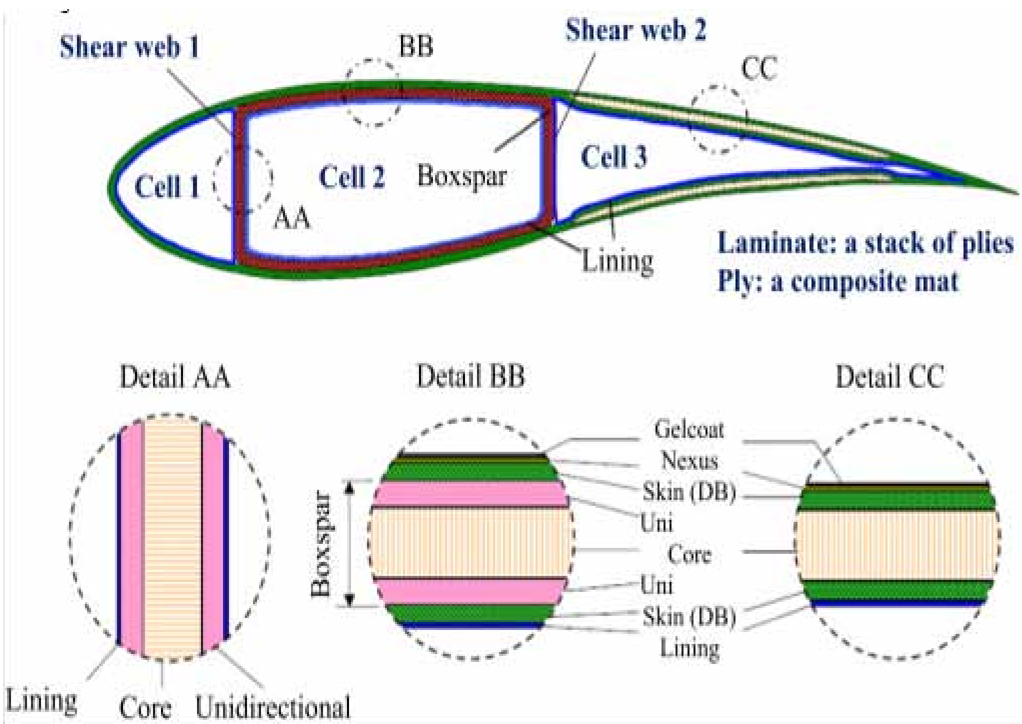
energy systems are aimed to take advantage of the diversity in wind speeds at different epochs over a given area using the wind blades. To achieve a higher efficiency rate of the wind blade, suitable materials must be chosen for the design and development of each of the units of the system. Figure 1; describe a schematic diagram of a wind blade which consists of layup of a composite material used in various regions of the system.

Figure 1. Schematic diagram of a wind turbine blade (Wang et al., 2016)



Composite materials especially the fibre reinforced plastic (FRP), which have found application recently in the design and development of turbine rotor of the Boeing 787 Dreamliner (Milberg, 2015; Nicolais et al., 2011), is one candidate that can be used in the design of wind turbine blade (Mishnaevsky et al., 2017; Schubel & Crossley, 2012). To fully take advantage and control of the material for the wind turbine blade design and for other engineering purposes, it is important therefore that the reliability of the wind turbine blade designed with this material is adequately studied and investigated. Although, the attractive characteristic of the FRP, particularly its physical and mechanical properties, some of which includes, its high strength and stiffness, low weight characteristic, high durability, damping property, resistance to corrosion, fire and wear, has been studied extensively in literature, and has made it one of the most sorts after material for engineering design (Aikhuele, 2019; Mohammed et al., 2015). The complete benefits of the FRP material for the design of wind turbine blade however, cannot be fully realised in practice, where this is due to the conventional safety factors issues which normally arise as a result of lack of understanding of the uncertainties associated with the material, which research have shown could affect its overall performances.

Uncertainties in FRP components exist at several scales or levels, as such they interact with one another. Some of the scales or levels include; the micro-scale (e.g. bonding of matrix and fibre,

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