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MODAL ANALYSIS OF WIND TURBINE BLADE NACA2412

Ramesh R**
*Department of Mechanical Engineering, Agni College of Technology, Chennai, India

Abstract: The wind turbine blade is a very important part of the rotor. Wind turbine provides an Alternative way of generating energy from the power of wind. Extraction of Energy depends on the design of blades. The main scope of this research is to identify natural frequencies and natural vibration modes of the NACA 2412 horizontal wind turbine blade. This experimental analysis performed the characterization of the modal parameters (frequencies and modal shape) of a wind turbine of 10m length. In this project three different artificial fiber materials properties like Kevlar, Basalt, E-glass material are used as composite material for wind turbine blade. The Wind Turbine blade design is complex procedure. For the design of wind turbine blade Solid work software is used and the model is imported in ANSYS 14.0 for modal analysis.

Keywords: "*Ansys Workbench, modal, NACA 2412, Horizontal wind turbine blade, Hybrid composite, finite element method, Optimization; Modal analysis; Aerodynamic Airfoil.*"

1. INTRODUCTION

Wind power is one of the world's fastest-growing energy sector and relatively mature technologies. Wind power is changing the wind energy into electricity, in which the blade plays a very important role. Wind energy is to be considered as one of the most viable sources of renewable energy when environmental issues such as acid rain, climate change, and imbalance of natural resources have been developed due to use of oil, gas and coal as fuel in power generation. Wind energy is considered as a clean source of energy. Wind power is an alternative to fuels. In India wind power accounts for 6% of India's total installed power capacity, and it generates 1.6% of the country's power. A wind turbine is a rotary machine that extracts energy from the wind. There are two forces acting by wind on turbine blades known as Lift and Drag force. The Lift Force is perpendicular to the direction of motion of wind whereas the Drag Force is parallel to the direction of motion of wind. For maximum power generation Lift force should be large and Drag force should be less. A wind turbine consists of three elements known as Towers, Nacelles and Turbine Blades. A wind turbine tower must be stiff and strong so that it can bear the load of turbine blades and generator/nacelles. Because of its high strength, stiffness, weight-lightness, resistance to fatigue, vibration, high temperature, easy-to-design, etc., the composite laminates plates have been widely used in the wind energy field. Therefore, blade vibration analysis, structural design technology and composite materials technology are closely linked. A wind turbine blade is of an elastic structure, so the load on it is of stress alternation and random variability. That causes vibration inevitably occurring and it often direct leads to malignant structural damage and failure. The Blade's vibration analysis and vibration design have become a key process for the blade analysis and design. In this paper, hybrid fiber reinforced composite material, characteristics of hierarchical structure, based on finite element analysis software ANSYS, laminated shell element is used to create finite element model, and the finite element modal analysis is made to obtain modal parameters and the natural frequency spectrum of blade. The stiffness is most important factor to be considered because tower is also subjected to fluctuating wind loads due to rotation of blades. Nacelles are considered as a house of shafts, gearbox, generator and others supporting elements. In case of Nacelles weight is an important factor to be consider not the material. Turbine Blades are required to have an optimum cross section for aerodynamic efficiency to generate the maximum torque to drive the generators. The turbine blades are subjected to a wide range of loads like twisting, tension, and compression and flapping induced by variable wind loading [2-3].

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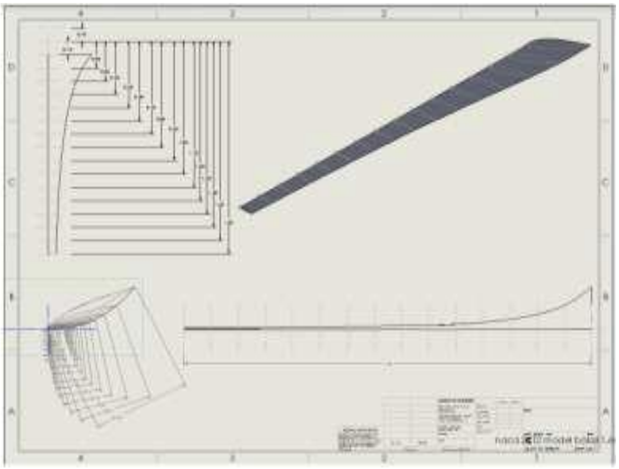
The wind blades must be stiff to avoid hitting the towers when deflected by the wind loads. For any given material the internal structure will determine the strength and stiffness of the turbine blades. Also when we are considering the strength and stiffness the weight of turbine blades play an important role to determine the cost and saving from fatigue failure. In general we require a material that is stiff as well as light also in order to minimize the overall weight of wind turbine system. Here NACA 2412 is used composite material which is stiff and strong having recycling sustainability as shown in [figure 1.1] in all three elements of wind turbine, blades are the most critical component for design and analysis. The aerodynamics efficiency and weight of blades are two critical parameters for design and analysis. Blades are attached to rotor hub which rotates the generator shaft for producing electricity [6-7].All turbine blades have airfoil shaped cross sections which utilizes combination of Kevlar, basalt, and e glass fiber as a blade material. The wind turbine blades functions with principles of lift to transfer the wind energy into mechanical energy.

Figure 1.1 NACA 2412 horizontal axis wind turbine blade



FEM is an approximation technique used for numerical solution of acoustic problems, electromagnetic problems, heat transfer, fluid problems and static and dynamic structural 9 analysis. In finite element method, the geometry is divided into finite number of small elements and these elements are connected to each other at a point termed as nodes. Finite Element Method or Finite Element Analysis is a mathematical modelling and analysis tool used for finding the natural frequency and mode shape of the NACA 2412 wind turbine blades. The ANSYS workbench is a product of ANSYS software which has two interface areas such as toolbox and project schematic [4].

PROPERTIES OF FIBERS.

Table 1.1: Properties of artificial composite fibers used in analysis.

FIBRES	POISSON RATIO	TENSILE STRENGTH	SHEAR MODULUS	YOUNG'S MODULUS
kevlar	0.36	3-3.6Gpa	2.9gpa	83Gpa
Basalt	0.26	2.8-3.1Gpa	21.7Gpa	89Gpa
E Glass Fiber	0.21	1.9Gpa	30Gpa	72Gpa

A new material NACA 2412 is selected based on its inherent properties for the design and analysis of wind turbine blades. NACA 2412 is a combination of KEVALR, BASALT, EGLASS artificial fiber

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is used for the high strength to weight ratio application. The material property of composite fiber is shown in [Table 1.1]. It possesses good fatigue resistance property. This thesis describes the development of a new frequency domain model with the ability to analyses fully flexible turbines using a Finite Element analysis approach. He has also concentrated on possibility of sitting wind turbines offshore. In recent years Indian government also is at the cusp of a renewable energy revolution. The government has already set an ambitious target to achieve 175 gigawatt (GW) of renewable energy capacity by 2022. Keeping the target in mind, states have already started ramping up their installed solar and wind powered capacity. Here, ETEnergy World takes a look at top 9 states by installed wind power capacity. Also Tamil Nadu government tops the list of states with the largest installed wind power generation capacity in the country. The state's total wind capacity at the end of 2018 stood at 8,631 Mw while its total installed electricity generation capacity stood at 30,447 Mw at the end of 2018, with wind sector's share at 28.34 per cent.

This research work is based on these details and we have selected new light weight composite material for design and analysis purpose. In design of a wind turbine it considered design of the blades, controls, generator, design of the hub, supporting structure and foundation. IEC 61400 standards are used for wind turbines design and validation [10]. The majority of commercial turbines are based on Horizontal axis wind turbines (HAWT).The aerodynamics of a HAWT is not simple. The speed and condition of air is different at blade in comparison to air flow far away from the turbine.

All the wind turbines are designed for survival speed known as maximum wind speed, above which wind turbine do not survive. The normal survival speed is 60 m/s. It can vary (40-72) m/s. So a wind turbine can have three mode of operation-Below survival speed, around survival speed and above survival speed. For a given survivable speed the mass of a turbine is proportional to the cube of its blade length. The maximum blade length depends on strength and stiffness of material selected for manufacturing.

2. METHODOLOGY

Thus the flowchart 2.1 shows the Methodology of NACA 2412 Wind Blade.

Flowchart 2.1- Methodology for NACA 2412 wind blade

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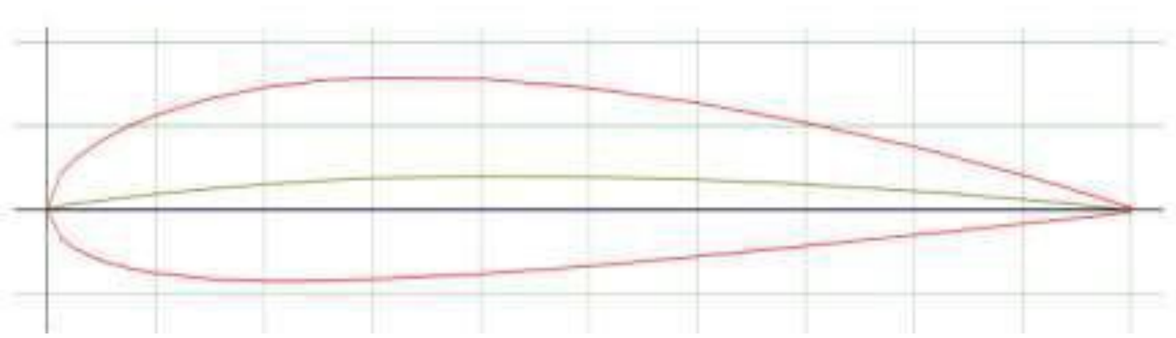
2.1. SELECTION OF AIRFOIL

Wind turbines are operating on two principles such as thrust (drag) and lift operated. Lift-operated turbines are more efficient than the thrust operated turbines. Performance of the lift operated turbines depends on the blade airfoil and is decided by the ratio of lift coefficient (CL) to drag coefficient (CD). Performance of wind turbine is improved by improving this CL/CD ratio. In order to improve the performance of these turbines and to extract maximum possible power from wind at low speed, the researchers have focused on the design of effective blade geometry. The entire span of the blades of small horizontal axis wind turbines operates at low Reynolds number where laminar separation effects can reduce the performance of airfoil not designed for this flows regime. Fast rotational speed of small horizontal axis wind turbines give centrifugal stiffening that reduces blade bending loads therefore it permits thinner airfoil for small wind turbine compared to airfoils designed for large wind turbines.

Figure 2.1.1 NACA 2412 airfoil.



2.1 DESIGN & GEOMENTRY NACA2412

After doing several iteration in the excell worksheet with HAWT design formula for each design parameters. The optimized blade design geometry for NACA 2412 wind blade is obtained as shown in Table 2.2.1 shows.

NO OF AIRFOIL SECTION	CHORD LENGTH OF THE AIRFOIL CL (in m)	DISTANCE OF THE AIRFOIL SECTION L (in m)	ANGLE OF TWIST θ
1	0.385	2.981	26.41
2	0.268	2.240	19.46
3	0.215	1.792	14.85
4	0.179	1.493	11.61
5	0.153	1.280	9.22
6	0.134	1.120	7.39
7	0.119	0.996	5.95
8	0.107	0.896	4.78
9	0.097	0.814	3.82
10	0.089	0.747	3.02
11	0.082	0.689	2.34
12	0.076	0.640	1.75
13	0.071	0.597	1.24
14	0.067	0.560	0.79
15	0.063	0.527	0.39
16	0.059	0.498	0.04

Table 2.2.1. Angle of twist of NACA2412.

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2.2 MODELLING OF WIND BLADE

The CAD software SOLID WORKS is selected to prepare the solid model of the NACA 2412 wind turbine blade. The CAD model is shown as figure 1. The blade geometry is similar about the axis of blade. In general a turbine assembly consist of three blades identical in design parameters and manufacturing. Blades are fixed in a turbine hub subjected to various loading conditions according to speed. So using [Table 2] blade geometry output for optimized blade NACA 2412 we can able to design the blade in solid works and the obtained optimum blade design using solid works is shown in [Figure2.3.1].

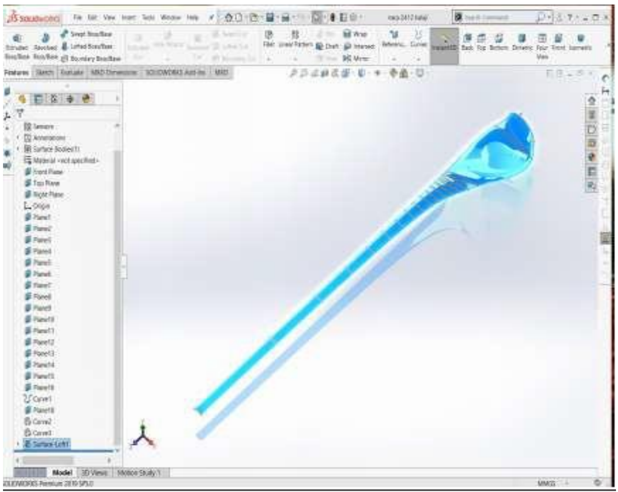

Figure 2.3.1 Cad solid model of NACA 2412 wind turbine blade using design calculation.

2.3 MESHING OF WIND BLADE

After the completion of the model the IGES file is imported from the SOLID works to ANSYS 14.0 software for the analysis. The main step of the FEM based analysis is to divide the blade in small pieces called elements and these elements are connected at nodes. The material properties were approximately defined as orthotropic, as the blade was made of glass fiber composite materials. The material number and properties were defined by the Material Models menu. The corresponding real constants were distributed to every part of the blade and appropriate grid size was set. The meshed model of blade is shown in [figure 2.4.1]. It consists of 30798 nodes and 6930 elements as shown in figure 2.4.1

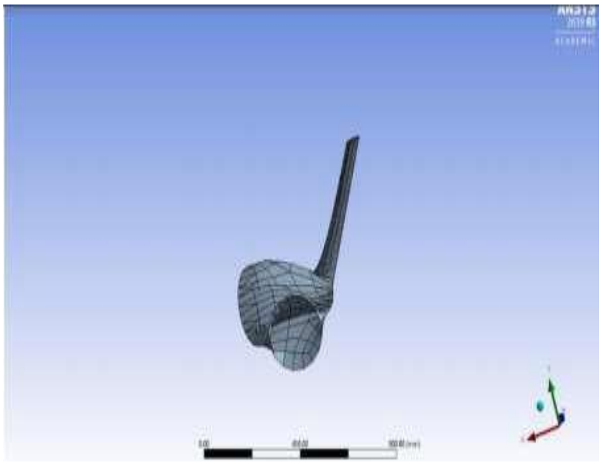

Figure 2.4.1 meshing of wind blade [NACA2412].

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2.3 CONSTRAINT OF WIND BLADE

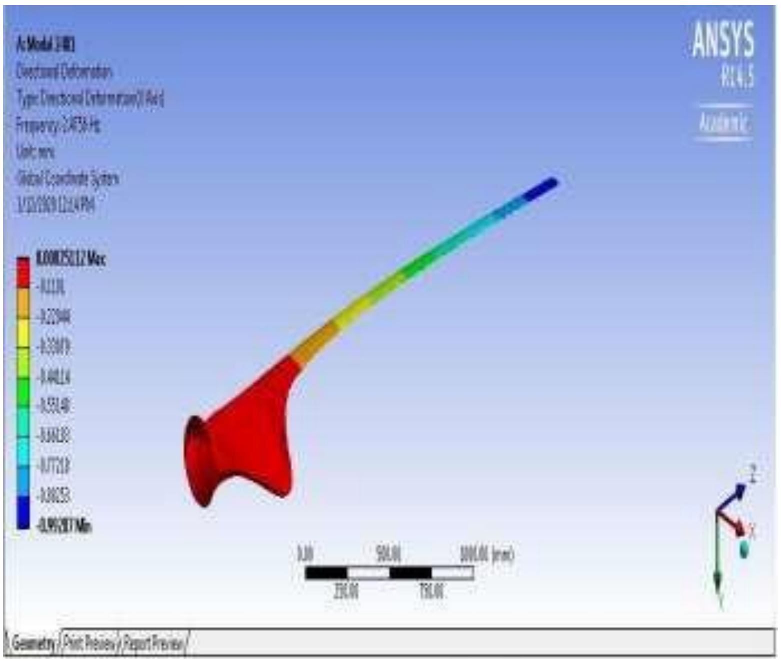
The problem statement is to evaluate the natural frequencies for NACA2412 wind turbine blades. • The deformation and stresses are calculated by structural analysis. Natural frequency and vibration mode shapes are obtained by modal analysis.

SOLID WORKS software [5] is used to model the turbine blade and ANSYS 14.0 [4] to find the Natural frequency and Vibration mode shapes. • The study is limited to single blade study without assembly. It is assumed that the behavior of all the blade will be identical under same loading conditions.

Here the meshed wind blade is constrained at one end like cantilever beam and we do the modal analysis to find the natural frequencies due to its self-weight. • These wind blade constraint will leads to do further process in to obtain natural frequency [HZ].

2.3 ANALYSIS OF WIND BLADE - MODAL ANALYSIS - NACA2412.

The modal analysis is done by using ANSYS 14.0 workbench. The one end of wind turbine blade is supported by the hub and another end is free in air. In this study the hub end is provided a constant angular velocity of 10 rad/sec and different values of deformations and stresses are calculated. Structural analysis is the determination of the effects of loads on physical structures and their components. It computes structure's deformations, stresses, support reactions, accelerations, and stability. There are many ways for ANSYS modal analysis, of which the Block Lanczos method is most widely used because of its powerful features. Moreover, it is frequently applied with model of solid units or shell units [8] that is why this paper chose Block Lanczos to perform the modal analysis. The vibration modes of the first six orders were extracted with the frequency range of 0~60Hz, as shown in [Figure 2.6.1]. The connections of blades and hub could be regarded as fixed, so it is only need to restrict all DOFs of the root, for modal analysis does not require applying loads. At last, after solving with the solver, the vibration modes of all the orders and the result of frequencies could be observed in the post-processor.



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2.4 EVALUATE MESHING AND MODAL ANAYSIS FROM PREVIOUS RESEARCH WORK NACA - AI 2024 WIND BLADE.

By evaluating the meshing and modal anaysis we can verified wheather our windblade design and anaysis project result is optimum condition or not also we get clarification why our design of the windblade differ from their result. Here we take previous research work from literature review [IV Ashwani Kumara]. This previous research work devolped the wind blade and do meshing as [shown in figure 2.7.1] with different aerodynamic airfoil and different blade length.

This wind blade length is large as we compare to our project here they take 25 m blade but the procedure of designing and Calculation of blade design parameters are same so that this blade is designed and cariied out into meshing and constrained.

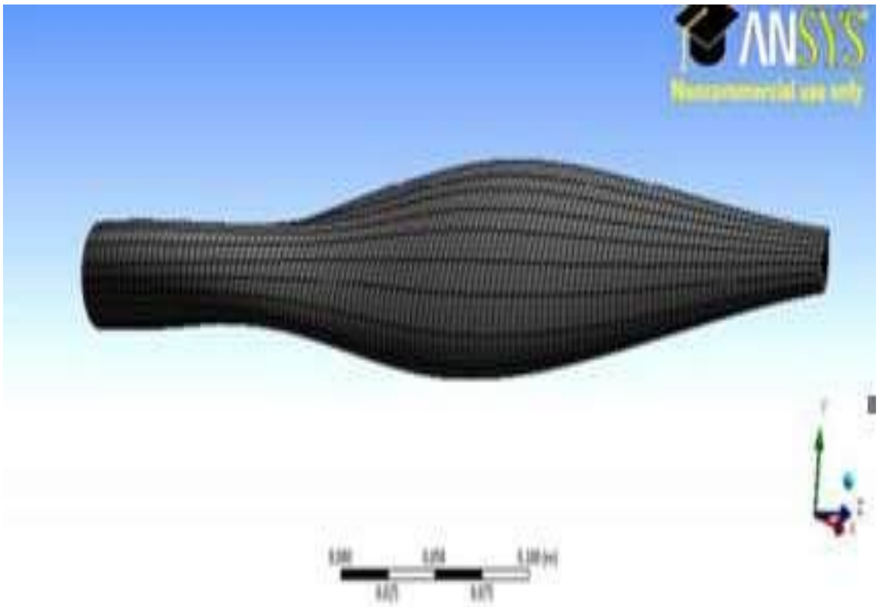

Figure 2.7.1 Meshing of wind blade NACA AI 2024

Also this previous project understand the importance of analyzing the free vibrational occurs in wind blade and their experiments showing the different mode shape at different natural frequencies in modal analysis as shown in [figure 2.7.3]. From this analysis and meshing part from previous project we can get the important data of modal analysis which is natural frequency of NACA wind turbine blade at different vibrational mode.

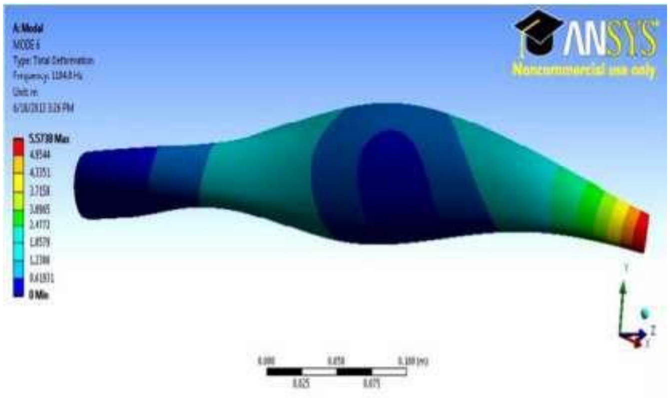

Figure 2.7.3. Modal analysis of wind blade NACA -AI 2024.

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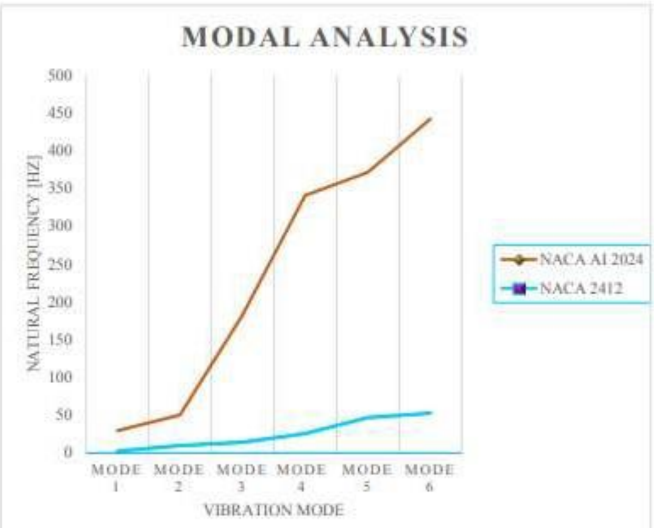
3. RESULT AND DISCUSSIONS

This research work provides a detail study of NACA2412 wind Turbine blade using modal analysis. The free Vibration analysis of NACA 2412 wind turbine blade modal analysis using ANSYS 14.0 was conducted. Through our study we have find the natural frequencies for first six modes shape of NACA 2412 then compare and verified it with literature Ashwani kumar [21] NACA Al 2024 wind turbine blade of the Vibration Mode v/s Natural Frequency obtained from the NACA 2412 and NACA Al 2024 wind turbine blade.e3

3.1 NATURAL FREQUENCY OF THE NACA 2412 WIND TURBINE BLADE.

After doing modal analysis of NACA 2412 wind turbine blade, different natural frequency will obtained at different mode at vibrational conditions. Here we summarized all the result in Graph.

3.1.1 for understanding the scenario of wind blade while at free vibrational condition.



Graph 3.1.1 Comparison of natural frequency of the NACA 2412 wind turbine blade with NACA AI 2024 wind turbine blade.

4. CONCLUSION

The NACA 2412 aerodynamic airfoil profile is taken to design optimized wind turbine blade which is designed by applying SOLIDWORKS software and is transferred to ANSYS 14.0 for modal analysis. Finally the NACA 2412 Airfoil is obtained the optimum blade shape and evaluate with literature Ashwani kumar [21] NACA Al 2024 wind turbine blade of the Vibration Mode v/s Natural Frequency obtained from the NACA 2412 and NACA Al 2024 wind turbine blade as shown in graph 3. under this comparison we concluded that our NACA 2412 Airfoil blade design is the optimized wind blade which have very less vibrational natural frequency [HZ] generated at each node which is very less while comparing NACA AI 2024 wind turbine blade.

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