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SIMULATION AND OPTIMIZATION MATERIAL OF WIND TURBINE BLADE PROFILES USING CATIA AND ANSYS

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ABSTRACT - I Wind energy is a fast-growing way to make power from wind, and it's good for the environment. Wind turbines have big blades that catch the wind to make electricity. This project is all about making those blades work better and cost less money. First, we use special computer programs called CATIA and ANSYS to design and evaluate the blades. CATIA helps us design the shape and size of the blades, while ANSYS helps us see how strong they are and how well they catch the wind. We start by making different blade shapes in CATIA, changing things like length, width, and twist. Then we use ANSYS to evaluate them. We look at things like how much stress they can manage, how much they bend, and how well they catch the wind. After testing, we try to make the blades even better. We use special tools in ANSYS and CATIA to find the best combination of blade features. We want blades that are super-efficient at catching wind, strong enough to last a long time, and don't cost too much to make. By varying material to blade profile checking strength and mode shapes for Aluminum, Carbon fiber and E glass epoxy

Keywords: wind energy, Turbines, Wind blades, CATIA, ANSYS

1. INTRODUCTION

In an era marked by a pressing need for sustainable energy solutions, the harnessing of wind power stands as a beacon of promise. Wind energy, with its abundance and renewability, has emerged as a vital component in the global transition towards a cleaner, greener future. Central to the efficacy of wind energy generation are wind turbine blades, the pivotal elements responsible for converting the kinetic energy of wind into usable electrical power. This project endeavors to delve into the realm of wind turbine blade design and optimization, leveraging advanced simulation and analysis tools such as CATIA and ANSYS. By harnessing the power of cutting edge software technologies, our aim is to explore, refine, and optimize wind turbine blade profiles to maximize efficiency, performance, and durability Through meticulous simulation and optimization processes, we seek to push the boundaries of traditional wind turbine blade design, striving for innovations that not only enhance energy

output but also mitigate environmental impact and operational costs. By integrating CATIA's robust modelling capabilities with ANSYS's

Through meticulous simulation and optimization processes, we seek to push the boundaries of traditional wind turbine blade design, striving for innovations that not only enhance energy output but also mitigate environmental impact and operational costs. By integrating CATIA's robust modelling capabilities with ANSYS's comprehensive analysis tools, we aim to develop a systematic methodology for refining wind turbine blade profiles, ensuring they are finely tuned to withstand varying wind conditions while delivering optimal power output. This interdisciplinary end ever brings together expertise from engineering, computer aided design, and computational analysis domains to tackle the multifaceted challenges inherent in wind turbine blade optimization. By synergizing theoretical insights with practical implementation, we aspire to contribute to the advancement of renewable energy technologies, fostering a sustainable energy landscape for generations to come. wind turbine blades play a pivotal role in democratizing energy access, particularly in remote or underdeveloped regions where traditional energy infrastructure is lacking. By harnessing the natural power of the wind, these blades offer a decentralized and environmentally friendly means of electricity generation, empowering communities and driving socioeconomic development.

Fig 1. Horizontal Axis Wind Turbine

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2. LITERATURE STUDY

1. "Performance Evaluation of Savonius Wind Turbine based on a New Design of Blade Shape"

Salih Meri AR, et al.,(2019), explained about the effect of the parameters of the blade shape and the overlap ratio on the performance efficiency of the elliptical Savonius wind turbine. A new model of Savonius blade has been designed by changing the inner surface of the concave blade with an overlap ratio of (0.2). The new model is printed using 3D-printer technology for experimental testing in the wind tunnel at different wind speeds of (6 m/s, 8 m/s, and 10 m/s).

2. "Performance Analysis of Vertical Axis Wind Turbines"

I**ndala Nageswara Rao and V.V.R.Murthy, (2017)**, discussed about a new model for the design and performance of a vertical axis wind turbine for small scale energy applications. Based on the wind speed, Small 4 & 8 bladed turbines will be constructed and investigated for the performance of turbines at various speeds. An artificial wind speed is created in a closed room to evaluate the Coefficient of Performance of the Wind turbines.

3. "Design and CFD Analysis of Drone Thrust with Duct"

K. S. S. Gurudatta, V. Harikiran, M. V. D. K. Raju, B. Rama Krishna & I. Jagadeesh (2023), In the current chapter, the aerodynamic performance of a small ducted propeller within axial flow condition is studied using Ansys Fluent, and its performance in terms of thrust force and moment requires dyscalculia.

3. METHODOLOGY

1. CATIA V5

CATIA is a powerful computer-aided design (CAD) software used for creating 3D models, simulations, and engineering analyses. With CATIA, users can design products ranging from simple shapes to complex mechanical assemblies. The software offers various modules for different tasks, such as part design, assembly design, 2 drafting, surface modeling, and more. Its parametric modeling capabilities allow designers to easily modify designs by changing parameters, ensuring flexibility and efficiency throughout the design process.

2. CAD Model

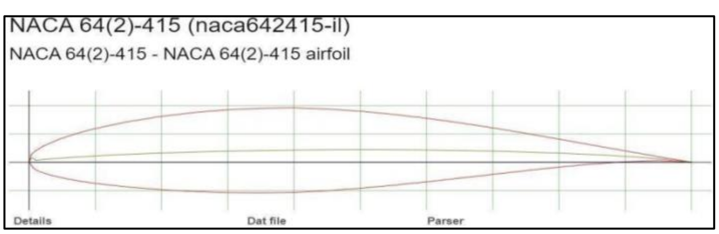

Fig 2. AIRFOIL SHAPE

NACA 64(2)	-415
1	0
0.95032	0.00976
0.90066	0.01982
0.85092	0.0302
0.80109	0.04062
0.75115	0.05084
0.70111	0.06055
0.65096	0.06954
0.60087	0.07762
0.5504	0.08456
0.5	0.09016
0.44954	0.09414
0.39904	0.09614
0.34853	0.09541
0.29803	0.0926
0.24756	0.08771
0.19714	0.08066
0.14681	0.07122
0.09662	0.05864
0.07162	0.05075
0.04673	0.04121
0.02207	0.02883
0.00996	0.02038
0.00526	0.01579
0.00299	0.01291
0	0
0.00701	-0.01091
0.00974	-0.01299
0.01504	-0.0161
0.02793	-0.02139
0.05327	-0.02857
0.07838	-0.03379
0.10338	-0.03796
0.15319	-0.0443
0.20286	-0.04882
0.25244	-0.05191
0.30197	-0.05372
0.35147	-0.05421
0.40096	-0.0533
0.45046	-0.05034
0.5	-0.04604
0.5496	-0.04076
0.59928	-0.03478
0.64904	-0.02834
0.69889	-0.02167
0.74885	-0.01504
0.79897	-0.00878
0.84908	-0.00328
0.89934	0.00086
0.94968	0.00288
1	0

TABLE 1. CO-ORDINATE OF WIND TURBINE BLADE

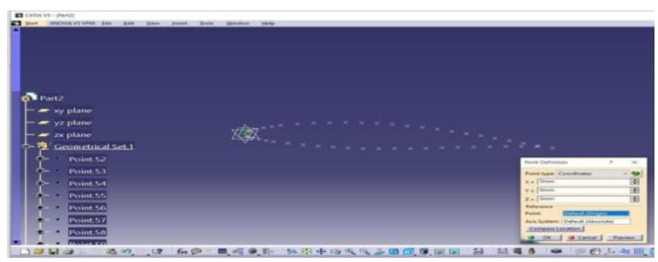

Fig 3. CO-ORDINATE POINTS OFAIRFOIL

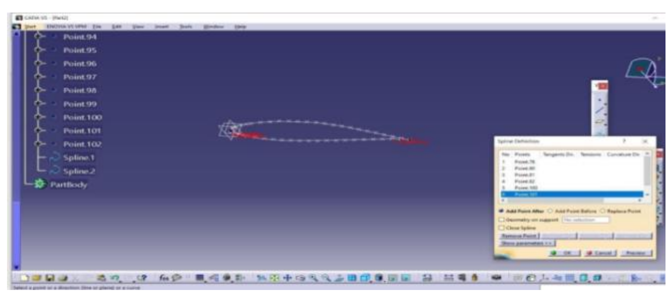

Fig 4. JOINING OF CO-ORDINATES

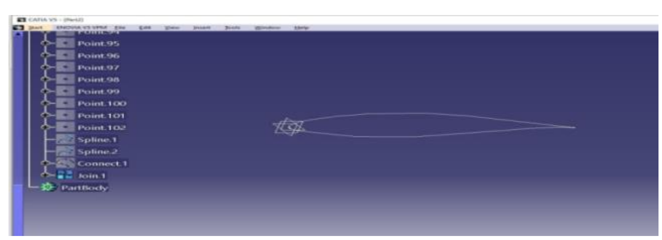

Fig 5. joining of spline and coordinate points

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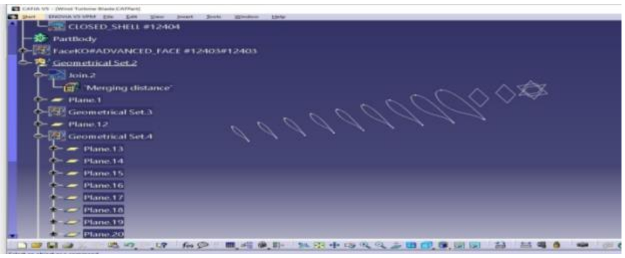

Fig 6. Transferring Of Equal Points

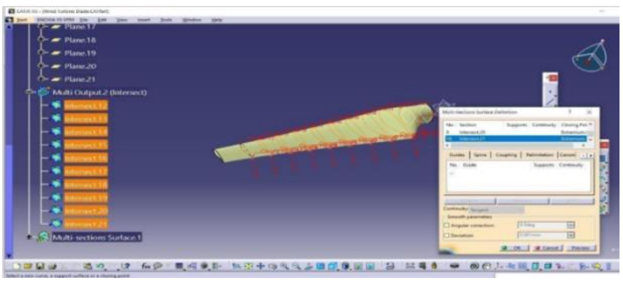

Fig 7. Usage of Multi Section

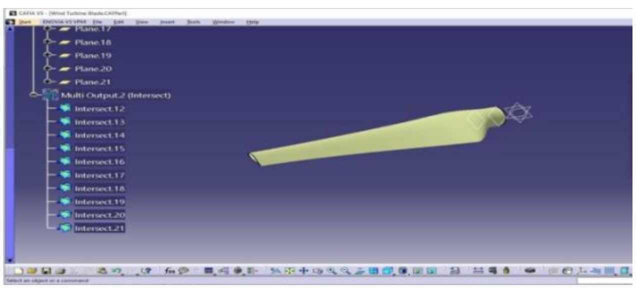

Fig 8. Final Output Of Model

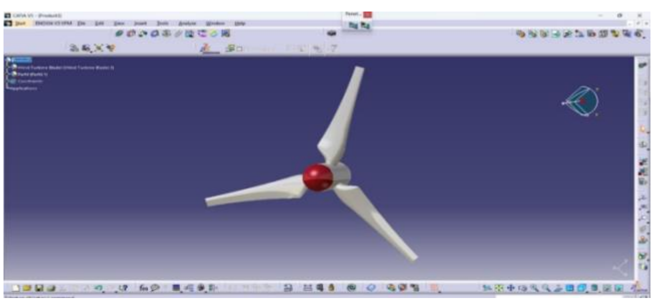

Fig 9. Overall view of Wind Turbine Blade

3. ANALYSIS

ANSYS Workbench is a unified platform that enables engineers to perform various simulation sand analyses, covering a wide range of engineering disciplines such as structural, thermal, fluid dynamics, electromagnetic, and more. It provides a user-friendly interface that simplifies the complex simulation process and allows for efficient collaboration and integration of different simulation tools. ANSYS

Workbench incorporates a robust solver technology, post-processing capabilities, and optimization algorithms, making it a comprehensive solution for engineers to simulate and evaluate the performance of their design.

Steps in Finite Element Analysis:

- **STEP 1:** First the domain is represented as finite elements. This is called discretization of domain. Mesh generation programs called processors, help in dividing the structure.
- **STEP 2:** Formulate the properties of each element in stress analysis. It means determining the nodal loads associated with all element deformation stress that is allowed.
- **STEP 3:** Assemble elements to obtain the finite element model of the structure.
- **STEP 4:** Apply the known loads, nodal forces in stress analysis. In stress analysis the support of the structure must be specified.
- **STEP 5:** Solve simultaneous line algebraic equations to determine nodal displacements in the stress analysis.
- **STEP 6:** Post processors help the user to sort the output and display in the graphical output form. A typical finite element model is comprised of nodes, degrees of freedom, elements material properties, externally applied loads, and analysis type. The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide range of engineering problems.

A. STATIC ANALYSIS FOR ALUMINUM MATERIAL:

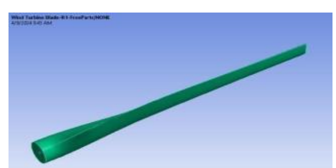

Fig 10. Ansys import Model

Fig 11. Mesh Model

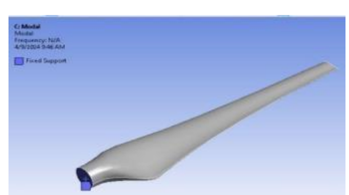

Fig 12. Fixed Support

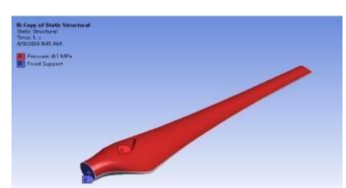

Fig 13. Load and Boundary Condition

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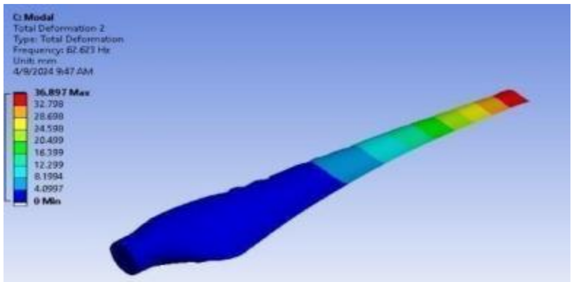


Fig 14. DEFORMATION 26.87MM

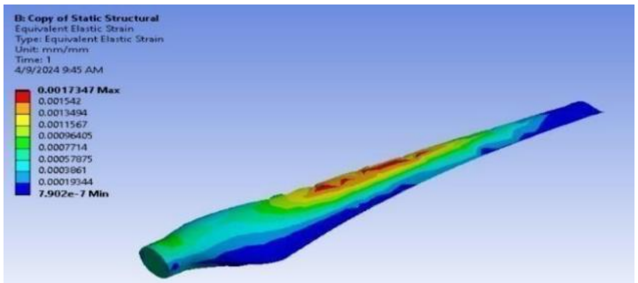


Fig 15. VONMISSES STESS 122.37MPA

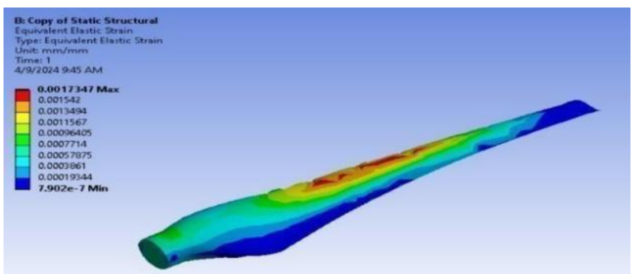


Fig 16 VONMISSES STRAIN 1.7-3

B. DYNAMIC ANALYSIS FOR ALUMINUM MATERIAL:

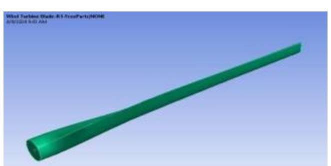


Fig 17. Ansys import Model

Fig 18. Mesh Model

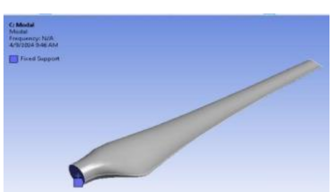


Fig 19. Fixed Support

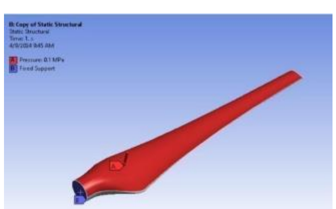


Fig 20. Load and Boundary Conditions

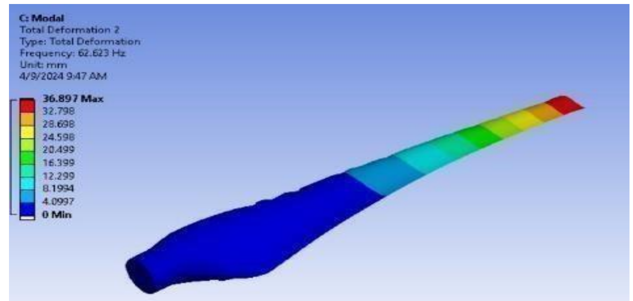


Fig 21. MODE:01 DEF36.96 MM FFQ:62.62HZ

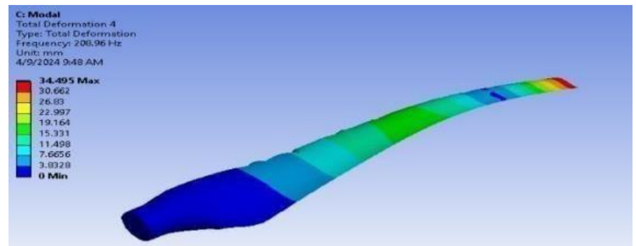


Fig 22. MODE:03 DEF 34.49MFFQ:208.96 HZ

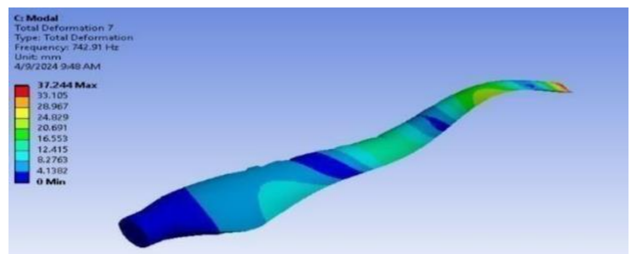


Fig 23. MODE:06 DEF 32.24 MM FEQ:742.91HZ

C. STATIC ANALYSIS FOR CARBON FIBRE MATERIAL:

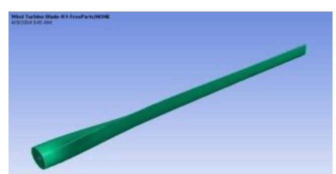


Fig 24. Ansys import Model

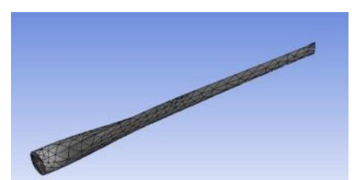


Fig 25. Mesh Model

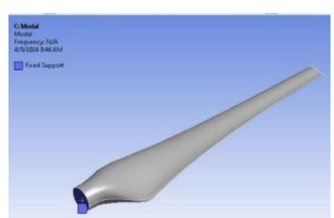


Fig 26. Fixed Support

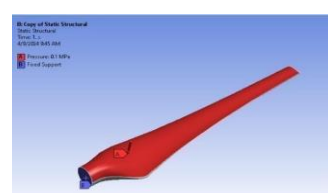


Fig 27. Load and Boundary Condition

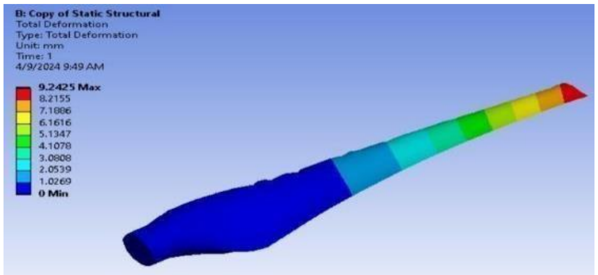


Fig 28. DEFORMATION 9.2MM

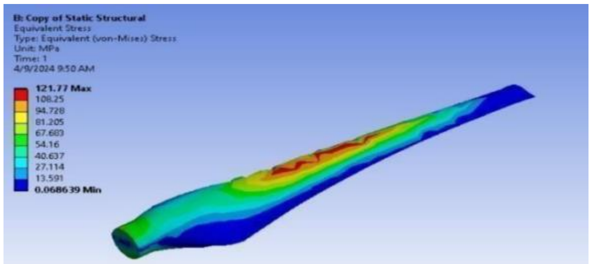


Fig 29. VONMISSES STRESS 121.77 MPA

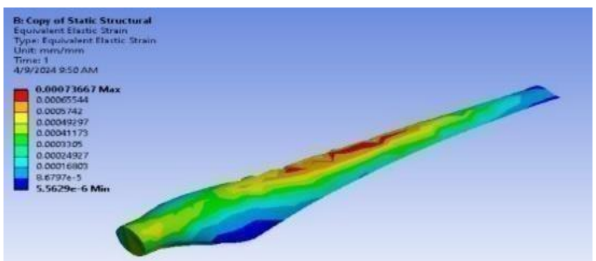


Fig 30. VONMISSIES STRAIN 7.3E-4

E. DYNAMIC ANALYSIS FOR CARBON FIBER MATERIAL:

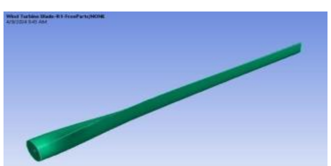


Fig 31. Ansys import Model

Fig 32. Mesh Model

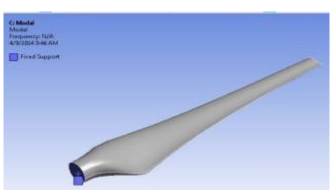


Fig 33. Fixed Support

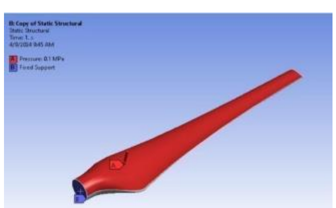


Fig 34. Load and Boundary condition

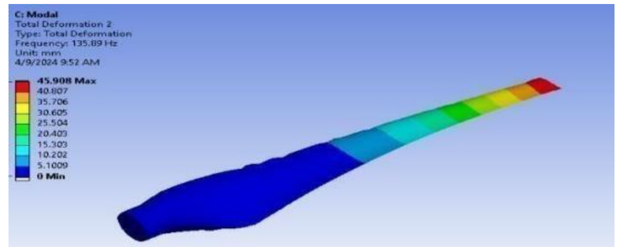


Fig 35. MODE :01 DEF45.09MM FEQ:135.89HZ

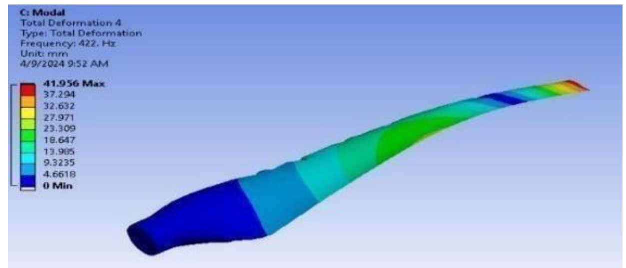


Fig 36. MODE :03 DEF 41.95MM FEQ:422HZ

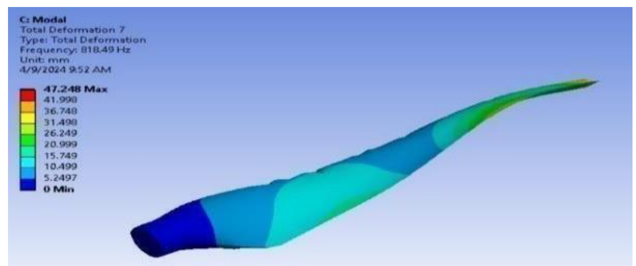


Fig 37. MODE :03 DEF 41.95MM FEQ:422HZ

F. STATIC ANALYSIS FOR E GLASS EPOXY:

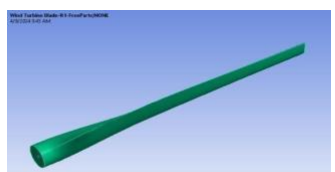


Fig 38. Ansys import Model

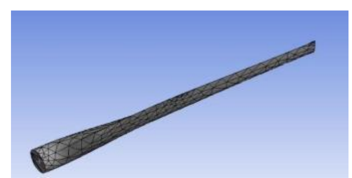


Fig 39. Mesh Model

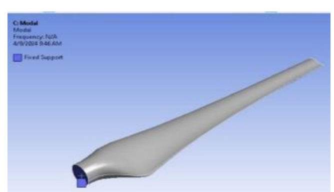


Fig 40. Fixed Support

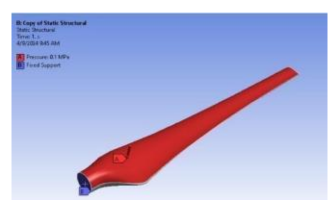


Fig 41. Load and Boundary Condition

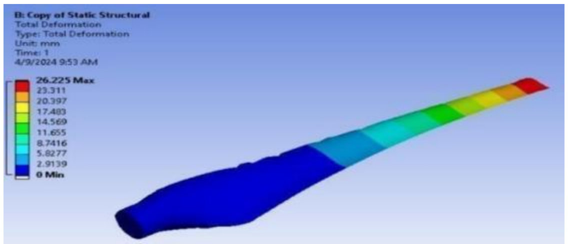


Fig 42. DEFORMATION 26.22MM

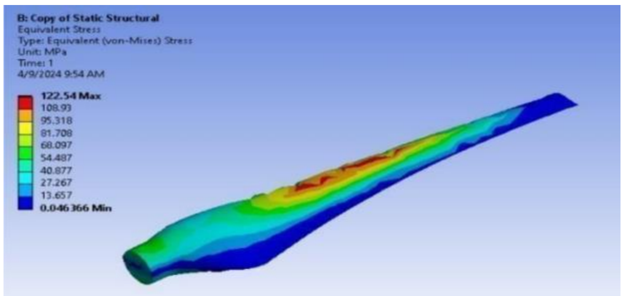


Fig 43 VON MISSES STRESS 122.54MPA

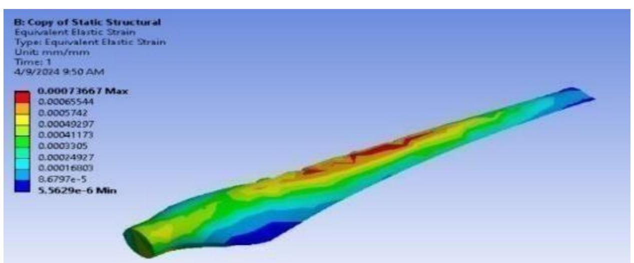


Fig 44. VONMISSIES STRAIN 1.6E-4

G. DYNAMIC ANALYSIS FOR E GLASS EPOXY:

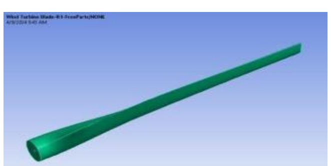


Fig 45. Ansys import Model

Fig 46. Mesh Model

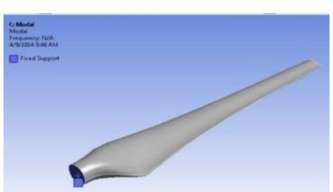


Fig 47. Fixed Support

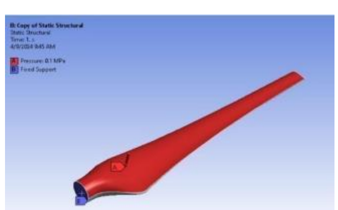


Fig 48. Load and Boundary condition

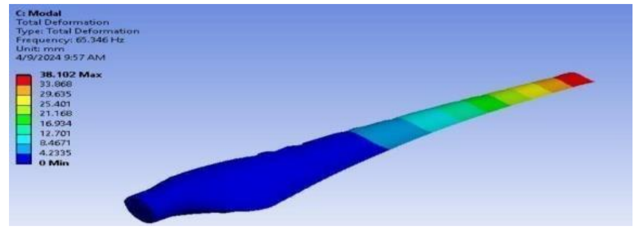


Fig 49. MODE :01 DEF 38.10MM FEQ:65.34HZ

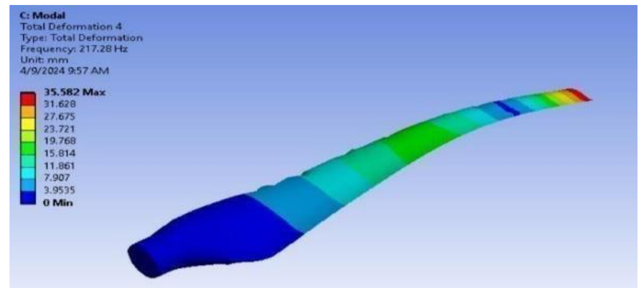


Fig 50. MODE :03 DEF35.58MM FEQ:217.28HZ

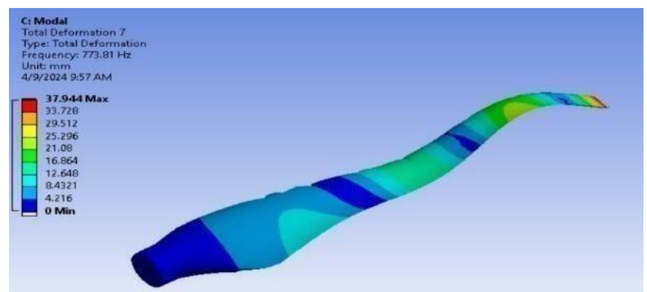
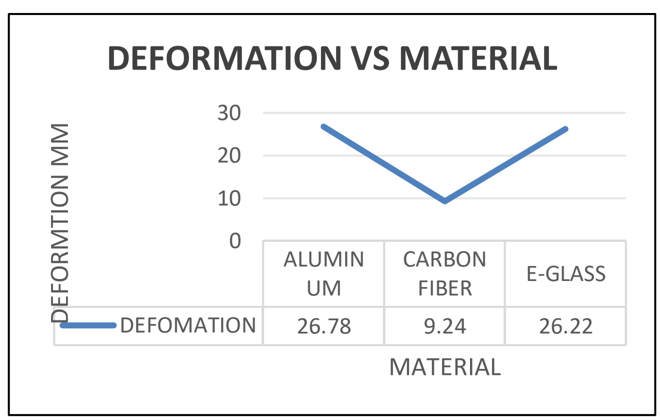
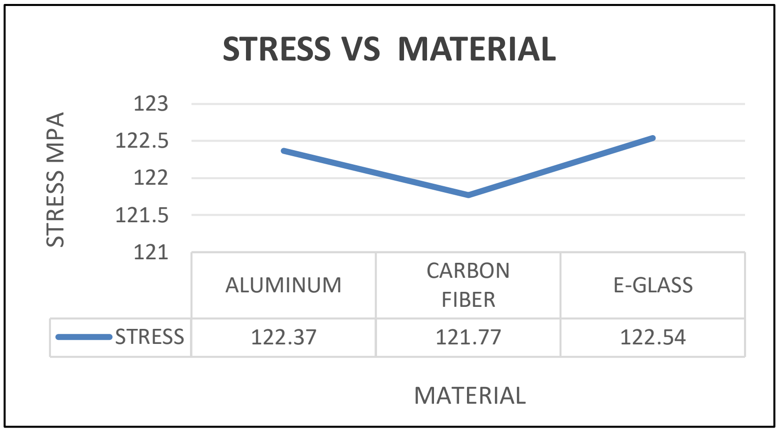


Fig 51. MODE :06 DEF 37.94MM FEQ: 773.81HZ

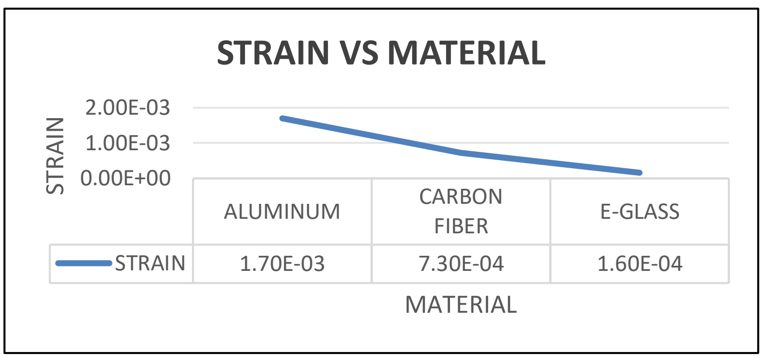
4.RESULTS



Graph 1. Deformation vs Material



Graph 2 Stress vs Material



Graph 3. Strain vs Material

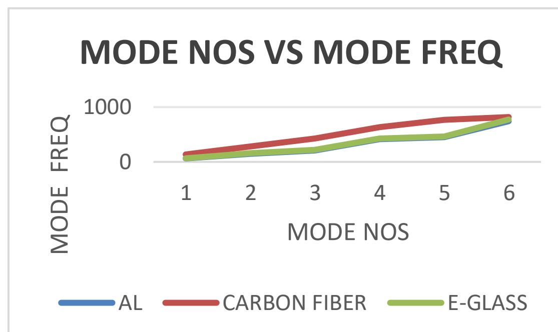
MATERIAL	DEFOMATION	STRESS	STRAIN
ALUMINUM	26.78	122.37	1.70E-03
CARBON FIBER	9.24	121.77	7.30E-04
E-GLASS	26.22	122.54	1.60E-04

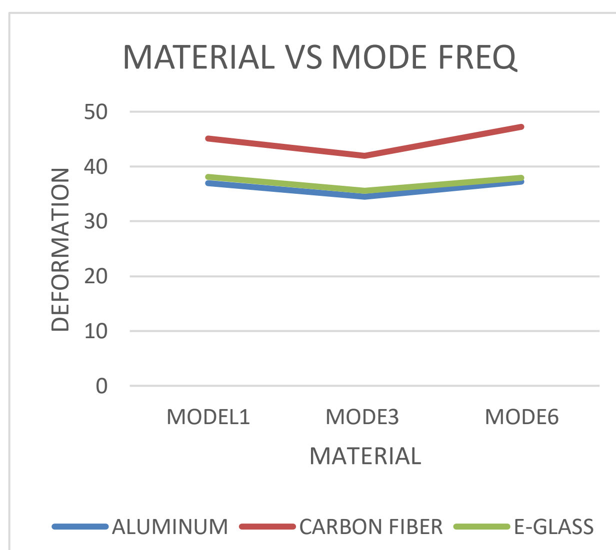
Table 1. Results of Static Analysis

MATERIAL	MODEL1	MODE3	MODE6
ALUMINUM	36.96	34.49	37.24
CARBON FIBER	45.09	41.95	47.24
E-GLASS	38.1	35.58	37.98

Table 2. Mode Deformation results

s. no	AL	CARBON FIBER	E-GLASS
1	62.623	135.89	65.346
2	148.83	282.28	154.76
3	208.96	422	217.28
4	413.74	639.3	430.61
5	448.43	762.16	467.13
6	742.91	818.49	773.81





CONCLUSION

Our Analysis study has been conducted on wind turbines, their types, and their applications in different streams of engineering. A comprehensive study has been conducted to illustrate the effect of blade profile on the aerodynamic performance of a Horizontal axis wind turbine. From the simulation of the airflow over the Horizontal wind turbine at a particular velocity, it has been found that the torque produced by the wind Turbine increases up to an extent and then decreases with increase in the blade angle.

By taking NACA 64-415 profile for model design which is un symmetrical profile with blade angle 9.250 Reynolds no.50,000 Ncrit 9.

By changing materials of blade study Aluminum, Carbon Fiber, and E-glass. Material alternative E glass and Carbon fibers gives best results compared to Aluminum. Static and Dynamic analysis of Model are done result compared as per graph shown. Carbon fiber and E glass are shown Deformation and stress less Compared to Aluminum.

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