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Comparative Study on Structural Analysis of Wind Turbine Blade with Different Materials Using ANSYS Workbench.15

Irayya Shikkerimath¹, Ananda B², Mahesha G³, Mutthanna B⁴, Shivaraj D⁵

Assistant Professor, Department of Mechanical Engineering, Ballari Institute of Technology and Management, Ballari, Karnataka, India¹

U.G Students, Department of Mechanical Engineering, Ballari Institute of Technology and Management, Ballari, Karnataka, India^{2,3,4,5}

ABSTRACT: Wind energy is a promising renewable energy source, and wind turbine technology continues to evolve to harness it efficiently. One crucial aspect of wind turbine design is the choice of materials for the blades, as it directly impacts performance, durability, and cost-effectiveness. This study presents a comparative structural analysis of wind turbine blades made from four different materials: aluminium alloy, titanium alloy, magnesium alloy, and PEEK composite material, using ANSYS Workbench. The analysis aims to evaluate and compare the mechanical behaviour and performance of these materials under typical wind loading conditions. Finite Element Analysis (FEA) techniques are employed to simulate various loading scenarios, including static and dynamic loads encountered during operation. Parameters such as stress distribution, deformation, natural frequencies, and mode shapes are analysed to assess the structural integrity and performance of the blades. The study investigates how each material responds to the complex loading conditions experienced by wind turbine blades, considering factors such as material strength, stiffness, density, and fatigue resistance. Additionally, the influence of material properties on blade weight, cost, and manufacturability is examined to provide insights into the overall feasibility and suitability of each material for wind turbine blade applications. The findings of this study contribute to the understanding of the performance characteristics of different materials in wind turbine blade design, helping designers and engineers make informed decisions regarding material selection to optimize performance, reliability, and cost-effectiveness of wind energy systems

KEYWORDS: wind turbine blade, NX12 software, ANSYS work bench software

I. INTRODUCTION

With the increasing demand for renewable energy sources, wind power has emerged as a viable and sustainable solution for electricity generation. Wind turbines, which convert the kinetic energy of wind into electrical power, are key components of wind energy systems. Among the various components of a wind turbine, the blade plays a critical role in capturing wind energy efficiently. The design and material selection of wind turbine blades significantly impact the overall performance, durability, and cost-effectiveness of the system. Traditionally, wind turbine blades have been predominantly manufactured using fiberglass-reinforced composites due to their favorable combination of strength, stiffness, and lightweight properties. However, advancements in material science have led to the exploration of alternative materials for wind turbine blade construction, including metals and high-performance polymers. This comparative study focuses on analyzing the structural performance of wind turbine blades made from four different materials: aluminum alloy, titanium alloy, magnesium alloy, and PEEK (Polyether Ether Ketone) composite material. Each material offers unique mechanical properties that may influence the behavior of the blade under various loading conditions. ANSYS Workbench, a widely-used finite element analysis (FEA) software, is employed to conduct the structural analysis of the wind turbine blades. FEA allows for the simulation of complex mechanical behaviors and loading scenarios, providing valuable insights into the performance of different materials in practical wind turbine applications. Evaluating the structural integrity and performance of wind turbine blades made from aluminum alloy, titanium alloy, magnesium alloy, and PEEK composite material. Analyzing stress strain distribution, deformation of the blades under typical wind loading conditions. Comparing the mechanical behavior and performance of the blades made from different materials to identify strengths, weaknesses, and trade-offs. Assessing the influence of material properties on blade weight, cost, and manufacturability. Providing insights into the feasibility and suitability of each material for wind turbine blade applications based on structural analysis results. By conducting a comprehensive comparative study,

this research aims to contribute to the advancement of wind turbine blade design and material selection, ultimately enhancing the efficiency, reliability, and cost-effectiveness of wind energy systems.

II. LITERATURE REVIEW

Wind turbine blade design and material selection have been extensively studied in the field of renewable energy and structural engineering. Previous research has focused on understanding the mechanical behavior, performance, and optimization of wind turbine blades made from various materials. The literature review highlights key findings and insights from previous studies related to the structural analysis of wind turbine blades using aluminum alloy, titanium alloy, magnesium alloy, and PEEK composite material. Overall, the literature review highlights the importance of material selection in wind turbine blade design and the need for comprehensive structural analysis to evaluate the performance of different materials under varying operating conditions. While each material offers distinct advantages and challenges, a comparative study using ANSYS Workbench can provide valuable insights into the structural behavior and performance of wind turbine blades, aiding designers and engineers in making informed decisions for optimizing wind energy systems.

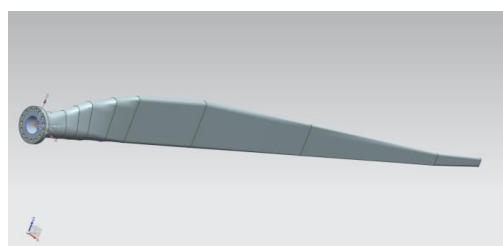
III. METHODOLOGY

Material Selection: The first step involves selecting representative materials for wind turbine blade construction, including aluminum alloy, titanium alloy, magnesium alloy, and PEEK composite material. Material properties such as density, Young's modulus, Poisson's ratio, and yield strength are collected from literature sources or material databases. **Geometry and Meshing:** A representative wind turbine blade geometry is created using CAD software. The geometry is then imported into ANSYS Workbench for mesh generation. Mesh refinement studies are conducted to ensure mesh convergence and accuracy of results. Different mesh types and sizes are evaluated to determine the optimal meshing strategy. **Boundary Conditions and Loading:** Boundary conditions are applied to simulate realistic operating conditions for wind turbine blades. This includes defining constraints at the root of the blade to represent attachment to the hub and applying aerodynamic loads to simulate wind-induced forces. Load cases may include steady-state and dynamic wind loads, as well as additional loads such as gravity and centrifugal forces. **Material Properties and Material Models:** Material properties obtained in the material selection phase are inputted into ANSYS Workbench. Material models are selected based on the behavior of each material under loading conditions. For metallic materials (aluminum alloy, titanium alloy, magnesium alloy), isotropic linear elastic material models are typically used. For the PEEK composite material, orthotropic material models are employed to account for material anisotropy. **Analysis Setup:** Structural analyses are performed using appropriate solvers and solution techniques available in ANSYS Workbench. Static analyses are conducted to evaluate the static structural response of the blades under steady wind loads. Dynamic analyses may also be performed to assess the natural frequencies, mode shapes, and dynamic behavior of the blades. **Post-Processing and Results Analysis:** After completing the analyses, results are post-processed to visualize and interpret the structural response of the wind turbine blades. Key output parameters such as stress distribution, deformation, displacement, natural frequencies, and mode shapes are analyzed and compared across different materials. Sensitivity analyses may be conducted to investigate the influence of various parameters on blade performance. **Validation and Verification:** The validity and accuracy of the simulation results are assessed through validation and verification studies. This may involve comparing numerical results with analytical solutions, experimental data, or results from validated numerical models. Sensitivity analyses and convergence studies are conducted to ensure the reliability of the simulation results.

IV. SCHEMATIC DIAGRAM

Geometry Creation:

NX 12 Software: Design representative blade geometries for each material (Aluminum, Titanium, Magnesium, and PEEK). Import NX 12 geometry into ANSYS Workbench.



Apply boundary conditions to simulate realistic operating conditions: Fixation at blade root (hub attachment). Aerodynamic loading (wind-induced forces). Additional loads (gravity, centrifugal forces). Material Properties & Models: Input material properties into ANSYS Workbench: Aluminum Alloy, Titanium Alloy, Magnesium Alloy: Isotropic linear elastic material models. PEEK Composite Material: Orthotropic material model. Analysis Setup: Structural analyses using ANSYS solvers: Static analyses for steady wind loads. Dynamic analyses for natural frequencies, mode shapes. Post-Processing & Results Analysis: Visualize and interpret results: Stress distribution, deformation, displacement. Natural frequencies, mode shapes. Compare results across different materials. Validation & Verification: Assess validity and accuracy of results: Validation against analytical solutions or experimental data. Verification through sensitivity analyses, convergence studies. Discussion & Conclusion: Analyze findings and draw conclusions: Identify material performance, structural integrity, suitability. Discuss strengths, weaknesses, trade-offs. Provide recommendations for blade design and material selection optimization. This schematic diagram provides a visual overview of the methodology and workflow for conducting the comparative study on wind turbine blade analysis using different materials in ANSYS Workbench.

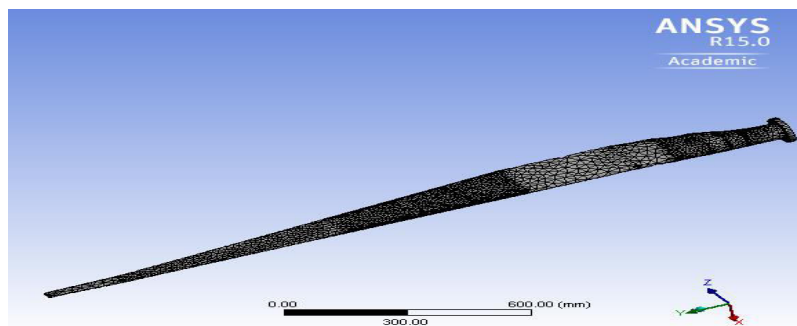
V. OBJECTIVES

- To develop a 3D model of wind turbine blade using NX 12 software.
- To study the behavior of different material of wind turbine blade under structural analysis.
- To compare the total deformation, Von misses stress, Equivalent elastic strain which is develop on a wind turbine blade for Aluminium alloy, titanium alloy, and carbon fiber reinforce composite materials.
- To compare the all three results a best material for the wind turbine blade.

VI. EXPERIMENTAL RESULTS

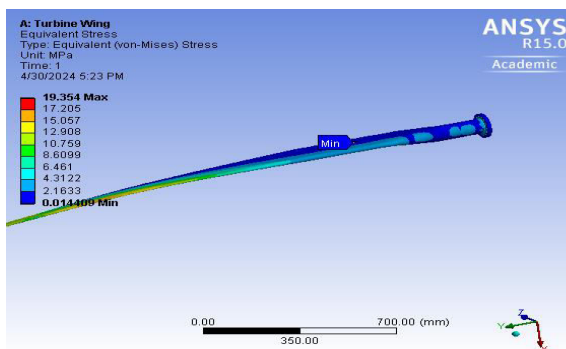
Mesh Generation:

Define Mesh Settings And Generate Meshes For All Blade Geometries. Conduct Mesh Refinement Studies For Convergence.

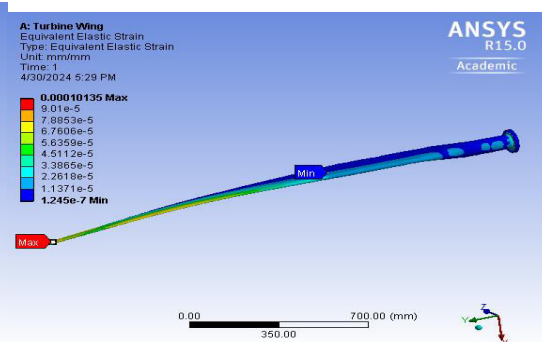


Meshed wind turbine blade

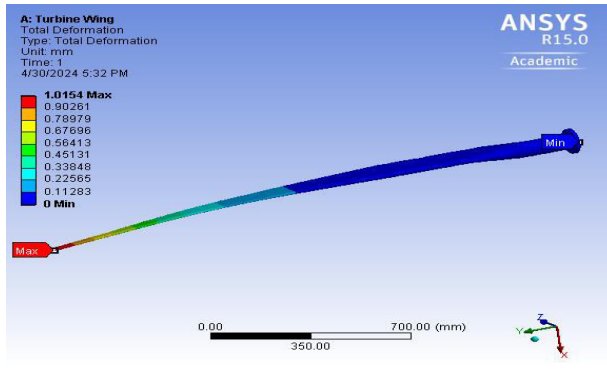
Aluminium Alloy



Equivalent (von-mises) Stress



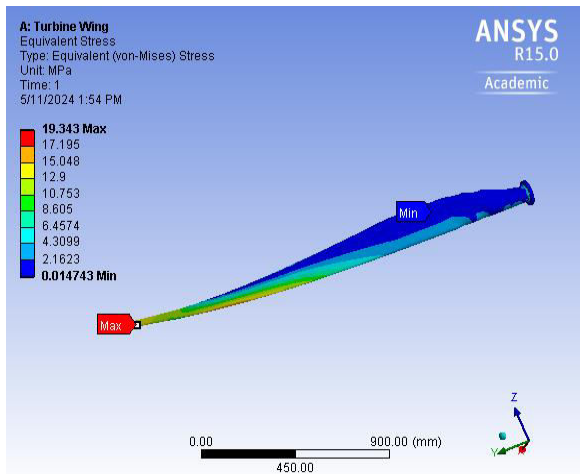
Equivalent Elastic strain



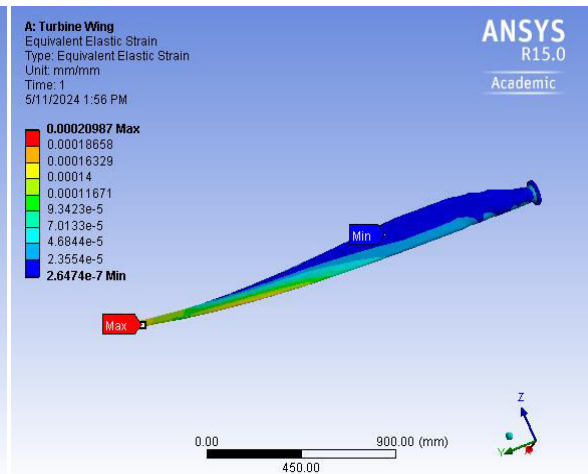
	Equivalent (von-mises) Stress	Equivalent Elastic strain	Total Deformation
Max	19.354	0.00010135	1.0154
Min	0.014409	1.245e-7	0

Total Deformation

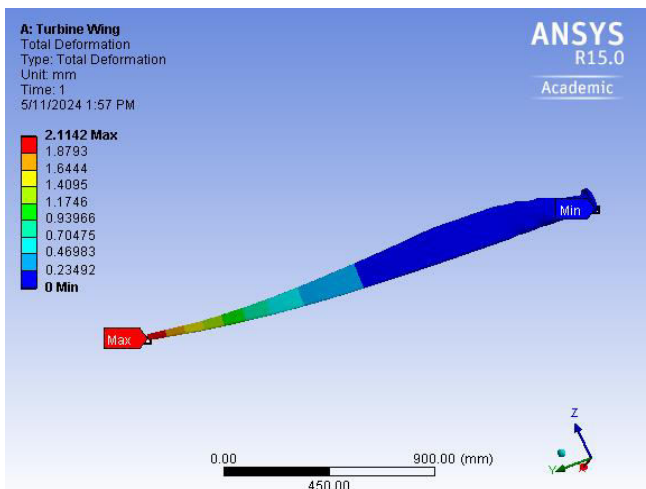
Titanium alloy



Equivalent (von Misses) Stress



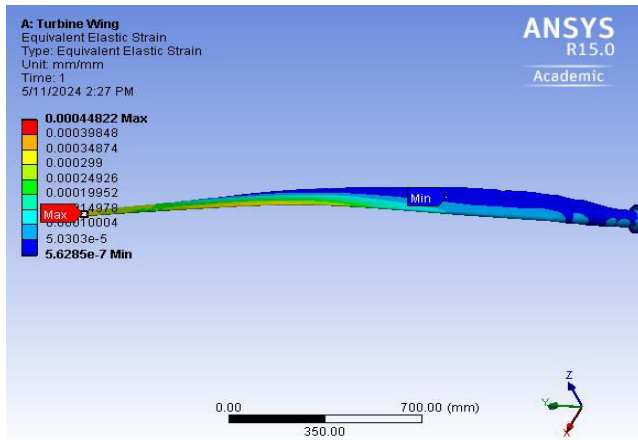
Equivalent Elastic Strain



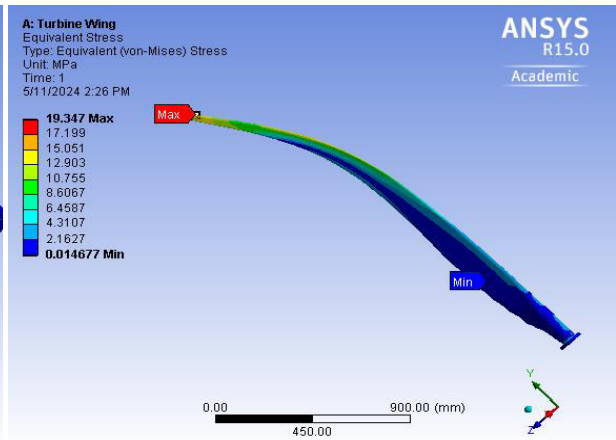
Total Deformation

	Equivalent (von-mises) Stress	Equivalent Elastic strain	Total Deformation
Max	19.343	0.00020987	2.1142
Min	0.014743	2.6474e-7	0

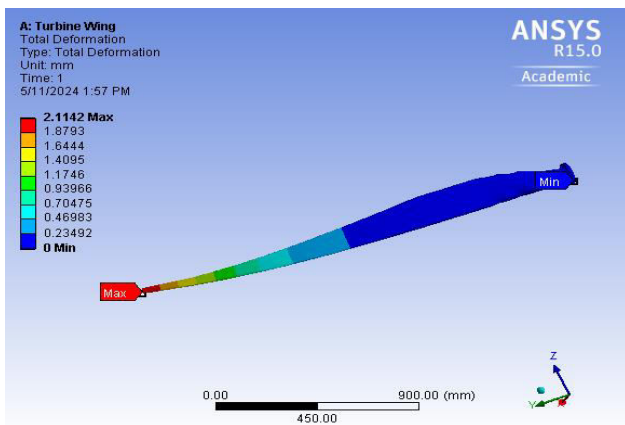
MAGNESIUM ALLOY



Equivalent Elastic strain



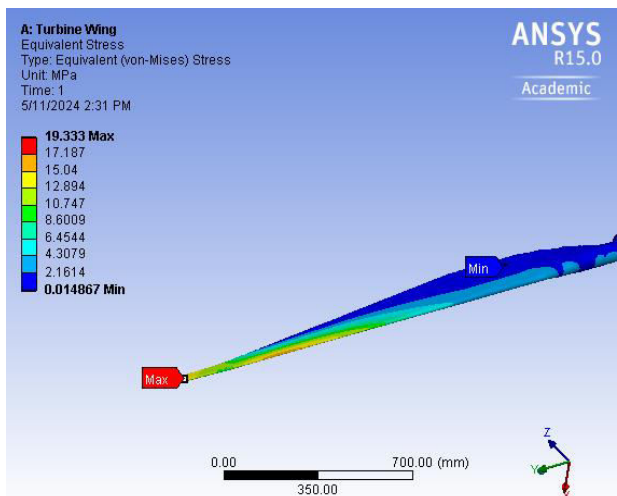
Equivalent (von-Mises) Stress



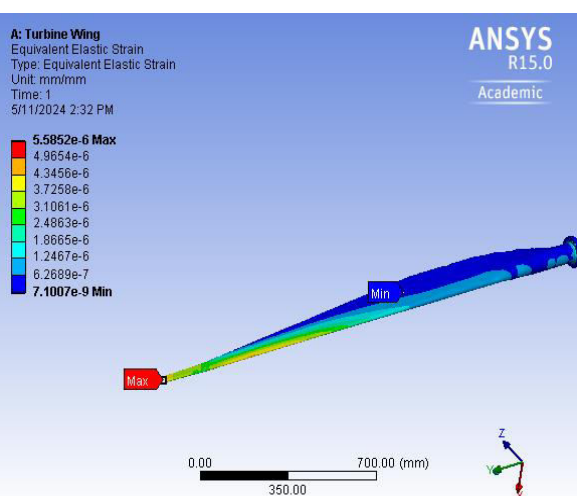
Total Deformation

	Equivalent (von-mises) Stress	Equivalent Elastic strain	Total Deformation
Max	19.347	0.00044822	2.1142
Min	0.014677	5.6285e-7	0

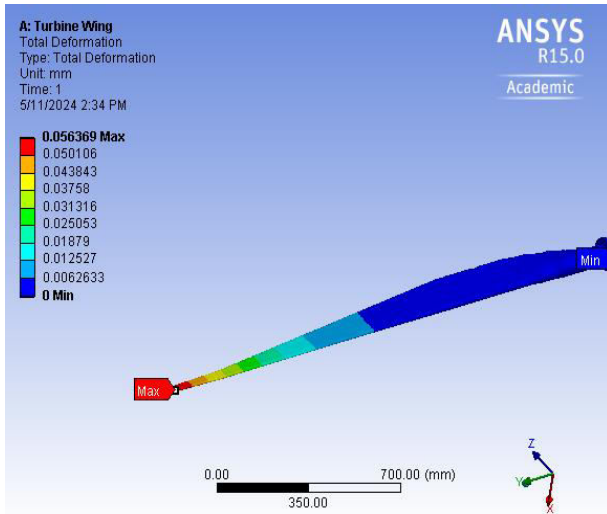
PEEK(Poly Ether Ether Keton)



Equivalent (von-Mises) Stress



Equivalent Elastic strain



	Equivalent (von-mises) Stress	Equivalent Elastic strain	Total Deformation
Max	19.333	5.5852e-6	0.056369
Min	0.014867	7.1007e-9	0

TOTAL DEFORMATION

TABULAR COLUMN

MATERIALS	EQUIVALENT (VON MISSES) STRESSES		EQUIVALENT ELASTIC STRAIN		TOTAL DEFORMATION	
	Max	Min	Max	Min	Max	Min
ALUMINIUM ALLOY	19.354	0.014409	0.0001013	1.245E-7	1.0154	0
TITANIUM ALLOY	19.343	0.014743	0.0002098	2.6474E-7	2.114	0
MAGNESIUM ALLOY	19.347	0.014677	0.00044	5.6285E-7	2.1142	0
PEEK	19.333	0.014867	0.00055	7.1007E-9	0.0563	0

VII. CONCLUSION

The comparative study on the structural analysis of wind turbine blades with different materials, including aluminium alloy, titanium alloy, magnesium alloy, and PEEK composite material, using ANSYS Workbench, has provided valuable insights into the performance and suitability of each material for wind energy applications. Through comprehensive structural analyses Based on the analysis results, recommendations can be made for optimizing wind turbine blade design and material selection. Hybrid material approaches, combining the strengths of different materials, could be explored to mitigate trade-offs and enhance overall performance. Further research is warranted to address specific challenges associated with each material, such as improving corrosion resistance for aluminium and magnesium alloys and reducing manufacturing costs for PEEK composites. In conclusion, the comparative study has advanced our understanding of the structural behaviour and performance of wind turbine blades with different materials, contributing to the optimization and advancement of wind energy systems. Continued research and innovation in material science and engineering will play a crucial role in further enhancing the efficiency, reliability, and cost-effectiveness of wind turbine technology.

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