Analysis of Wind Turbine Blade By using FEM

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Abstract: A wind turbine extricates vitality from moving air by backing the wind off, and moving this vitality into a turning shaft, which as a rule turns a generator to create power. The power in the wind that is accessible for reap relies upon both the wind speed and the region that is cleared by the turbine edges. With the improvement of wind control age innovation, the wind turbine sharp edge is ending up increasingly imperative. Demonstrating and stress examination of the wind turbine cutting edge are exceptionally basic for the further outline and the utilization of wind turbine edge. In this work the investigation center around the Finite component examination of 5 MW wind turbine edge by utilizing diverse sort of composite fibre material. The anxieties happen in the wind turbine cutting edge and distortion is the biggest issue in the wind turbine and which results in substantial harms and miscreant of turbine edges. In this work an endeavor has been made to diminish the weights on turbine sharp edge and furthermore diminishes the distortion in the cutting edge. The IGES model of 5MW turbine cutting edge is foreign made to basic investigation and after that the FEA work has been finished. In this investigation the aggregate misshaping, directional distortion and von-misses worry of turbine sharp edge have figured and make a pressure of different material.

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I. BACKGROUND

In this day and age vitality situation, sun powered, wind, biomass and hydro control have turned into the major inexhaustible portions that are assuming an essential job in endeavouring to locate a correct harmony between developing vitality requests and making it as 'green' as could reasonably be expected. No big surprise, they have so much consideration and push over the previous years that nations are attempting to move their vitality profile from customary assets to renewables.

Power has been extracted from the wind over hundreds of years with historic designs, known as windmills, constructed from wood, cloth and stone for the purpose of pumping water or grinding corn. Historic designs, typically large, heavy and inefficient, were replaced in the 19th century by fossil fuel engines and the implementation of a nationally distributed power network. A greater understanding of aerodynamics and advances in materials, particularly polymers, has led to the return of wind energy extraction in the latter half of the 20th century.

Wind power devices are now used to produce electricity, and commonly termed wind turbines. Wind control is developing at the rate of 30 % every year and, thus with this advancement, the outline of a wind turbine and its suggestions should be surely knew. Yearly vitality creation (AEP) and cost are the two significant drivers administering the general outline of a wind turbine. The plan ought to be sufficiently dependable to keep any undesirable upkeep or downtime and fundamentally stable enough to manage every one of the heaps following up on it through its normal lifetime of around 20 years.

II. WIND TURBINE

Wind Turbine “rotary engine in which the kinetic energy of a moving fluid is converted into mechanical energy by causing a bladed rotor to rotate Wind turbine blades spin opposite of a fan from the wind and make energy, instead of using energy to make wind.

Wind rotates the turbine blades, spins a shaft connected to a generator and the spinning of the shaft in the generator makes electricity. Wind turbines, like windmills, are mounted on a tower to capture the most wind energy, wind speed varies by height, wind current 100m above the ground dropped in speed by 10% when its height declined to 50m. This property is known as wind shear in which wind speed increases in speed with height, due to friction at the Earth’s surface.

Wind turbine is one of the renewable energy sources whose importance is increasing. Therefore, the analysis, design and production of wind turbines is very important for the world's power generation industry. The most critical components of a wind turbine are turbine blades. The turbine blade, the first link in the energy conversion chain, is an important issue in wind turbine design. The kinetic energy in the wind should be transferred to the turbine blades without any loss. This significantly affects the yield to be achieved. For this reason, the turbine blades must be designed in such a way that they can capture the maximum energy from the wind. In the production of wind turbine rotors, the strength of the turbine blades at high wind speeds is an important consideration.

III. TURBINE BLADE

The wind is a free vitality asset, until the point that administrations put a duty on it, however the wind is additionally an exceptionally capricious and a questionable wellspring of vitality as it is continually altering in both quality and course. To create valuable measures of intensity, wind turbines for the most part should be substantial and tall, yet to work productively they additionally should be very much outlined and designed which makes them costly as well.

Most wind turbines intended for the creation of power have comprised of an a few bladed propeller pivoting around an even hub. It's conspicuous to state that these propeller like wind turbine cutting edge plans convert the vitality of the wind into usable shaft control called torque. This is accomplished by extricating the vitality from the wind by backing it off or decelerating the wind as it ignores the cutting edges. The powers which decelerate the wind are equivalent and inverse to the push compose lifting powers which pivots the sharp edges.

Much the same as a plane wing, wind turbine edges work by producing lift because of their bended shape. The agree with the most bend creates low gaseous tension while high weight air underneath pushes on the opposite side of the edge formed aerofoil. The net outcome is a lifting power opposite to the course of stream of the air over the turbines sharp edge. The trap here is to outline the rotor edge so as to make the appropriate measure of rotor sharp edge lift and push creating ideal deceleration of the air and along these lines better edge proficiency.

In the event that the turbines propeller sharp edges turn too gradually, it enables excessively twist to go through undisturbed, and accordingly does not separate as much vitality as it possibly could. Then again, if the propeller cutting edge turns too rapidly, it appears to the wind as an expansive level pivoting circle, which makes a lot of drag.

At that point the ideal tip speed proportion, TSR, or, in other words the proportion of the speed of the rotor tip to the wind speed, relies upon the rotor cutting edge shape profile, the quantity of turbine sharp edges, and the wind turbine propeller edge outline itself. So which is the best sharp edge shape and plan for wind turbine cutting edges.

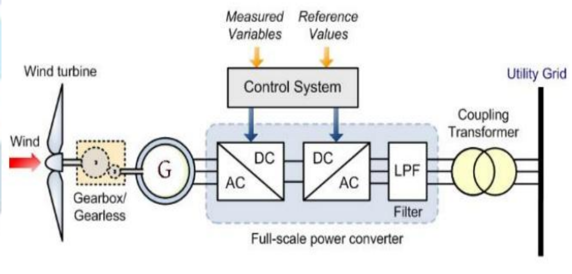

Figure 1: Block Diagram of Wind Turbine

IV. PREVIOUS WORK

Designing a blade by using well known Blade Element Momentum (BEM) Theory is a fascination to many researchers who are interested to get better geometrical parameters to maximize the power output of the blades.

Jixie Qiangdu Journal (2024) reported that mixed layups, varying proportions of carbon and glass fibers, can achieve structural performance comparable to full carbon fiber blades when carefully placed, especially near blade tips. used ANSYS FEA to identify optimal hybrid replacement of glass fiber with carbon fiber, finding that 75% carbon replacement in spar caps significantly enhances structural performance. Thermoplastic composites have been explored for enhanced impact resistance and repairability. demonstrated that thermoplastic resin-based blades showed promising flexural and impact strengths using ANSYS ACP, supporting their viability as sustainable alternatives to traditional thermosets. Lifecycle and environmental concerns are also guiding material selection.

Gursel et al (2025) underlined the growing need for recyclable strategies given the challenge of decommissioning GFRP blades. evaluated CFRP, GFRP, and hybrid composites with FEA and experimental data, emphasizing the implications of tensile strength, fatigue life, environmental sensitivity, and cost. These studies collectively reflect the state-of-the-art in composite blade research, from material selection and hybrid layup strategies to environmental lifecycle, fatigue behaviour, passive aerodynamics, and predictive maintenance techniques.

Xiaosong Huang (2024) CFRP continues to be favored for high-stiffness and low-weight structures, whereas GFRP remains cost-effective in suitable applications. Hybrid designs and thermoplastic alternatives are gaining traction, particularly for balancing performance with sustainability. Furthermore, modeling of fatigue, defects, and structural health is becoming crucial to extending blade lifespan and optimizing maintenance

Chen-Hsu Wang et. al. [2020] worked on Stress analysis of composite wind turbine blade by finite element method. The finite element analysis software ANSYS was used to analyse the composite wind turbine blade. The wind turbine blade model used is adopted from the 5 MW model of US National Renewable Energy Laboratory (NREL).

Chong-wei Zheng,et. al. [2022} worked on Rezoning global offshore wind energy resources. In this study, a new wind energy classification scheme that incorporates a comprehensive consideration of wind energy factors, environmental risk factors and cost factors is proposed to rezone the potential offshore wind energy resources worldwide.

Cristina L. Archer [2019] worked on Wind farms with counter-rotating wind turbines. The objective of this study is to assess the effects of using counter-rotating wind turbines on the performance of a wind farm. Large eddy simulations, coupled with the actuator line model, were conducted to investigate flow through a test wind farm with 48 large-scale wind turbines with the same layout as Lillgrund in Sweden.

Sami et al. [2020] extracted fundamental flapwise and edgewise modal frequency of a 5KW GFRP wind turbine blade by using 3d shell elements. It is to understand better the dynamic behaviour that he conducted experiments using electrodynamics shaker system to predict the resonant frequencies. He observed that flapwise frequencies are found to be in agreement to each other while % of error is more in case of edgewise frequency.

Yangfeng Wang [2017] considered two cases of turbine blades having 1m and 5m in length and conducted damage detection technique by comparing the dynamic response analysis and mode shape curvature methods using composite multi-layer materials. The dynamic analysis method is used to understand the damage severity of wind turbine blades.

X Y Wang [2015] worked on Comparison of the pressure distribution of a wind turbine blade based on field experiment and CFD. The distribution of pressure is gathered by disposed 191 taped pressure sensors span-ward on seven particular sections of a blade. And the parameters of experimental condition of inflow and operation condition of the wind turbine are obtained at the same time.

The problems identified from the study of literature review are as follows:

- Design of Turbine blade play an important role in Power generation of wind turbine.

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- The Stresses occurs on the turbine blade is the major problem in blade design.
- The deformation occurs in the turbine blade is the beginning of damage of turbine blade.

V. OBJECTIVES

- The main objective of project is to protect the turbine blade from various hazards like deformation and directional deformation.
- The aim of the study to compare between horizontal axis wind turbine and vertical axis wind turbine.
- The FEA simulation of E Glass Fibre and S glass fibre Turbine blade have been done and make a compression on deformation, Directional deformation and Von misses stress occurs on the turbine blade.

VI. METHODOLOGY

The finite element method (FEM), is a numerical method for solving problems of engineering and mathematical physics. Typical problem areas of interest include structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. Theanalytical solution of these problems generally requires the solution to boundary value problems for partial differential equations. The finite element method formulation of the problem results in a system of algebraic equations. The method yields approximate values of the unknowns at discrete number of points over the domain. To solve the problem, it subdivides a large problem into smaller, simpler parts that are called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses variation methods from the calculus of variations to approximate a solution by minimizing an associated error function.

Table 1: Property of 5MW wind turbine

Rating	5 MW
Rotor diameter	130 m
Hub diameter	3 m
Cut in wind speed	3 m/s
Cut rated wind speed	11.6 m/s
Cut out wind speed	25 m/s
Cut in rotor speed	7 rpm
Rated rotor speed	12.1 rpm
Rated tip speed	80 m/s

Table 2: Composition of wind turbine blade material

Composition	**E- Glass Fibre (%)**	**S- Glass Fibre (%)**
Al_2O_3	15.2	24.8
B_2O_3	---	0.010
BaO	8.0	0.20
CaO	17.2	0.010
FeO	4.7	0.21
MgO	---	10.27
NaO_2	0.60	0.27
SiO_2	54.3	64.2

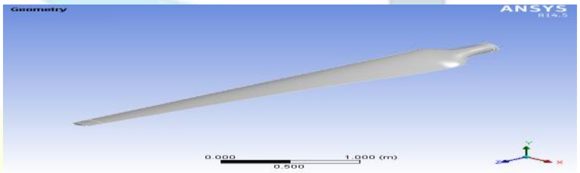

Figure 1: Geometrical model of wind turbine blade.

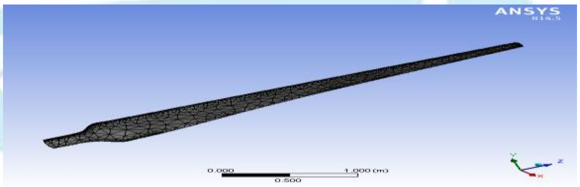

Figure 2: Meshing of Wind Turbine Blade.

VII. BOUNDARY CONDITION

The Hub End of turbine blade is taken fixed support and provide a load on 20878 N on the Blade Profile at 120 Degree clockwise direction at various pitch 0, 5 and 15 degree.

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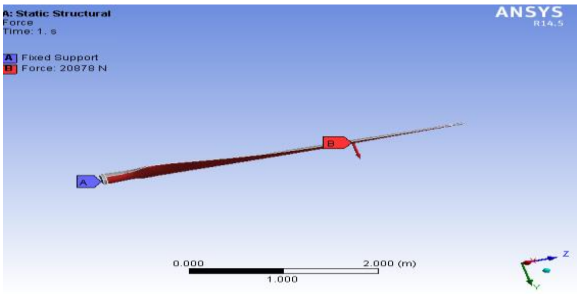

Figure 3: Boundary condition Wind Turbine Blades

VIII. RESULTS AND DISCUSSIONS

RESULT VALIDATION ON E – GLASS FIBRE WIND TURBINE BLADE

After putting the boundary conditions, the solution is initialized and then iteration is applied so that the values of all parameters can be seen in a curve or line graph. After the iteration gets completed final result could be seen.

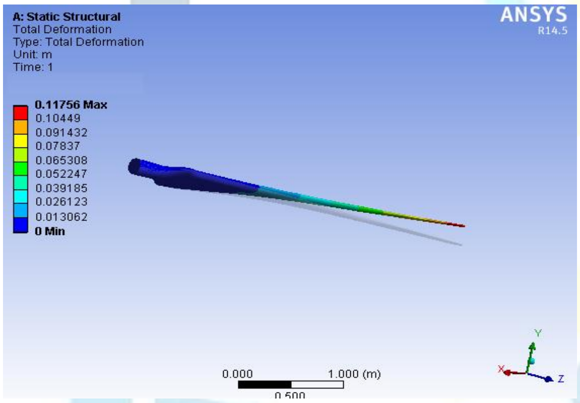

Figure 4: Total deformation occurs in E glass fibre wind turbine blade.

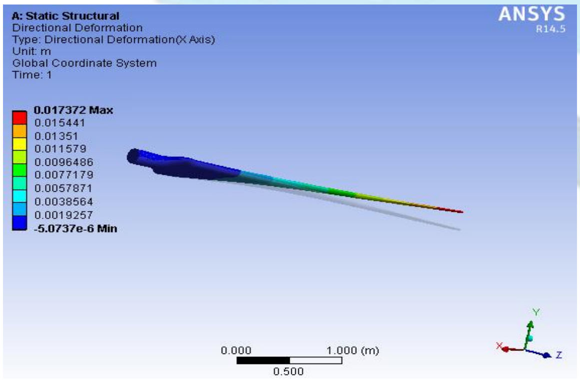

Figure 5: Von misses stress and Directional deformation on E glass fibre turbine blade.

RESULT OF S - GLASS FIBRE WIND TURBINE BLADE AT ZERO DEGREE PITCH

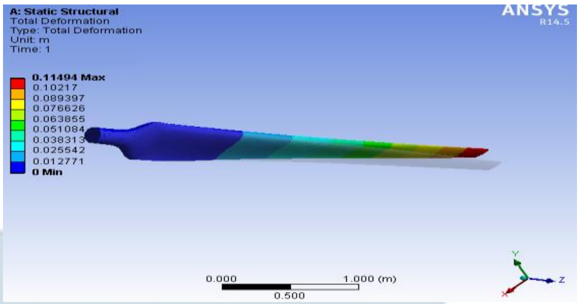

Figure 6: Total deformation on s- glass fibre turbine blade at pitch zero degree

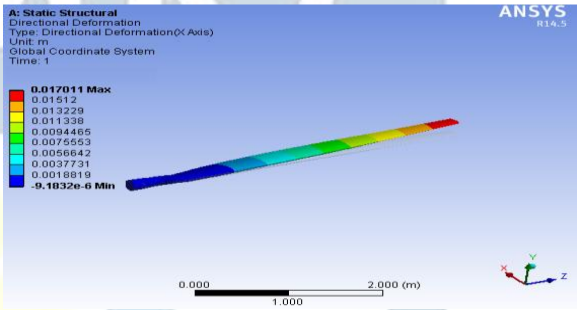

Figure 7: Directional deformation on s- glass fibre turbine blade at pitch zero degree

RESULT OF S-GLASS FIBRE WIND TURBINE BLADE AT 5 DEGREE PITCH

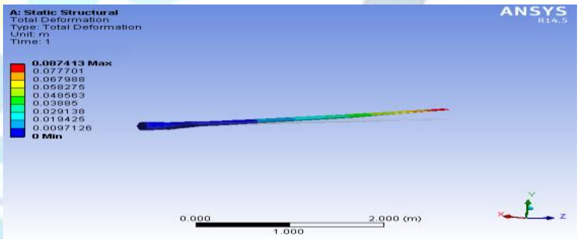

Figure 8: Total deformation son s- glass fibre turbine blade at pitch 5 degree.

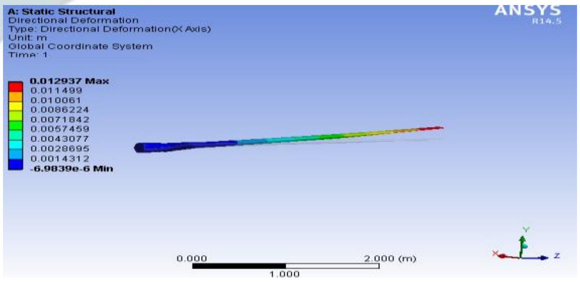

Figure 9: Directional deformations on s- glass fibre turbine blade at pitch 5 degree

RESULT OF S-GLASS FIBRE WIND TURBINE BLADE AT 15 DEGREE PITCH

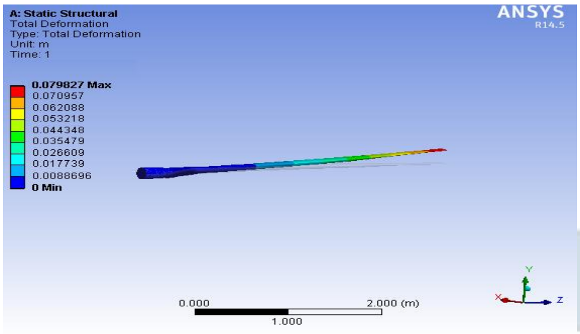

Figure 10: Total deformations on s- glass fibre turbine blade at pitch 15 degree.

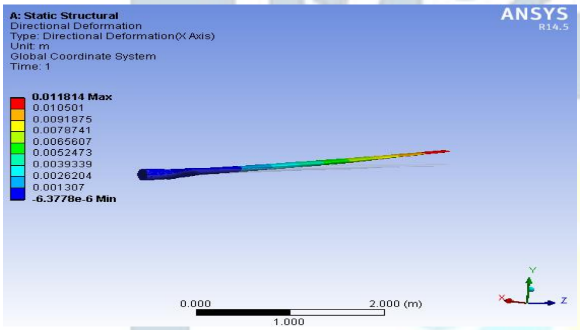

Figure 11: Directional deformations on s- glass fibre turbine blade at pitch 15 degree.

Table 3: Results Compression of FEA simulation

Materials	Von Misses stress in MPa		
	At pitch 0 degree	At pitch 5 degree	At pitch 15 degree
E-Glass Fibre	108.79	69.10	60.92
S-Glass Fibre	79.9	60.8	55.5

Table 4: Results in Deformation

Materials	Total Deformation in m		
	At pitch 0 degree	At pitch 5 degree	At pitch 15 degree
S-Glass Fibre	0.115	0.087	0.079

Table 5: Result in Directional Deformation

Materials	Directional Deformation in m		
	At pitch 0 degree	At pitch 5 degree	At pitch 15 degree
S-Glass Fibre	0.017	0.013	0.012

IX. CONCLUSIONS

FEA Simulation of E glass Fibre and S glass fibre turbine concluded that the various results that are discussed below are fallowing:

The Obtained results concluded that the Von misses stress occurring on the S glass Fibre wind turbine blade are reducing as compared to E Glass Fibre Wind turbine Blade. Which are shows in the previous chapter with the help of graphical and tabular representation also.

In this work the Total deformation of Wind turbine blade Has been calculated at varying pitch which shows that with respect to pitch the total deformation decreases but after a point it have minor changes.

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