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Vibration Analysis and Optimization of Wind Turbine Blade with Composite Materials

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Abstract - It is well known that the rotor's sharp edge is an essential part of the breeze turbine. Wind turbines provide an alternative means of generating electricity from the wind's power. The plan of edge is crucial for energy extraction. Wind turbines can be used to generate enough electricity in windy areas and high airflow speeds. The blades of such turbines are designed to generate lift from the wind and transform as a result. In this paper the leading edge of a breeze turbine is analyzed in Solid Work for five different materials: Structural Steel, Adhesive Epoxy Carbon, E-glass, S-glass, and Aluminum Alloy. The paper then explores the use of ANSYS programming to analyze the Wind Turbine Blade to determine the edge's intensity and compare the above materials to determine which is the best material for the wind turbine edge. The results demonstrate that Epoxy carbon and primary metal have the least value in terms of strain and deformity, but once a mass event occurs, the resulting steel has a wide range of properties. As a result, it's reasonable to assume that Epoxy Carbon is best suited to make turbine cutting edges.

Index Terms - Wind turbines, ANSYS, Finite Element, Optimization, Composite Material.

INTRODUCTION

The Bridling wind energy needs a cutting-edge approach. In this paper, a wind turbine edge with the NACA axial plan is subjected to a small part inquiry. The investigation of a new breeze turbine cutting edge is the subject of this article. Cutting edge streamlining takes into account boundary conditions such as aerofoil profile states, tensions, and edge twisting. When designing a wind turbine, the aim is to achieve the highest possible force yield under complex environmental conditions, which is dependent on the hard edge's state as well as its content. The use of wind energy necessitates the creation of devices that turn the energy into more useful structures. This is usually accomplished by first specifically converting the straight strength of the air into a rotational movement via a windmill, and then converting the rotary motion of the windmill blades into electric power via a generator. For our purposes, we should think of the windmill as a mechanical device that separates a portion of the breeze's engine energy and converts it into the rotary motion of the edge movement. This is achieved, in detail, by positioning the cutting edges in relation to the wind, so that the breeze flowing past them exerts a streamlined force on them, resulting in the production of a streamlined product by makes them turn. Changing the composite material of the edge will change the physical and mechanical properties of an airflow turbine. The substance of the cutting edge will be emphasized from now on. The outcomes of examining different materials are compared to the results of assessing the one that is most suitable for practical use the airfoil used, which is a cambered airfoil with a spot in the NACA airfoil characterization's four-digit setup.

METHODOLOGY

Schematic of blade structure is shown in Figure 1. Sharp edges and nacelles are made of composite materials, as are most parts of wind turbines (centers, axles, generators, nacelles, towers, etc.). Low weight, power, and erosion resistance are the most important requirements for nacelles, which provide environment assurance to the pieces. Usually, glass fiber composites are used to make nacelles. Increasing the consistency and lifespan of wind sharp edges is a major concern for wind turbine developers. The cutting edges of the tornado turbine are controlled as below. The functions of turbine component are show in Table 1.

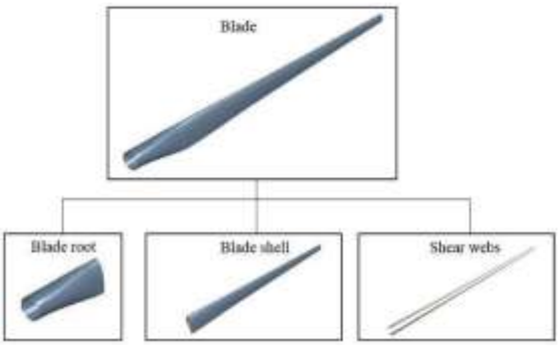

Figure 1. Schematic of blade structure

Table 1. The functions of turbine component

PART	FUNCTION	MATERIAL USED
Blade Shell	Maintaining The Blade Shape, Resisting The Wind And Gravitational Forces	Strong, Light Weight Composite
Unsupported Parts Of The Shell	Resisting The Buckling Load	Thickened Sandwich Structures With Light Core Materials And Multidirectional Face Laminates
Integral Web, Spar Or Box Beam	Resisting The Shell Buckling Shear Stresses Due to Flap wise Bending	Biaxial Lay-Ups At+/45o
Adhesive Layers Between Composite Plies, And The Web And Blade Shell	Ensure The Out-Of Plane Strength And Stiffness Of The Blade	Strong And Highly Adhesive Matrix

A cutting edge is made up of two distinct appears (on the pull and pushing factor ends), which are fused and solidified by one or more critical (shear) networks linking the upper and lower parts of the cutting-edge shell, or by a case shaft (the fight of the box with shell fairings). The case pillar within the edge is adhered to the shell with adhesive. Figure 2 shows the basic shape of the modern wind turbine blade and region classification.

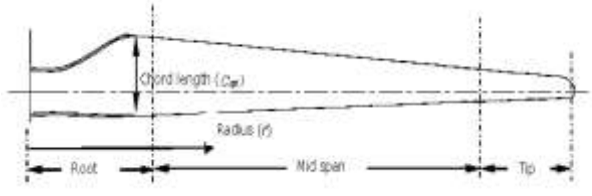

Figure 2. A wind blade turbine plan and region classification

Present day wind turbine blade are primarily cutting-edge developments using composite overlays, sandwich center materials, gel coat movies and glue joints. Although there is an assortment of wind turbine plans. At long last, the sharp edges are presented to outward powers during the revolution. In any case, these longitudinal burdens are generally low and regularly not considered in the plan. Besides, the plan loads are separated into static burdens and cyclic burdens. Notwithstanding, the blade are exposed to different ecological loadings as shown in Figure 3. The aerodynamic force effect on the blade is shown in Figure 4. Wind and gravity are the main forces acting on the sharp edges. Fold savvy and edgewise twisting are primarily prompted by wind stacks. The weariness on the edge material is caused by both a static and a special section (variations in wind speed and daily breeze shear) in these loads. When the sharp edge is smooth, gravity stacks primarily cause edgewise twisting. Edge revolution results in blade bowing and, as a result, material weakness along these lines.

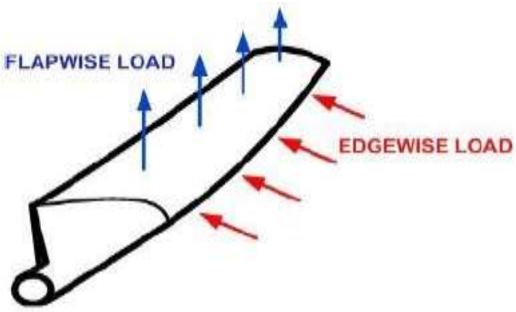

Figure 3. Load on wind blade turbine

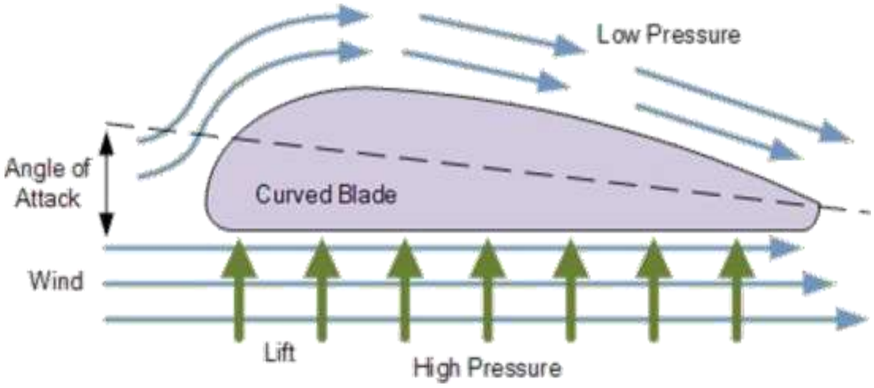

Figure 4. Aerodynamic force effect on the blade

Overall, both turbines can be classified as either lift- or drag-based, with the former being more effective. The centralized control that is used to isolate the energy is the difference in these gatherings. The drag energy refers to the wind stream, while the lift power is the polar opposite. HWAT is a well-executed lift-based breeze turbine that creates a differential pushing factor between upper and lower surfaces, causing net power to be directed in the reverse direction of the wave. The overall wind does not slow down; rather, it accelerates. As a result, these machines' greatest force cut-off points are far higher than that of drag-based devices. The following is the administering state for power output:

$$P = F.V$$

Where P stands for power, F stands for power vector, and V stands for the speed of the running breeze turbine component. As turbines increase in size, the mass of the blade is said to increase proportionately at a cubic rate as shown in Figure 5.

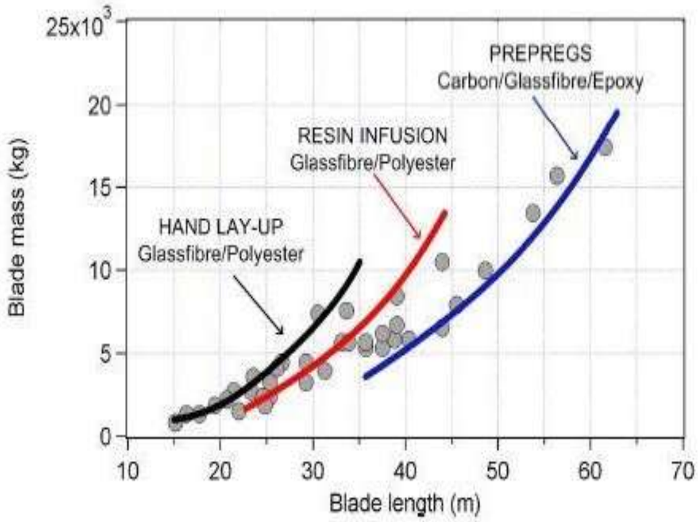

Figure 5. Growth of blade mass with blade length

Harm lenient conduct suggests that the principal method of harm doesn't lead straightforwardly to disappointment yet proliferates in a steady way and gives perceivable changes so the harm can be distinguished before it arrives at a basic size where it prompts disappointment. In this way, disappointment of wind turbine blade doesn't happen as an immediate aftereffect of break commencement along an interface or by reformist harm to the strands and lattice. Maybe, worldwide disappointment of a wind turbine blade includes the movement of a few harm systems that can act in arrangement or in equal. There are many properties that are required to analyze the wind blade turbine such as:

• accessibility.
• Thickness, minimal effort
• firmness
• break strength.
•The capacity ecological effects like lightning strikes, stickiness, and temperature.
•The edges should be solid to forestall impact with the pinnacle under outrageous burdens. Nearby solidness should be likewise adequate to forestall outrageous burdens and security of parts under pressure (to stay away from neighborhood or worldwide clasping). Another of the primary objectives of venture practice is to find a suitable material for the wind turbine edge. Fiber-supported method is widely used for sharp edges. Underlying structural steel, Adhesive Epoxy carbon, E-glass, S-glass, and Aluminium Alloy were included in the new litigation as shown in Table 2.

Table 2. Mechanical Properties of Material Selection

Properties	Values				
	structural	EPoxy Carbon	E Glass	S Glass	Aluminum Alloy
Density(g/cm3)	7.85	1.518	2.6	2.495	2.7
Young's modulus (Gpa)	80	123.34	85	93	7.73
Poisson's ratio	0.29	0.27	0.23	0.23	0.33
Shear modulus	31.008	3080	36	39	26.0
Tensile stress (MPa)	450	1632	2050	4800	324
Shear stress (MPa)	515	80	80	80	207

FINITE ELEMENT MODELING:

The static primary investigation is finished by utilizing ANSYS workbench. The one finish of wind turbine blade is upheld by the center and another end is free in air as shown in Figure 6. In this examination the center end is given a steady precise speed of 10 m/s and various estimations of misshapenness and stresses are determined. Underlying examination is the assurance of the impacts of burdens on actual constructions and their parts. It processes construction's misshapenness, stresses, support responses, speed increases, and steadiness. The greatest twisting happens at tip of the blade and least at center point end while the twisting at others part is typical. The activity is divided into three stages: hypothetical evaluation, solid model development, and the analysis of finite element.

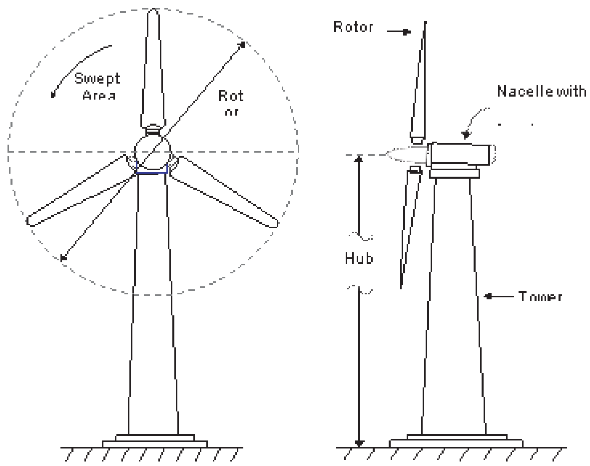

Figure 6. Schematic Diagram of Wind Energy System

For example, response powers, component stresses and warmth stream. In reality, the element in this progression like network control, mathematical joining and condition addressing are done naturally by business programming. In post preparing, the examination and assessment of the outcome led in this progression. There are three basic stages: pre-handling, preparation, and post-preparation. Pre-handling (pattern definition) has the following: define the problem's computational space, the part type(s) to be used, component material parameters, element analysis, figure (length, area), component interaction (blend the model), physical constraints (shear stress), and workloads

The administrating logarithmic situations in network configuration are collected and obscure predictions of the critical field variable are produced during the arrangement stage. Back replacement is then used to determine additional, expressed variables such as reaction forces, part stresses, and warmth flow using the compound results. Other aspects considering, market programming handles the elements of this evolution automatically, such as lattice power, statistical combination, and state settling. The analysis and evaluation of the result guided in this progression is referred to as post. The SoldWork technology is used to build the 3D model of the wind farm bleeding edge, which is then imported into ANSYS. The concept of plan and equipment used in the cutting edge was examined in a hypothetical inquiry. The windmill's ability is to convert electrical energy into mechanical energy by extracting power from the environment. Figure 7 shows the main steps of Finite Element Modeling and Analysis

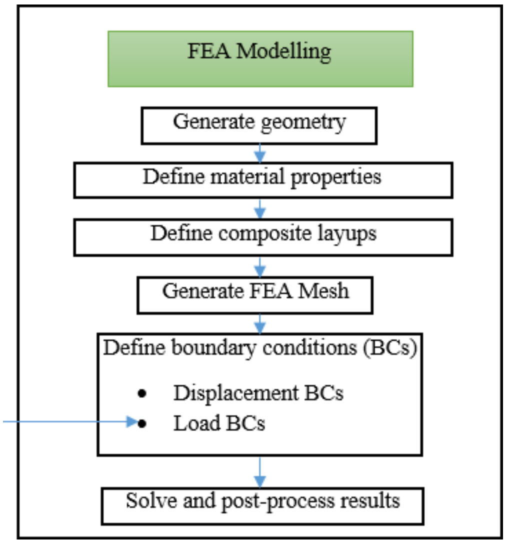

Figure 7. Finite Element Steps

Table 3 states the number of nodes and number of elements of the FE model used to model shown in Figure 8 the system to get more accurate results.

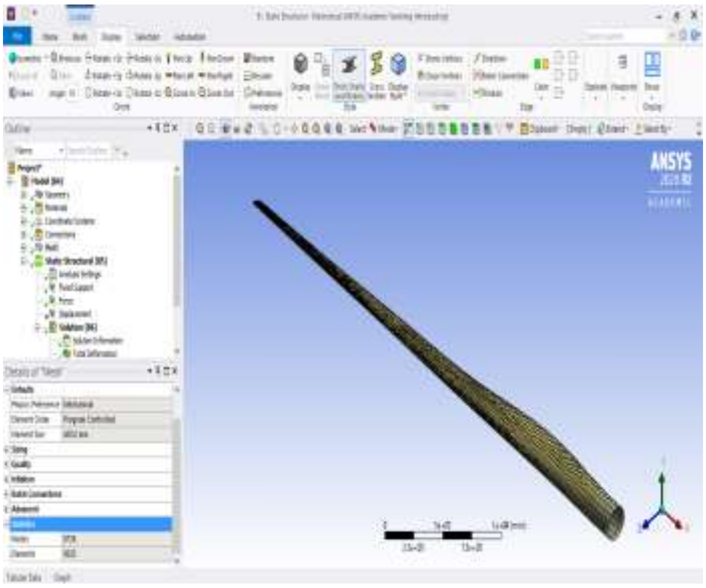

Figure 8. Meshing Information

TABLE 3. Meshing details

Object Name	Mesh
Statistics	
Nodes	8736
Elements	9020
Element Size	400 mm

RESULTS AND DISCUSSIONS:

A. Structural Steel Analyses as Blade Material

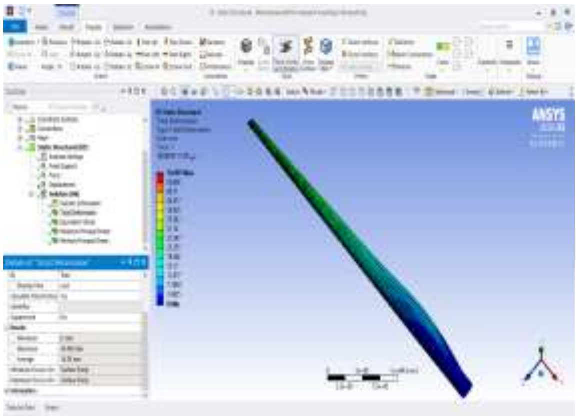

Figure 9. total deformation effect

Figure 9 shows the value of total deformation that effect on structural steel 54 mm, also we know the best material that we select due to low deformation was structural steel, but unfortunately it has high weight which conflict with design requirements.

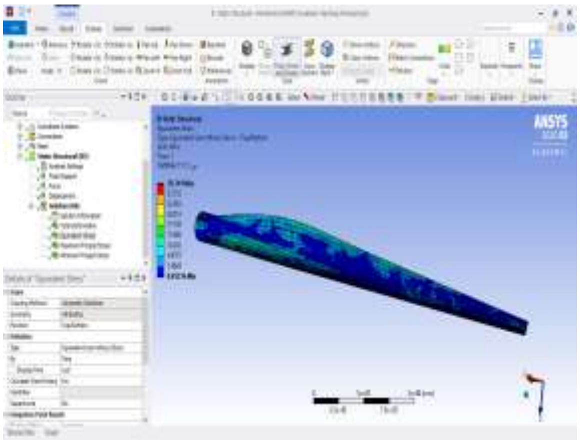

Figure 10. Von-Mises Stress Effect

Von-Mises stress in case of Structural Steel is 30 MPa as shown in Figure 10, so by default we have low stress due to the materials properties.

B. Epoxy Carbon Analyses as Blade Material

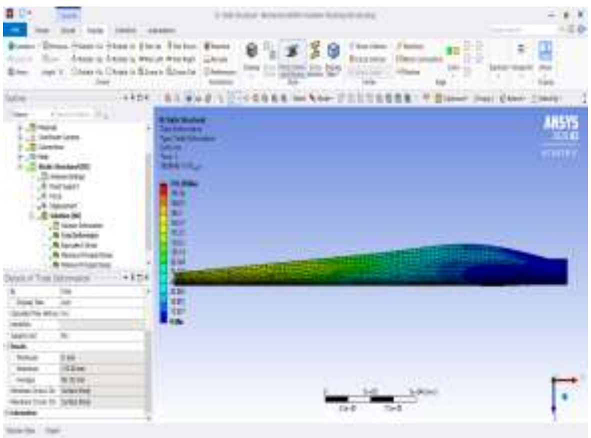

Figure 11. Deformation Effect value on Epoxy Carbon

It has been found that the maximum deformation in Epoxy carbon 210 mm in the end of wind blade turbine and average deformation 86 mm as shown in Figure 11.

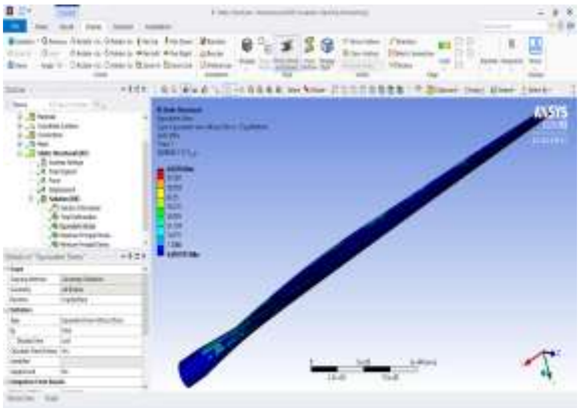

Figure 12. Von-Mises Stress Effect on Epoxy Carbon

One can see from Figure 12 that the Von-Mises stress that effect on Epoxy carbon of wind blade turbine in top hup section with value 65 MPa.

C. E Glass Analyses

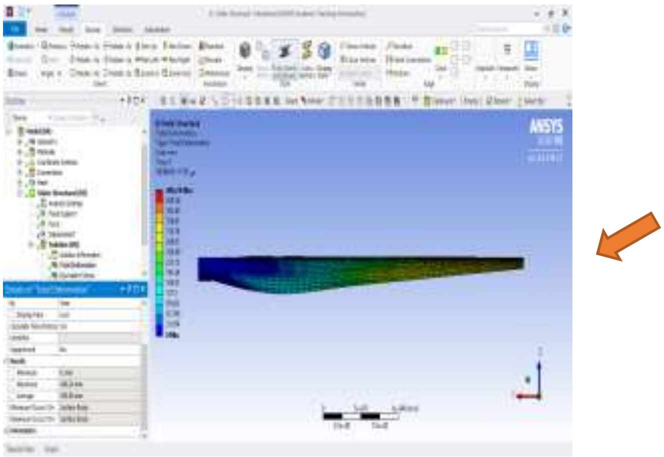

Figure 13. Total Deformation Effect

The total deformation of the wind blade in case of the E glass material value is 446 mm as shown in Figure 13 so the hup section is in safe side.

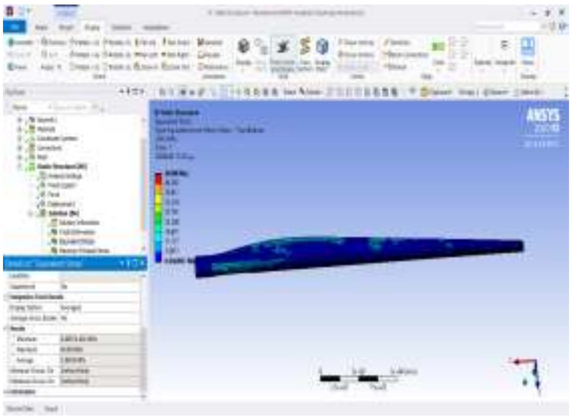

Figure 14. Von-Mises Stress

In Figure 14, the Von-Mises stress of 49.88 MPa and one can see that the stress is centered at the downside wind blade turbine of hup section.

D. *S-glass Analyses as Blade Material*

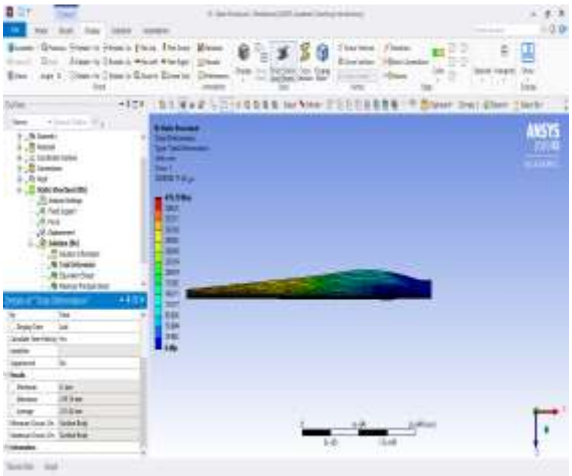

Figure 15. Total Deformation Effect on S-glass

The deformation value of the wind blade turbine in case of S-glass is 419 mm where the average deformation is 221.5 mm and high deformation is at the end as shown in Figure 15.

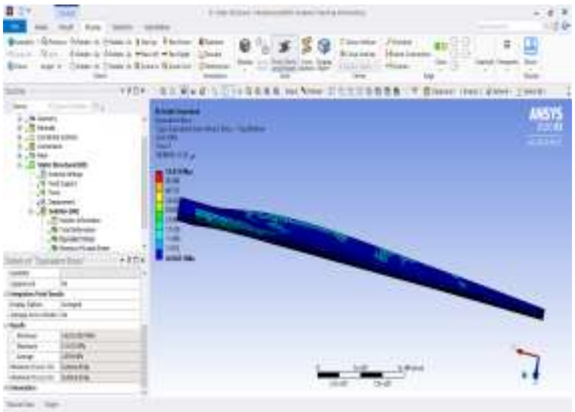

Figure 16. Von-Mises Stress Effect on S-glass

The stress on s glass material blade turbine is 51 MPa that is maximum value where the average value that effects on the blade is 2.939MPa as shown in Figure 16.

E. Aluminum Alloy Analyses as Blade Material

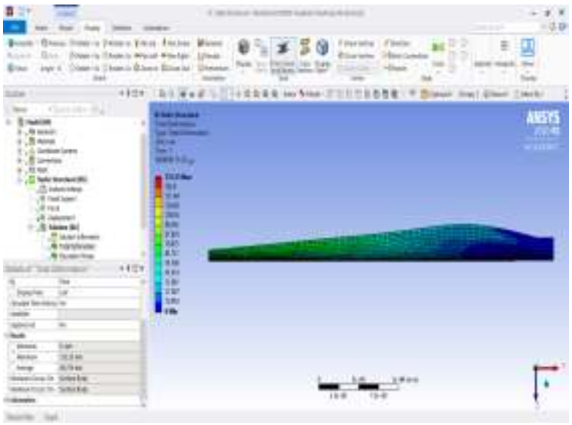

Figure 17. Total Deformation Effect on Aluminum Alloy

Figure 17 shows that the total deformation of the wind blade turbine in case of aluminum is 153 mm with save location on hup section and high deformation is at the end.

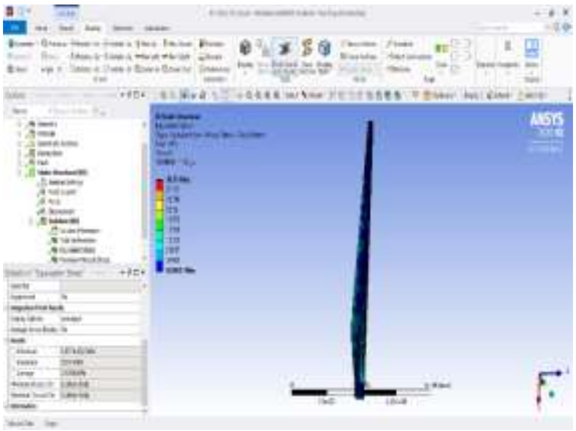

Figure 18. Von-Mises Stress Effect on Aluminum Alloy

The value of Von-Mises stress in case of Aluminum alloy is 30.51 MPa and one can see that the high value of stress on the upper surface as shown in Figure 18. A comparison between the five materials used is illustrated in Table 4.

Table 4. Comparison of All Materials

MATERIAL	DEFORMATION (mm)	STRESS (Mpa)	MASS (Kg)
STRUCTURAL STEEL	54.5	30.741	732.31
EPOXY CARBON	210	65	138
EPOXY E-GLASS UD	446	50	168.5
EPOXY S-GLASS UD	419	51	186
ALUMINIUM ALLOY	153	30.5	258.5

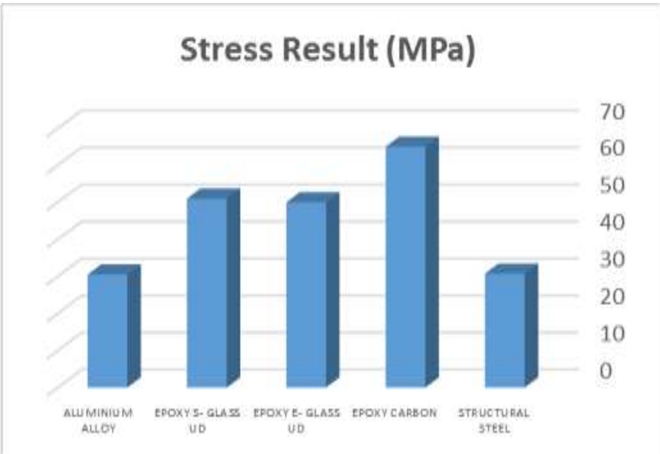

Figure 19. Comparison of Stress

Comparison of Stress that effects on the is shown in Figure 19. It is clear that the best option is the aluminum alloy material due to low stress. Figure 20 shows a comparison of the deformations of the blade where the steel is the best. Comparison of mass of the blade shown in Figure 21

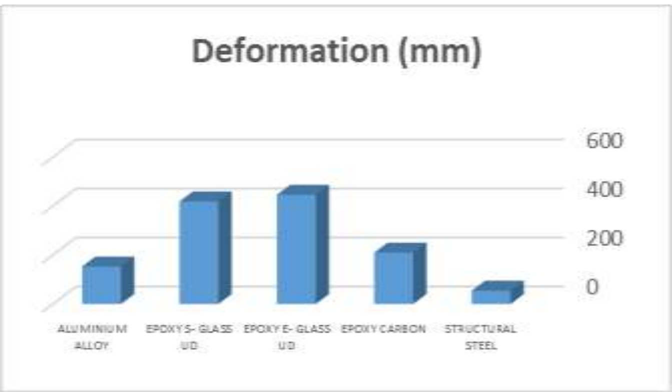

Figure 20. Comparison of Deformation of The Blade

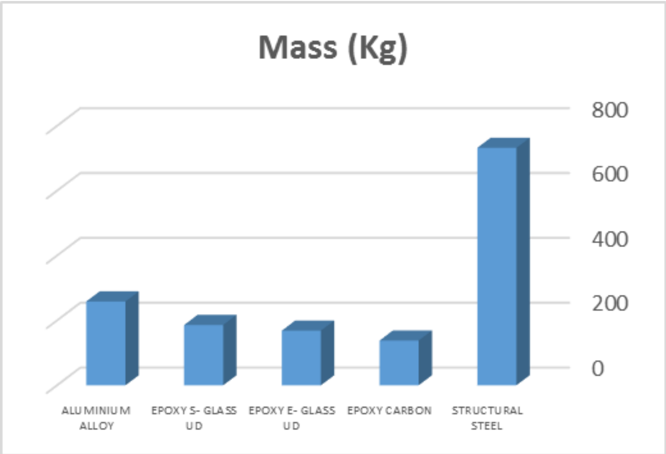

Figure 21. Comparison of mass

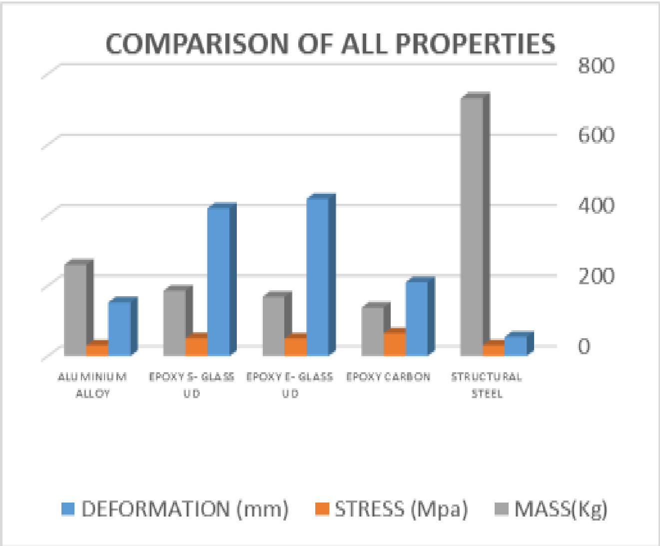

Figure 22. Comparison of All Materials

Figure 22 shows that the best material among all five materials is the Epoxy carbon. Now the best material is used to make the optimization and find the optimum dimensions that can take more load and low mass.

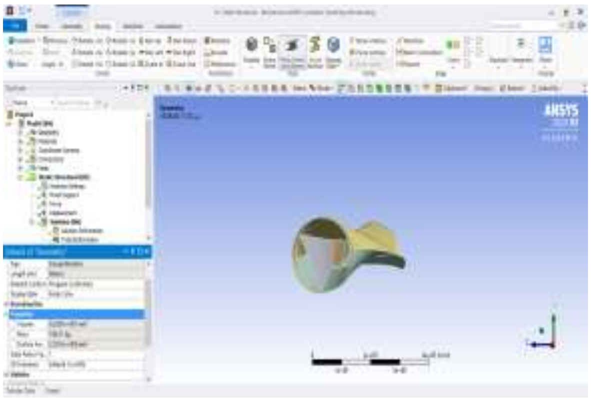

Figure 23. S-Glass Mass

The mass for S glass material 186 Kg as shown in Figure 23, also the blade support will be used in ANSYS as objective and constrain from 0.25 mm to 0.5 mm.

F. Optimization Method

When we finished the analyses for all materials that used in wind blade turbine, it has been found that the best material is the Epoxy carbon due to low deformation and low mass. The constraints are the thickness as shown in Figure 24, and the objective is to minimize the mass and deformation for wind blade design as shown in Figure 25.

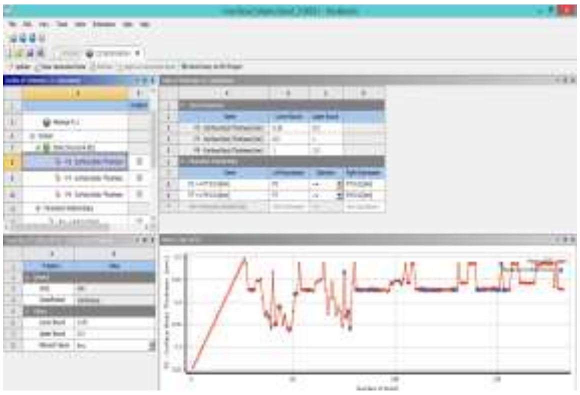

Figure 24 constraints

Figure 25. The objective of the optimization

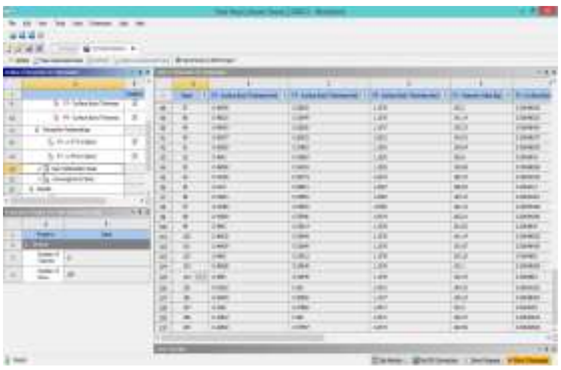

Figure 26. Raw Data

There are three constraints used in the optimization method, the first one is the surface body thickness from 0.25 mm to 0.5 mm, the second constrain is the thickness of the body of wind blade turbine to be from 0.5 mm to 1 mm, and the last constrain is the blade root to be from 1 mm to 1.5 mm. Figure 26 shows the ANSYS raw data optimizations method which shows 110 answers for different dimensions and thickness.

Figure 27. Best Result for Mass

The optimization process leads to three values of mass according to the objective and constrain, 195Kg, 193Kg and 192Kg as shown in Figure 27. The best answer that is recommended is 192 Kg.

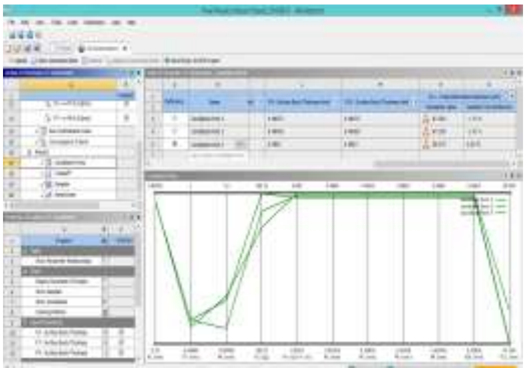

Figure 28. Best Result for Deformation

On the other hand, the optimization process shows that the optimum deformation of 87.383 mm and surface body thickness of 0.48mm as shown in Figure 28. There is saving mass of 1.79% of original E poxy carbon material.

CONCLUSION

In this paper, the mechanical behavior of a composite wind plant edge with different materials was studied. Under the same load conditions, correlations amongst different composite materials are produced. ANSYS is used to calculate stress, deformations, and bending. The results demonstrate that Epoxy carbon and primary metal have the least value in terms of strain and deformity, but once a mass event occurs, the resulting steel has a wide range of properties. As a result, it's reasonable to conclude that epoxy carbon is the best suited to make turbine cutting edges.

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