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Design and Analysis of Wind Turbine Blades using Carbon Nano Tubes Reinforced Polymer

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Abstract - *Several synthetic polymer composites are used for wind turbine blade fabrication glass, Kevlar, and carbon-reinforced matrix are commonly used. Combining Kevlar with epoxy matrix creates a composite that is durable, light, and dimensionally stable Dielectric strength of Kevlar improves epoxy lightning damage resistance. Composite materials can provide higher stiffness in many cases and reduce the weight of finished parts. These materials may require unique manufacturing techniques to meet design requirements. Thermosetting and thermoplastics polymers can be used for such techniques and carbon-reinforced matrixes are commonly used. Combining Kevlar with epoxy matrix creates a composite that is durable, light, and dimensionally stable. Dielectric strength Synthetic materials using epoxy resin and woven Kevlar fibre nanocomposites were fabricated in the presence of functionalized multi-walled carbon nanotubes (F-MWCNTs). It is important to estimate the deflection of the versatile composite turbine blades to forestall the blades from breakage. This paper investigates the effect of F-MWCNTs on mechanics and deflection of reinforced epoxy composites. Substantial improvement on the deflections was determined based on finite element analysis (FEA) using ANSYS software. The results showed that the addition of F-MWCNTs to epoxy and Kevlar has a significant effect. ANSYS analysis results showed lower deflection on the blade using epoxy with an additional of 0.50wt% of MWCNTs-COOH, when compared to the deflection made with the addition of 1.0wt% of MWCNTs-COOH.*

Key Words: F-MWCNTS, FEA, Ansys, Kevlar, polymer, composite, WES, Wind Turbine Blade, NREL

1.INTRODUCTION

Wind energy is a type of solar energy which is abundantly available. But the conversion of wind energy into electrical energy has significant losses in it. The current wind turbine blades is made up of Alloys [1]. Due to the weight the efficiency reduces. The weight of the blade is one of the reason why the efficiency is not 100%. This problem can be overcome by using material made of nanocomposites [2]. The authors found that the material made of nanocomposite has higher tensile strength compared to the Alloys, the weight is also significantly reduced and the efficiency can be increased further. The CNTS compared to that of nanocomposites have higher strength and can be easily reinforced with other matrix [8]. The authors cited that the strength produced by the CNT reinforced polymer is very high compared to that of nanocomposites. Carbon nano-tubes reinforced epoxy-Kevlar polymer is the material used as the blade material. Due to the higher strength incorporated by the carbon nanotubes is the basic reason it is used as a reinforcing material**.**

2. LITERATURE REVIEW

The literature review is based on the finding Turbine blades deformation with Carbon nanotubes reinforced polymer. Therefore, the pile of research are done about the current turbine blade materials, properties of carbon nanotubes reinforced polymers, designing the blades, analysing the blades made of CNT reinforced polymer using Ansys and finding the max deflection of the blades , frequency of the deformation and comparing the value with previous outcomes. In this context, categorized review has been presented with the help of a number of national and international journals. To fulfil the desired objective, possible outcomes of the literature review are summarized below.

The modal analysis of the current turbine blades (Aluminium Alloy) blades is considered and the frequencies at which the deflections start to occur is taken into consideration and the values are that is mentioned is used to compare the values with the F-CNTS.Table 1

Table 1: Modal values of aluminium alloys turbine blades

TYPES	DEFORMATION (mm)	FREQUENCY (Hz)
1st edgewise	191.85	62.23
2nd edgewise	260.85	221.34
1st flap wise	311.76	293.07
torsion	428.76	586.44
2nd flap wise	259.76	793.97
3rd flap wise	481.05	1170

2.1 PROPERTIES OF CARBON NANOTUBES REINFORCED EPOXY POLYMER KEVLAR-49

The properties for the carbon nanotubes reinforced epoxy polymer where the values of both the 0.5wt% of CNTS and 1.0wt% of CNTS is taken and shown in the above graph fig1 fig2.

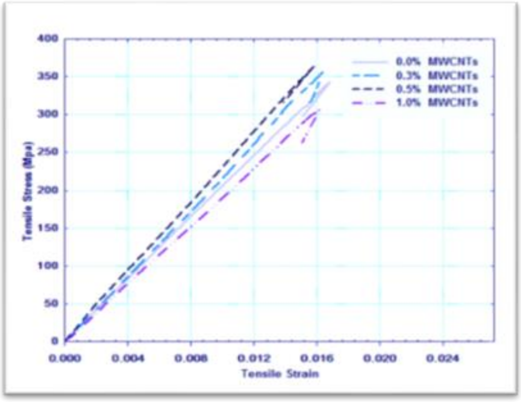

Fig 1: Tensile stress and strain for different value of F-MWCNTS

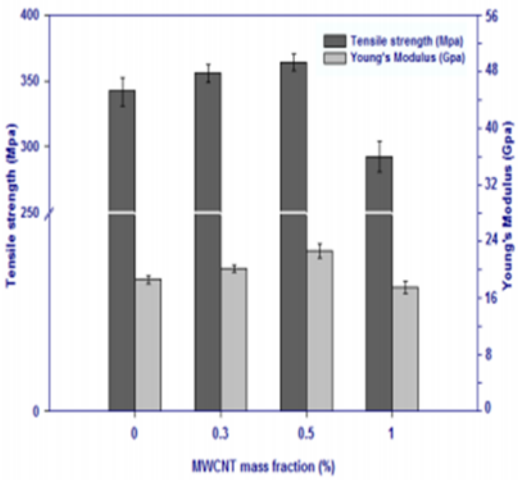

Fig 2: Young's modulus value for different value of F-MWCNTS

2.2 ANALYSIS OF THE TURBINE BLADES

As an outcome of the exhaustive review of available literature in the field of turbine blades made from different materials such as nickel based super alloys, epoxy-glass based and carbon fibre reinforced material the following major findings are obtained:

1. With the increases in turbine size the labour and maintenance cost increase gradually. The wind farm turbine cost are minimised by limiting the strength of blade materials and requirements. In the optimal wind speed ratio during energetic gust of wind allows the wind turbine to improve energy capture.
2. Tensile stress, compressive stress and shear stress are almost constant with respect to the direction of flow of wind.
3. In relation with the direction of wind flow the following values such as Tensile strain, compressive strain and shear strain are almost constant.
4. Maximum equivalent stress increases with increase of twist angle.
5. The mechanical properties of nickel base super alloy improved by increasing solidification rate so increase the ultimate strength, yield strength and hardness by decreasing thickness of the produced shapes.

2.3 PROBLEM STATEMENT

In the context of detailed and valuable literature review, the problem statement for the present research was devised. Due to the use of Nickel based super alloys there is a major problem such as cavitation occurs in the blade which leads to formation of rust on it. Due to the formation of rust the blades will fail. And Replacement of the blades cost high. Due to decreasing the thickness the stress carrying capacity of the blades get reduced which leads to failure of blades at very tough climates such as during storms. Due to usage of Glass reinforced epoxy polymer the blades are needed to be designed in a particular way that withstands those stresses, but the manufacturing of the blades needs a special process. The weight of the blades is also very high which need very high wind speeds to rotate; this leads to decrease in efficiency.

3. DESIGN AND ANALYSIS OF WIND TURBINE BLADES

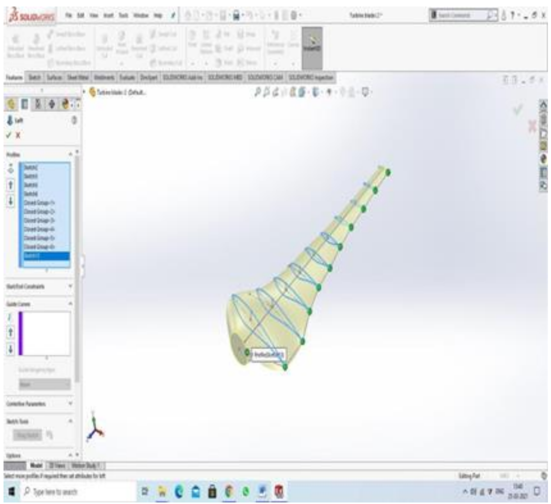

Fig 3: Loft design

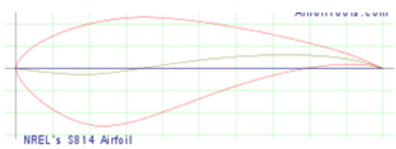

Fig 4: NREL S 814 –ROOT REGION AIRFOIL

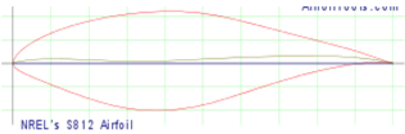

Fig 5: NREL S 812-Intermediate region airfoil

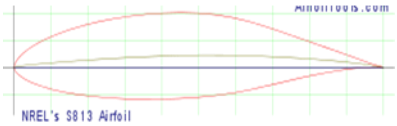

Fig 6: NREL S 813 – TIP REGION AIRFOIL

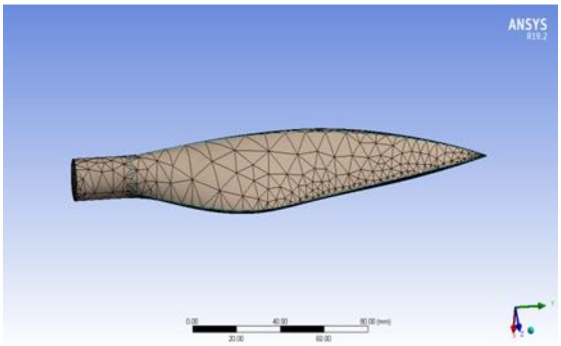

Fig 7: Meshing of turbine blade

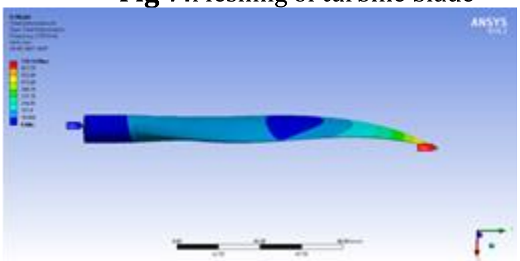

Fig 8: First Edge Wise

Analysis of 1.0wt% of MWCNTs

Density - 1.7e-009 tonne mm^-3

Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
17000	0.4	28333	6071.4

Table 1: Data values of 1.0wt% of MWCNTs

Mode	Freq [Hz]
1	285.84
2	346.62
3	1192.4
4	2049.8
5	2644.5
6	2787.8

Table 2: values of mode and the respective freq

Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
23000	0.4	38333	8214.3

Table 3: Data values of 0.5 wt% of MWCNTs

Mode	Freq[Hz]
1	332.48
2	403.18
3	1387.0
4	2384.3
5	3076.
6	3242.7

Table 4: Values Of Mode And Freq

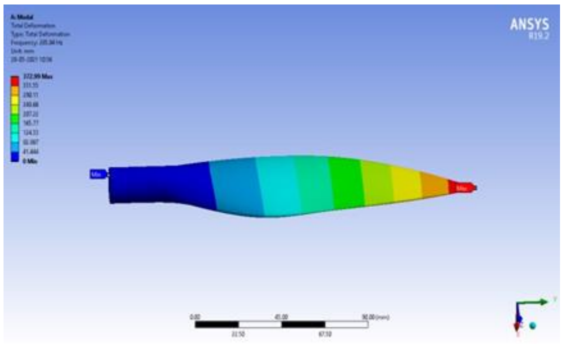

Fig 9: second edge wise

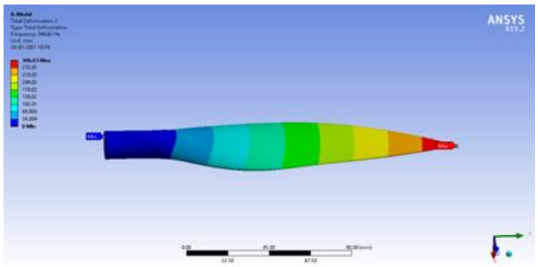

Fig 10: First flap wise

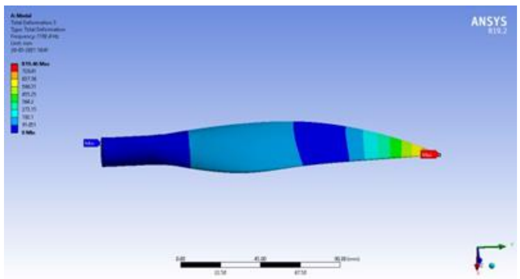

Fig 11: Torsion

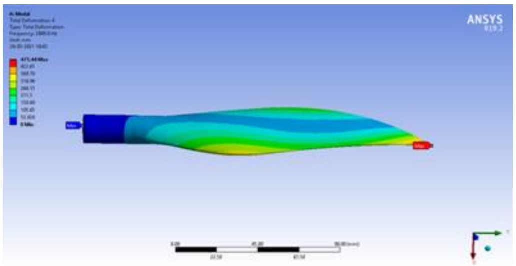

Fig 12: Second Flap Wise

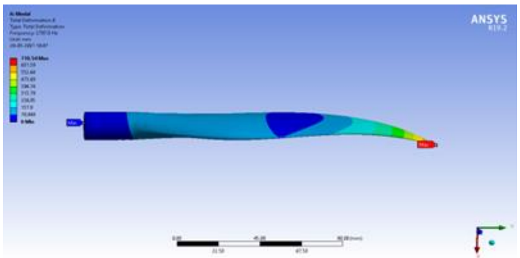

Fig 13: Third Flap Wise

4. RESULTS AND DISCUSSION

The experiment is performed in the ANSYS software and the results are noted down. The main motive of the experiment is to find the modal analysis of the turbine blades for different percentages of carbon nanotubes (0.5%, 1.0%) which helps us to find the deformation occurring at different frequencies. In this chapter all the values are shown in graph fig14 and the values are also explained.

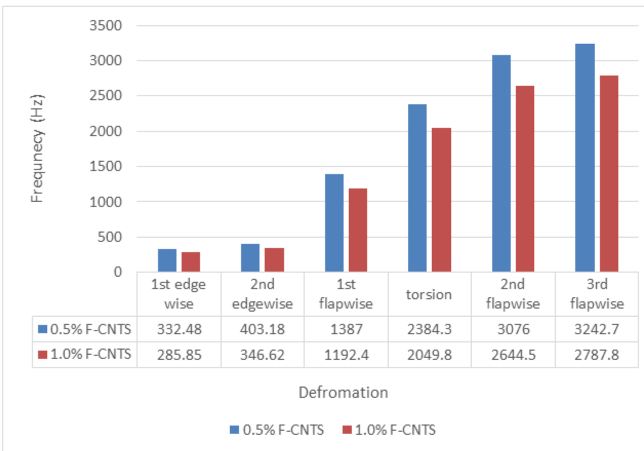

Fig 14: Graph showing the Frequency at various locations in the two compositions

The max deformation values at which the material starts to failure is taken into consideration and deformation values of the F-CNTs and the aluminium alloys are taken and the values are compared together. The deformation values of both the F-CNTS start the same point so the only 1.0wt% of F-CNTS is taken and depicted in the graph below fig15

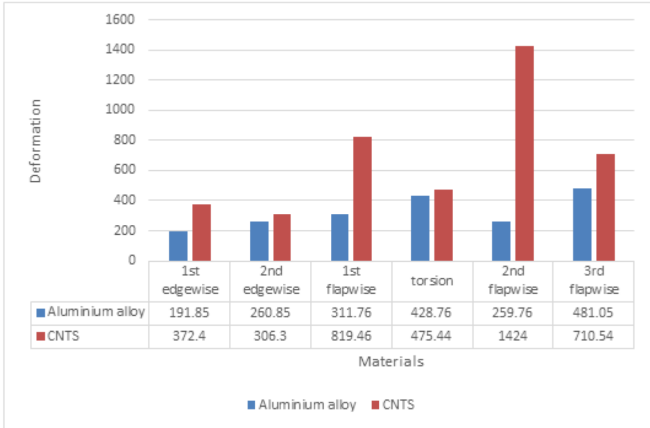

Fig 15: Graph showing the deformation at various locations in the two compositions

From the above graphs and analysis the result is depicted that the F-CNTS have higher Stiffness than the aluminium alloys. The blade which is made of (0.5%wt) of F-CNTS have higher stiffness and higher strength compared to that of (1.0%wt) of F-CNTs.

The torsional strength for the carbon nanotubes is three times higher than that the torsional value of the Aluminium alloys. Due to the higher rate of frequency occurring at the F-CNTS the blade failure due to the resonance is minimized. Due to the use of F-CNTS in Blade the possibilities of fatigue hotspots occurring in the blade edge is minimized. Since the density of the CNTS compared to the aluminium alloys is less the density of the blade is reduced to a great extent.

Since the density of the blade is reduced the torque required to turn the blade is reduced so that the efficiency is increased.

5. CONCLUSION

This comparative study has been made between 0.5% F-CNTS and 1.0 % F-CNTS for the maximum deformation and frequencies at which the deformation occurs are done by modal analysis using ANSYS. It is clear that if we use the blades made up of carbon nanotubes reinforced material it is clear that the flip wise, edge wise and torsional stiffness of the blade is increase. The resonance is also reduced which leads to increase in life of the blades .Even the cost of production of carbon nanotubes is high , in distant future it is evident that the cost of operation will get reduced and due to this material will be feasible and the much more energy can be produced efficiently.

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