International Journal of Research in Engineering, Science and Management
Volume-2, Issue-1, January-2019
www.ijresm.com | ISSN (Online): 2581-5792

Design and Analysis of Wind Turbine Blades by using Different UV Foam Alignments

Puram Rajendra[1], M. Adinarayana[2]
[1]PG Student, Dept. of Mechanical Engg., Sir Vishveshwaraiah Inst. of Science and Tech., Madanapalle, India
[2]Assoc. Prof., Dept. of Mechanical Engg., Sir Vishveshwaraiah Inst. of Science and Tech., Madanapalle, India

***Abstract*: The earth is polluted due to high degrees of depletion for various purposes. As a result; there is a deficiency in electricity. So, it is necessity to produce electricity using other energy resources like green energy and alternative energy. Human needs can be satisfied by technology usage but it should not affect the environment. So, wind energy become most important and main resources in producing clean energy for generation of electricity. As the earth revolves and Coriolis force is developed, the northern hemisphere wind move in anticlockwise and southern hemisphere move in clockwise direction and this effect is formed.**

***Keywords*: Wind Turbine Blades, UV Foam**

1. Introduction

In the present generation, there is a most demand and importance for electricity. The earth is polluted due to high degrees of depletion for various purposes.as a result; there is a deficiency in electricity. So, it is necessity to produce electricity using other energy resources like green energy and alternative energy. Human needs can be satisfied by technology usage but it should not affect the environment. So, wind energy become most important and main resources in producing clean energy for generation of electricity.

2. Literature survey

In wind turbines, the turbine blades play an important role as it directly comes in contact with the wind. The shape of wind turbine blade are deigned to generate the maximum power from the wind at minimum cost. The turbine blades are designed for longer life as they subjected to high fatigue loads. Tenguria [1], has used BEM theory to optimize the lift , drag, coefficient of power characteristics with various tip speed ratio, lift and drag coefficients. In this work, to observe that the power coefficient 0.46 and lift to drag coefficient is 124.47, the absorption of power is maximum.

John Mc Croker [2], has developed optimized code for a discrete 9 element wind turbine blade having a length of 0.95m. in his work obtained optimal speed ratio, angle of wind, the pitch angle and relative chord length for each element. The airfoil shape is changed from NACA 4412 to NACA 23012, to find the where the angle of attack is maximum glide ratio for each profile. Anjali et al [3], in her work cost generation of wind power is critical and it can be possible by using suitable design changes and composite materials by using ant colony optimization method by varying the composite material of the blade by conducting stress analysis. Finally in her work, ultimately obtained the optimized value of chord length and blade twist angle and it found that kevler 149 material has the highest natural frequency and less deflection compared to others. Thumthae and Chrisomboom [4] are investigated on untwisted blade for optimal pitch to get maximum power by using stead flow wind conditions. Research also performed by using generic algorithm to obtain maximum chord and twist angle. Ingram [5] derived an equations related to the Blade Element Theory, to find the axial force, lift and drag characteristics, by considering tip loss correction to calculate the rotor performance. By using iterative procedure to find the suitable results. Gursel et al [6] has studied the vibrational characteristics of rotor blades by using approximation method such as Rayleigh method to calculate the natural frequencies of each blade. It can be validated by using vibrational analysis of wind turbine blade by using Finite Element Analysis.

Larsen et al [7] has shown experiment on LM 19m to investigate the mode shapes, dominating deflections and error measurement by comparing with the computed theoretically values and experimental values. It is observed that for non-dominating deflection direction, the measured and computed mode shapes are found to be in good agreement. A forced vibration damper is used in the experimental set up to check damping characteristics of the blade. Liu et al [8] has performed experiments on 5MW S809 airfoil, to find the model and harmonic analysis in order to obtain natural frequencies along with harmonic responses in different phases. Allikas et al [9] has performed experiments on full scale single layer lay up small horizontal axis wind turbine by using bending test and model analysis. The wind blade can be made by using Glass Fiber Reinforced Composite Plastics. Damaging the blade due to obtained stress is greater than the yield strength of the element of the blade. Sami et al [10] has performed experiments on 5 KW GFRP wind turbine blade by using 3D shell elements to find the fundamental flap wise and edge wise modal frequency and also to understand better dynamic behavior he conducted experiments by using electro dynamic shaker to find the resonant frequencies. Finally, he concludes that edgewise frequency has more errors than 0 flap wise frequencies.

Fangfang song [11], has worked on optimization of of the blade, having NACA 63415 profile and then model of blade by using Solid works software. Then the finite element analysis of the model is performed to find out the modal analysis of the blade. The excited frequency from wind speed of 10m/s is calculated as 7.16 Hz which is found to be more efficient than the fundamental frequency obtained from the modal analysis. Therefore, no resonance will occur when the blades run at rated wind speed.

3. Profile development

Wind turbine blades are designed by using a combination of two dimensional airfoil tools and the Blade Element Momentum (BEM) theory. BEM theory gives the twist angle and length of the chord for a particular cross section of the airfoil and rotation speed at a finite number of positions along the blade span.Three dimensional sections can be designed from these two dimensional sections. The BEM theory assumes as a given airfoil cross sections as independent, then possesses the wind with a speed and direction that out from vector sum of the incoming wind speed and rotor rotation.

A. Wind power

The amount of wind energy can be obtained from swept area of turbine wind can be found from its kinetic energy and power.

B. Lift and drag

Lift can be defined as the force is perpendicular to the direction of incoming air flow as a consequence of unequal pressure on the upper and lower airfoil surfaces. It can be shown in fig. 1 & 2. Drag can be defined as the force is parallel to the direction of incoming air flow due to viscous frictional forces and unequal pressure on the airfoil surfaces facing towards. It can be shown in fig.1.

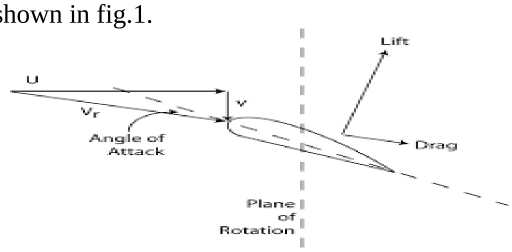

Fig. 1. Lift and drag of wind blade

C. NACA airfoils

The NACA airfoils are airfoil shapes for aircraft wings and wind turbine blades developed by the National Advisory Committee for Aeronautics (NACA). The shape of the NACA airfoils is described using a standard series of digits called the word "NACA." The parameters in the numerical code can be entered into equations to precisely generate the cross-section of the airfoil and also properties can be calculated. There are different types of airfoils are exists with different NACA series. Ex: NACA 63 series, NACA 62 series, NACA 60 series.

D. NACA 63415-series airfoil

The NACA 63 series is preferred as the basic group of investigation because they have good low speed characteristics with a minimum to maximum high speed characteristics. NACA 63 is suitable for low speed characteristics because, its

Power curve is better than the low and medium wind speed ranges, but drops under operation at wind speeds. The NACA 63415 airfoil is shown in fig. 3.

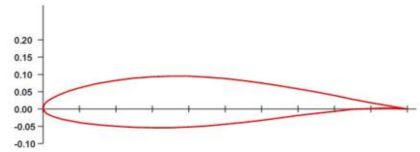

Fig. 2. NACA 63415 Series airfoil

The NACA 63 series airfoil profiles is most considered parameters that are to be considered for selecting the design lift coefficient and the maximum thickness in per cent of chord. The Blade Velocity diagram is shown in fig. 4. The NACA 63415 wind blade profile and Un Vinyl (UV) foams are developed from SOLID WORKS 13.0 Software Package. Fig. 11, 12, 13 & 14 shows the Wind Blade and UV foams.

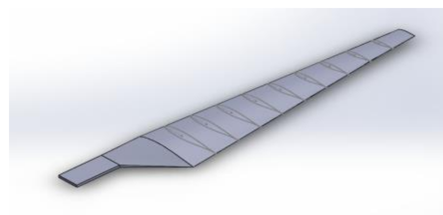

Fig. 3. Show the NACA 63415 Wind Turbine Blade

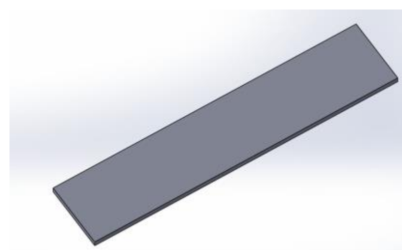

Fig. 4. Shows the Rectangular UV Foam

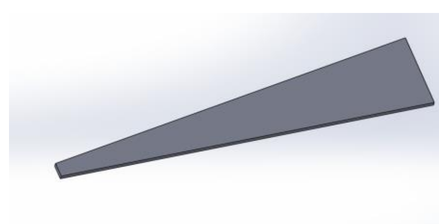

Fig. 5. Shows the Taper UV Foam

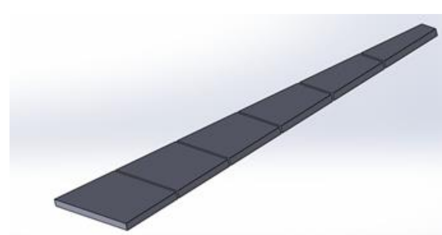

Fig. 6. Shows the Tear Drop UV Foam

4. Material properties of blade and UV foams

The properties of the materials which are essential at pre-processing stage during the analysis.

A. Static Structural analysis of SWT blades

The static structural analysis post processor is used to determine the Total Deformation and Vonmises Stress for wind blade developed by GFRP with Epoxy is used as resin and also UN Vinyl foams also developed. Fig. 7 and Fig. 8 shows the Total deformation and Vonmises stress of wind blade with GFRP with Epoxy with Rectangular UV Foam at pressure 0.006392 N/mm^2. Fig. 9 and Fig. 10 shows the Total deformation and Vonmises stress of wind blade with GFRP with Epoxy with Taper UV Foam at pressure 0.006392 N/mm^2. Fig. 11 and Fig. 12 shows the Total deformation and Vonmises stress of wind blade with GFRP with Epoxy with Tear Drop UV Foam at pressure 0.006392 N/mm^2.

B. Model and harmonic analysis of SWT blades

Model analysis is used to determine the natural frequencies and mode shapes of continuous structure. The natural frequencies and mode shaped are very important parameters in the designing of dynamic load conditions. The mass, damping and stiffness matrix are constant with respect to time. The nodal displacement will vary with time. Continuous structure has infinite degrees of freedom. The finite element method gives the real structure with a finite number of degrees of freedom. In model analysis, at one of its natural frequencies, the shape of the vibration will be scalar multiple of mode shapes. Natural frequencies and mode shapes are starting point for harmonic analysis. It solves the time-dependent equations of motion for linear structures undergoing steady state vibration. It is used to predict the sustained dynamic behaviour of the structure, thus verifying whether or not structure will successfully overcome resonance, fatigue and other harmful effects of forced vibrations.

Fig. 13, 14, 15, 16, 17 and 18 shows the mode shapes of the wind blade with rectangular uv foam. Fig. 19 shows the von-mises stress of wind blade with rectangular uv foam. Fig. 20, 21, 22, 23, 24 and 25 shows the mode shapes of the wind blade with taper uv foam. Fig. 26. Shows the von-mises stress of wind blade with taper uv foam. Fig. 27, 28, 29, 30, 31 and 32 shows the mode shapes of the wind blade with tear drop uv foam. Fig. 33 shows the von-mises stress of wind blade with tear drop uv foam. Fig. 34, 35 and 36 shows the total deformation, von-mises stress and Frequency Response Function (FRF) of the wind blade with Rectangular uv foam. Fig. 35, 36, 37 show the total deformation, von- mises stress and Frequency Response Function (FRF) of the wind blade with Taper uv foam. Fig. 35, 36, 37 show the total deformation, von- mises stress and Frequency Response Function (FRF) of the wind blade with Taper uv foam.

C. Wind blade with rectangular unvinyl foam at 0.006392 n/mm^2

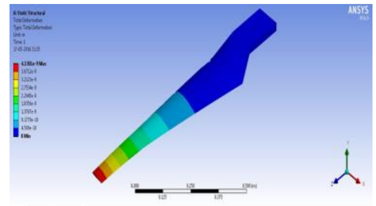

Fig. 7. Static analysis of wind blade with rectangular UV foam – total deformation

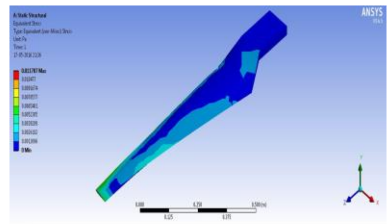

Fig. 8. Static analysis of wind blade with rectangular UV foam – vonmises stress

D. Wind blade with taper unvinyl foam at 0.006392 N/mm^2

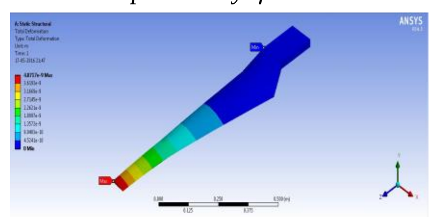

Fig. 9. Static analysis of wind blade with T taper UV foam – total deformation

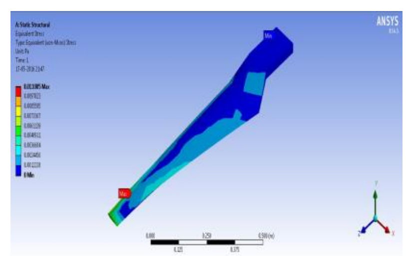

Fig. 10. Static analysis of wind blade with taper UV foam – V vonmises Stress

E. Wind blade with tear drop unvinyl foam at 0.006392 N/mm^2

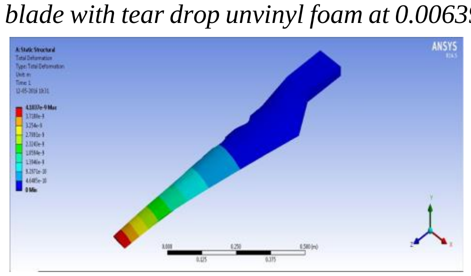

Fig. 11. Static analysis of wind blade with Tear Drop UV foam – Total Deformation

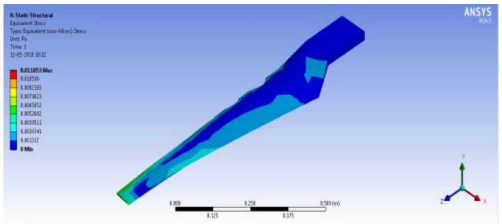

Fig. 12. Static analysis of wind blade with Tear Drop UV foam – Vonmises Stress

F. Wind blade with rectangular unvinyl foam at 0.006392 N/mm^2

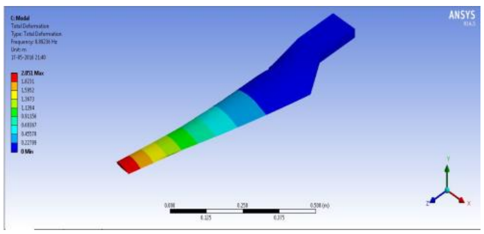

Fig. 13. Modal analysis of wind blade with rectangular UV foam – Total Deformation-mode1

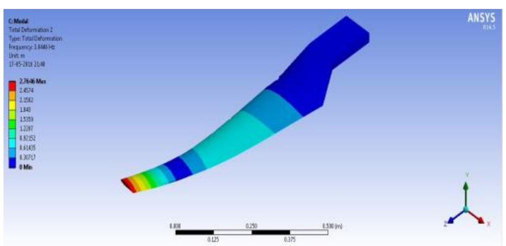

Fig. 14. Modal analysis of wind blade with rectangular UV foam – Total Deformation-mode2

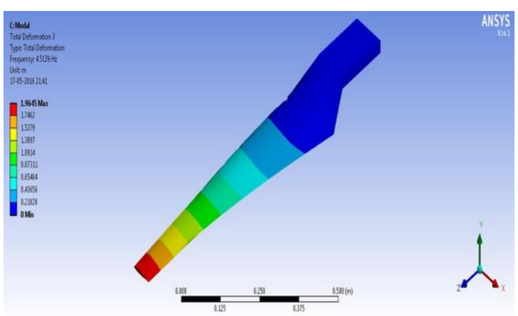

Fig. 15. Modal analysis of wind blade with rectangular UV foam – Total Deformation-mode3

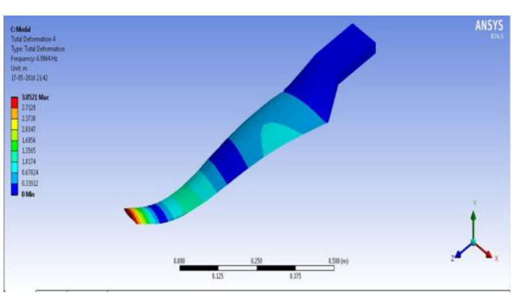

Fig. 16. Modal analysis of wind blade with rectangular UV foam – Total Deformation-mode4

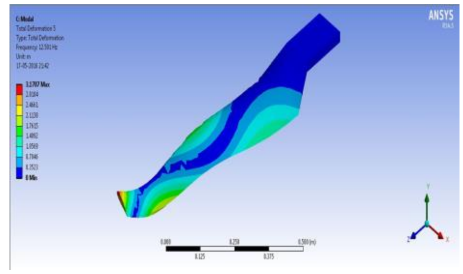

Fig. 17. Modal analysis of wind blade with rectangular UV foam – Total Deformation-mode5

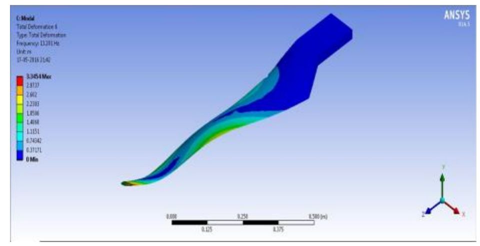

Fig. 18. Modal analysis of wind blade with rectangular UV foam – Total Deformation-mode 6

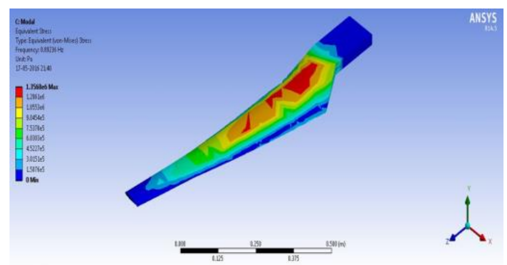

Fig. 19. Modal analysis of wind blade with rectangular UV foam – Vonmises Stress.

G. Wind blade with taper unvinyl foam at 0.006392 N/mm^2

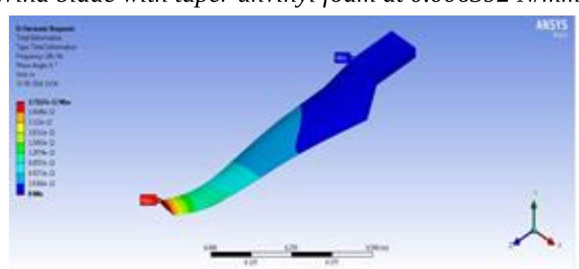

Fig. 20. Modal analysis of wind blade with Taper UV foam – Total Deformation-mode1

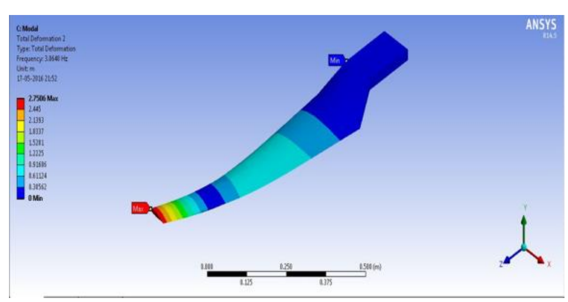

Fig. 21. Modal analysis of wind blade with Taper UV foam – Total Deformation-mode 2

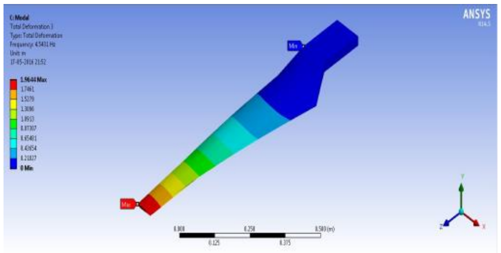

Fig. 22. Modal analysis of wind blade with Taper UV foam – Total Deformation-mode 3

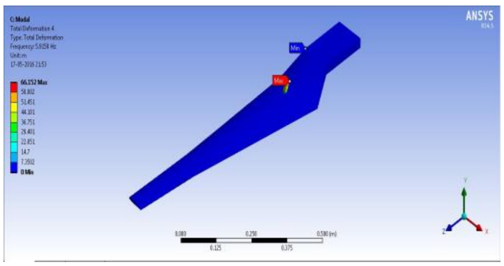

Fig. 23. Modal analysis of wind blade with Taper UV foam – Total Deformation-mode 4

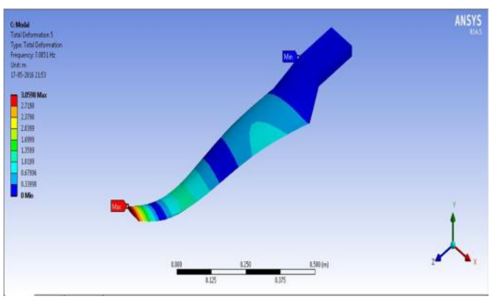

Fig. 24. Modal analysis of wind blade with Taper UV foam – Total Deformation-mode 5

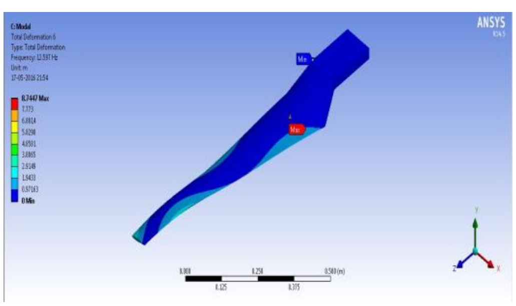

Fig. 25. Modal analysis of wind blade with Taper UV foam – Total Deformation-mode 6

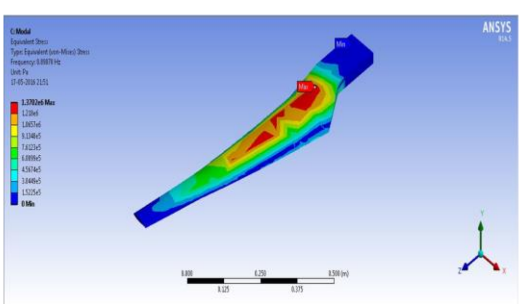

Fig. 26. Modal analysis of wind blade with Taper UV foam – Von mises Stress.

H. Wind blade with tear drop unvinyl foam at 0.006392 N/mm²

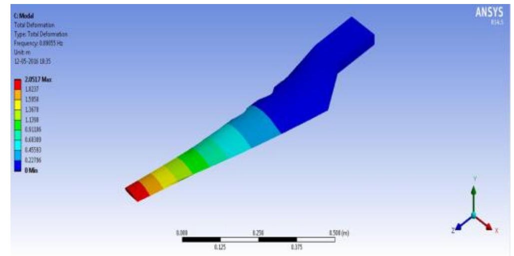

Fig. 27. Modal analysis of wind blade with Tear Drop UV foam – Total Deformation-mode1

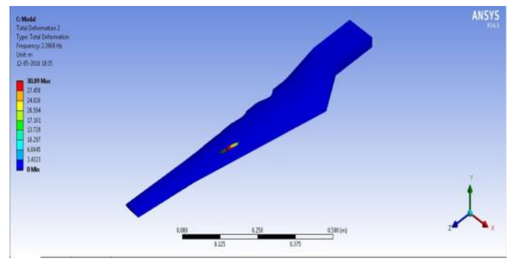

Fig. 28. Modal analysis of wind blade with Tear Drop UV foam –Total Deformation-mode 2

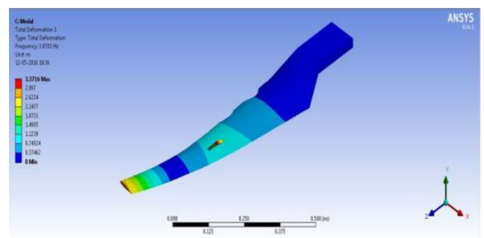

Fig. 29. Modal analysis of wind blade with Tear Drop UV foam – Total Deformation-mode 3

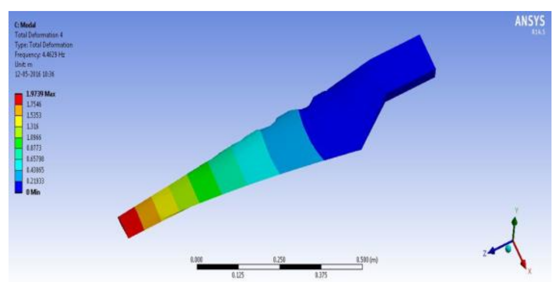

Fig. 30. Modal analysis of wind blade with Tear Drop UV foam – Total Deformation-mode 4

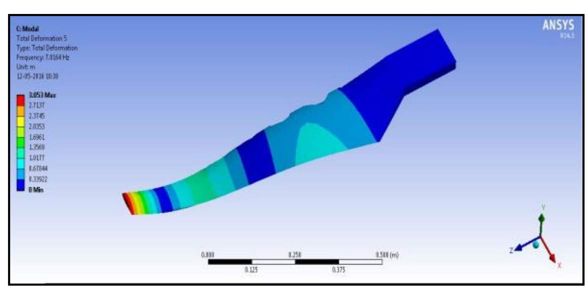

Fig. 31. Modal analysis of wind blade with Tear Drop UV foam – Total Deformation-mode 5

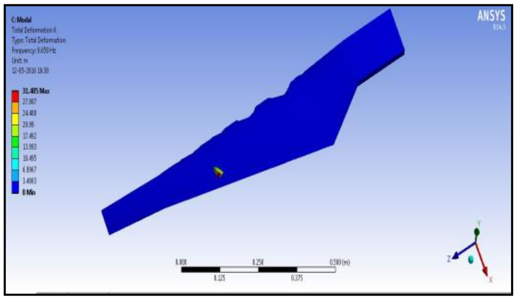

Fig. 32. Modal analysis of wind blade with Tear Drop UV foam – Total Deformation-mode7

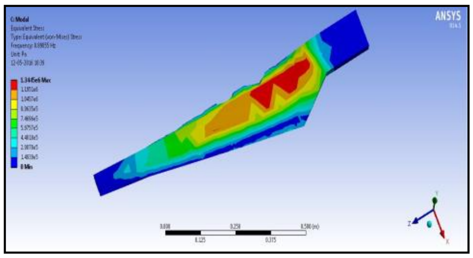

Fig. 33. Modal analysis of wind blade with Tear Drop UV foam – Von mises Stress.

I. Wind blade with rectangular unvinyl foam at 0.006392 N/mm²

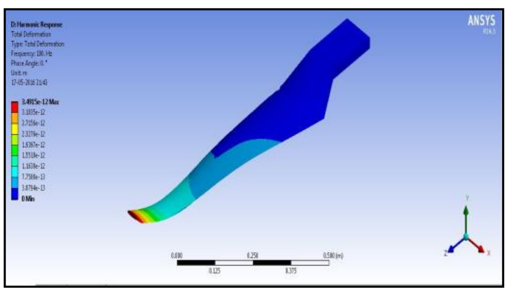

Fig. 34. Harmonoic response of wind blade with Rectangular UV foam – Total Deformation

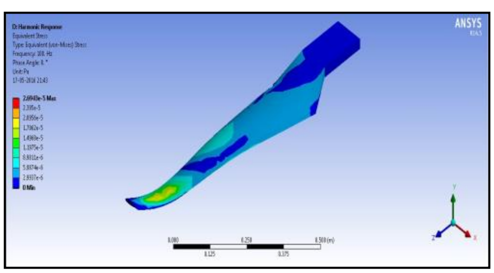

Fig. 35. Harmonic response of wind blade with Rectangular UV foam – Von mises Stress.

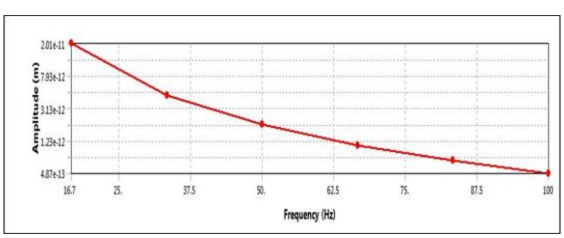

Fig. 36. Harmonic response of wind blade with Rectangular UV foam – Frequency Response function

J. Wind blade with taper unvinyl foam at 0.006392 N/mm²

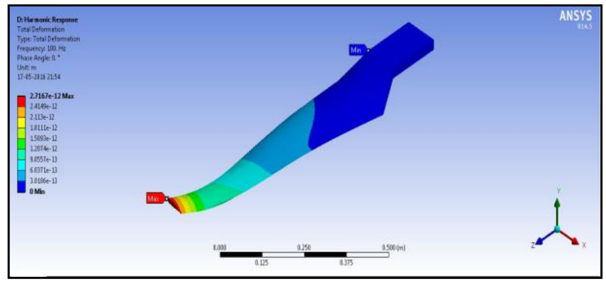

Fig. 37. Harmonic response of wind blade with Taper UV foam – Total Deformation

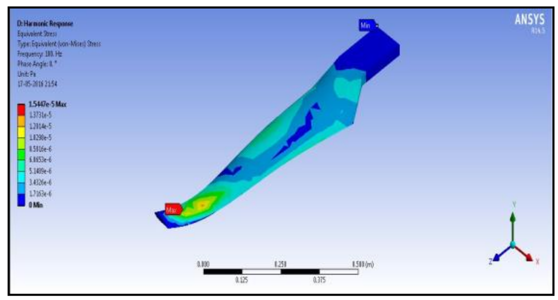

Fig. 38. Harmonic response of wind blade with Taper UV foam – Von mises Stress.

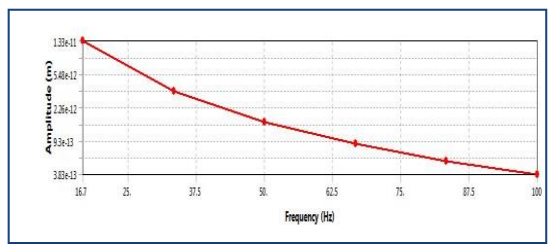

Fig. 39. Harmonic response of wind blade with Taper UV foam – Frequency Response function.

K. Wind blade with tear drop unvinyl foam at 0.006392 N/mm²

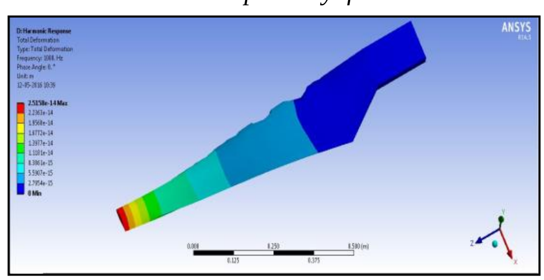

Fig. 40. Harmonic response of wind blade with Tear Drop UV foam – Total Deformation

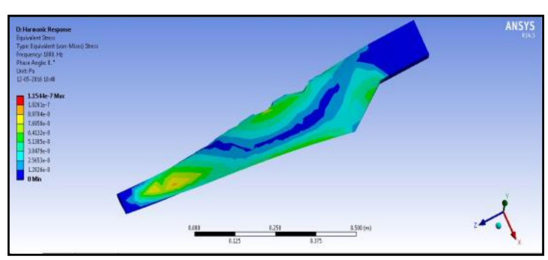

Fig. 41. Harmonic response of wind blade with Tear Drop UV foam – Von mises Stress.

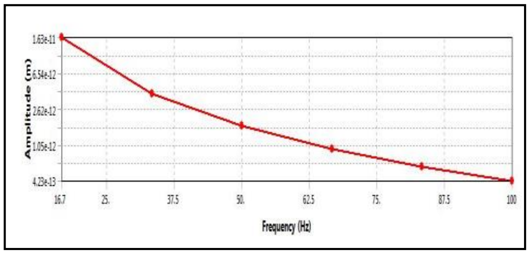

Fig. 42. Harmonic response of wind blade with Tear Drop UV foam – frequency Response Function

5. Results and discussions

In the present research work an attempt is made to investigate the performance of small wind turbine blades. The small wind turbine blades are produced with GFRP with epoxy resin with three different uv foams,

- Rectangular uv foam,
- Taper uv foam,
- Teardrop uv foam.

Finite element analysis was carried out to test the performance of SWT blade models by static structural analysis, modal and harmonic analysis on finite element software like ANSYS 14.5 Software.

The following conclusions are made from present work:

- In static structural analysis, wind bade + tear drop uv foam gives the maximum total deformation and von mises stress.
- In modal analysis, wind blade+ rectangular uv foam gives the maximum frequency at 6th mode.
- In harmonic analysis, at wind blade + tear drop uv foam shows the critical sections across the blade at which the maximum amplitudes of vibrations are taking place.

A. Discussions

This project work is presenting an overview of blade materials, blade design and testing methods.With more knowledge evolving, the blade design will be made more accurately and safety factors may be reduced. However, safety factors should only be reduced if quality control and damage assessment methods are improved. The reduction of safety factors could lead to an increasing amount of damage evolution in wind turbine blades in service.

6. Conclusion

For reasons of efficiency, control, noise and aesthetics the modern wind turbine market is dominated by the horizontally mounted three blade design, with the use of yaw and pitch, for its ability to survive and operate under varying wind conditions. An international supply chain has evolved around this design, which is now the industry leader and will remain so for the immediate foreseeable future. During the evolution of this design many alternatives have been explored and have eventually declined in popularity. Manufacturers seeking greater cost efficiency have exploited the ability to scale the design, with the latest models reaching 164 m in diameter. The scale of investment in creating alternative designs of comparative size now ensures that new challengers to the current configuration are unlikely.

A comprehensive look at blade design has shown that an efficient blade shape is defined by aerodynamic calculations based on chosen parameters and the performance of the selected aerofoils. Aesthetics plays only a minor role. The optimum efficient shape is complex consisting of aerofoil sections of increasing width, thickness and twist angle towards the hub. This general shape is constrained by physical laws and is unlikely to change. However, aerofoil lift and drag performance will determine exact angles of twist and chord lengths for optimum aerodynamic performance. A basic load analysis reveals that the blade can be modelled as a simple beam with a built in support at the hub end. A uniformly distributed load can be used to represent aerodynamic lift during operation. The increasing bending moment towards the support indicate that structural requirements will also determine blade shape especially in areas around the hub which require increased thickness. Currently manufacturers are seeking greater cost effectiveness through increased turbine size rather than minor increases through improved blade efficiency. This is likely to change as larger models become problematic through construction, transport and assembly issues. Therefore, it is likely that the general shape will remain fixed and will increase in size until a plateau is reached. Minor changes to blade shape may then occur as manufacturers incorporate new aerofoils, tip designs and structural materials. A conflict of increased aerodynamic performance in slender aerofoils versus structural performance of thicker aerofoils is also evident

A. Future scope

From a knowledge point of view, it is envisioned that the future developments is towards a better understanding of the damage evolution at a smaller length scales, leading to a better, more complete and more fundamental understanding of the damage evolution in composite structures. This opens the possibility for the development of larger and better, more damage tolerant materials.The cost savings come mainly from the fact that the vast majority of the blades are not expected to develop signify cant damages; with the use of SHM, these blades would not require any manual inspection.

References

[1] Nitin Tenguria, N.D. Mittal, Siraj Ahmed, “Aerodynamic Design of a HAWT Blade for Indian Wind Condition”, International Journal of Advances in Engineering, Science & Technology (IJAEST), Vol. 1 No.7, September – November 21, pp. 37-4011.

[2] John McCosker, “Design and optimization of a small wind turbine”, Rensselaer Polytechnic Institute, Hartford, Connecticut, December 2012, pp. 1-56.

[3] M. Anjali, C. Tara Sasanka, Ch. Deva Raj, K. Ravindra, “Meta Heuristic Method for the Design Optimization of a Wind Turbine Blade”, International Journal of Current Engineering and Technology, Special Issue -3, April 2014, pp. 175-179.

[4] Chalothorn Thumthae, and Tawit Chitsomboon, “Optimal Pitch for untwisted blade horizontal axis wind turbine”, 2nd Joint International Conference on “Sustainable energy and environment SEE, November 2006, pp. 1-6.

[5] Grant Ingram, "Wind Turbine Blade Analysis using the Blade Element Momentum Method Version 1.1", October 18, 2011, pp. 1-21.
[6] K. Turgut Gursel, Tufan Coban, Aydogan Ozdamar, "Vibration Analysis of rotor blades of a farm wind power plant", Mathematical and Computational applications, Vol. 17, No. 2, 2012, pp. 164-175.
[7] Gunner C. Larsen, Morten H. Hansen, Andreas Baumgart, Ingemar Carlen, "Modal Analysis of Wind Turbine Blades", Rise National Laboratory, Roskilde, Denmark February 2002, pp. 1-72.
[8] Chao Liu, Dongxiang Jiang and Jie Chen, "Vibration Characteristics on a Wind Turbine Rotor using Modal and Harmonic Analysis of FEM", IEEE 2010, pp. 1-5.
[9] O Pabut, G Allikas, H Herranen, R Talalaev, K Vene, "Model Validation and structural analysis of a small wind turbine blade", 8th International DAAAM Baltic Conference, Industrial Engineering, 19-21 April 2012, pp. 1-10.
[10] Saad Sami, Behzad Ahmed Zai, M. Amir Khan,"Dynamic Analysis of a 5KW Wind Turbine Blade with experimental Validation", Journal of Space Technology, Vol. 4, No-1, July 2014, pp. 82-87.
[11] Fangfang Song, Yihua Ni, Zhiqiag Tan, "Optimization Design, Modelling and Dynamic Analysis for Composite Wind Turbine Blade", International Workshop of Automobile, Power and Energy Engineering, Procedia Engineering, 16 (2011) 369-375.
[12] Model Validation And Structural Analysis Of A Small Wind Turbine blade Structural design and analysis of a 10 MW wind turbine blade Kevin Cox, PhD Candidate, Dept. of Engineering Design and Materials NTNU
[13] Federico Ghedin, Structural Design of a 5 MW Wind Turbine Blade Equipped with Boundary Layer Suction Technology Analysis and lay-up optimization applying a promising technology.