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Structural analysis of novel micro wind turbine

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ABSTRACT

The objective of this investigation is to search out the novel geometry of blade and performance is examined by using the structural analysis. During this paper, an effort is to check the point and Uniformly Distributed Load (UDL) apply on the trapezoidal and micro shape blade model of a micro wind turbine blade at various segments such as at the tip and overall length of the blade. This study is to find a better indulgent of structural behavior in the blades for the different swept area. On the basis of these results, the prototype will be created for experimental testing and more power achievement.

Keywords— *Wind energy, Novel blade profiles, Modeling, Loads investigation, Structural analysis*

1. INTRODUCTION

Nowadays the problem of the energy crisis, carbon emission and global warming has grabbed all the attention of the scientist and technologist. In the specialist meeting of green and renewable energy technologies for rural development, organized by the United Nation (UN) several promising answers were described for offering electricity [2]. At the early stage of wind turbine development, small project with 50KW capacity was developed. The present status of development of wind power set has achieved the target of approximate 2.7MW per wind turbine. Such a large power wind turbine generator system requires an infrastructure of well-distributed grid circuit along with adequate land in the area where required wind velocity is available. The wind available in nature is not uniform throughout the year this fact has imposed the limitation on the generation of electricity throughout the year. Moreover, the initial cost of such large capacity wind generation is very high. The time has come to develop a small capacity wind turbine, with minimum cost and high operating time over the period of the whole year. With this intention mini wind turbine have been developed and is utilized to generate electricity for lightening domestic bulbs and running home appliances. A present small wind turbine can be required inspection only every two years during their twenty to thirty-year design life. The put in the value of tiny alternative energy system is around Rs.125/Watt as compared to put in the value of PV that is Rs.250/Watt. The Indian business ought to try for an innovative and straightforward therefore on cut back the price of electricity generated by a small turbine as compared to small wind turbine suppliers.

2. MATERIALS AND METHOD

Wind energy is arrested via rotor blades rotation. In olden times rotor blades been made of wood, but due to its sensitivity to wetness and dealing out costs new materials such as Carbon Fiber Reinforced Plastic (CFRP), Glass Fiber Reinforced Plastic (GFRP), especially steel and aluminum are replacing the traditional wooden units. Aluminum turned into best carried out in checking out conditions because it was discovered to have a decrease fatigue level than metal. Aluminum is ductile and properly heat conductor. Aluminum is a low price metal however it has desirable reliability and has low tensile power. Aluminium is lightweight but weaker and much less stiff than metallic. So Aluminum sheet is chosen as blade fabric for evaluation statistics as follows, Density 2.7×10^{-6} $kgmm^{-3}$, Young's Modulus 71000 Mpa, Poisson's Ratio 0.33, Bulk Modulus 69608 Mpa and Shear Modulus -26692 Mpa.

2.1 Blade design

The primary objective in wind turbine design is to maximize the aerodynamic efficiency or energy extracted from the wind. So it's far clean that, an extended blade will choose the strength extraction. But, with growth in blade length, deflection of blade tip because of axial wind pressure additionally will increase. So, the blind boom in length of the blade may result in a risky state of affairs of the collision of blade and tower. Decide the diameter of the blade from the below equation.

$$P = Cp \times \left(\frac{1}{2}\right) \times \rho \times A \times V^3 \quad (1)$$

The wind turbine is designed for 40 to 60 Watt horizontal axis, layout technique of the 3-bladed rotor, to begin with, comes with the dedication of the rotor diameter and fabric. lift and drag force generate in the blade, drag is the pressure of wind pushing instantly downward however raise is the pressure which usually works at a right angle to the path of the wind. As shown in figure 1. A Horizontal Axis Wind Turbine (HAWT) blade in no way movements downwind that will get no assist from drag forces, as an alternative they use lift.

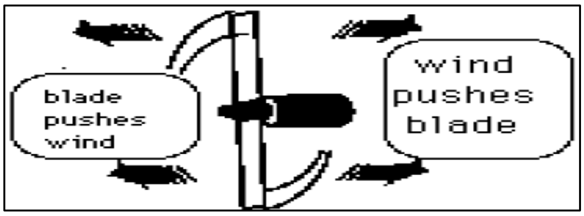

Fig. 1: Movement of blade

Straight, untapered and untwisted blades are designed on constant width and constant angle throughout length but in such types, there will be little loss of efficiency. Generally, taper and twist in the blade are used for better starting of rotations. For deciding the number of blades tip speed ratio as shown in figure 2**.** The variety of blades substantially impacts the HAWT overall performance. The maximum commonplace formats are two and three-blade machines, some small HAWTs may additionally have extra than 3 blades, and usually, they are low pace wind generators. Low-speed gadget operates with large torque. On the other hand, excessive speed wind generators have handiest 2 or 3 blades can, therefore, to attain similar wind power utilization with low using torque.

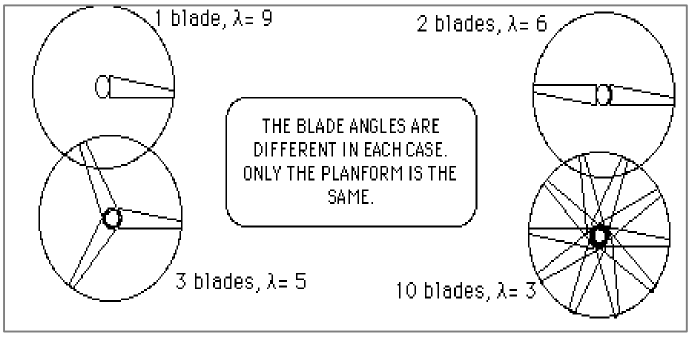

Fig. 2: Selection of numbers of the blade and tip speed ratio

2.2 Number of blades

The variety of blades in the wind turbine increases aerodynamic efficiency but in a diminishing way. Whilst moves from 2 blades to a few blades layout efficiency advantages is set 3%. But as when it actions from three blades to 4 blades design, efficiency benefit is marginal. As the boom in a variety of blades, the value of the device will increase significantly. Together with that mechanical layout of blades also turn out to be a difficult affair. With a greater range of blades, blades have to be thinner to be aerodynamically green. However, blades with the thinner element at the root might not withstand bending stress brought about because of axial wind load. So typically wind turbine with 3 blades can accommodate thicker root section are used. The number of blades governs the performance, fee, weight, and aesthetics to name some. For this project, the wide variety of blades changed into determined the usage of literature mentioned above. It's been proven that three blades produce fantastically precise overall performance. You may notice that the general public of horizontal wind generators these days are three-bladed for that reason. There are numerous variables that affect a variety of blade choice, inclusive of wind speed, TSR (Tip Speed Ratio), weight, drag, cost and so on. Industrial three-bladed turbines operate very efficiently in a huge variety of wind pace and TSR.

2.3 Blade aerofoil profile

For horizontal axis wind mills, its miles advocated to have a higher raise but decrease drag aerofoil. There are many forms of aerofoil which include the general aviation aerofoil, consisting of other than NACA collection, however, with the development of wind generators, the dedicated aerofoil passed off. In this study, the sheet metal is used for the development of a novel blade profile.

3 STRUCTURAL ANALYSIS

The ultimate strength of the blade is checked through a structural investigation procedure. For dissimilar loading condition (such as point load and UDL) deflection and the equivalent, stresses arise in trapezoidal and micro shape blade are going to calculate by evaluation. Stresses occur in the blade is safe or fail is depends on load applied on the respective sections. So by using below conditions will have to check and decide the shape of the blade.

(a) Trapezoidal blade model
- When point load is applied on the top portion trapezoidal blade model.
- When the uniformly distributed load is applied to the trapezoidal blade model.

(b) Micro shape blade model
- When the uniformly distributed load is applied on a micro shape blade model.
- When the uniformly distributed load (UDL) is applied for the different load on the micro shape blade model.

3.1 When point load is applied to the top section trapezoidal blade model

The blade geometry is developed in CATIA V5, it exports in ANSYS for the structural analysis. According to the force applied in various sections is to improve the overall stiffness of the blade and increase the load carrying capacity and prevent local buckling. As shown in figure.3. Model of different types of blades such as trapezoidal shape, square and micro shape done in CATIAV5, with proper blade dimensions, all dimensions are selected according to power requirement by the above equation.

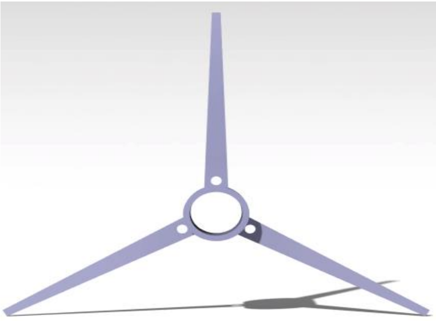

Fig. 3: Developed trapezoidal shape blade model

3.2 Equivalents stress analysis in the trapezoidal blade structural model

According to the calculation when the 10N load applied on the trapezoidal blade at the top portion of the blade (i.e. point load). It generates stresses on the blade on each section such as at the root of the blade, at the middle section of the blade and also at the tip of the blade. Figure 4 shows the von-Mises stress in the blade is 21 Mpa, which indicate the maximum stress occurred in the aluminum blade. The ultimate strength of aluminum is 40-50 Mpa, Hence the maximum von-mises stress found in the blade is below the ultimate strength of aluminum so; the blade will not fail when 10 N forces are applied on the tip of the blade. The figure also shows the distribution of equivalent stresses on two sides of the blade such as equivalent stress occurs in inside and outside of the blade surface for the same loading condition.

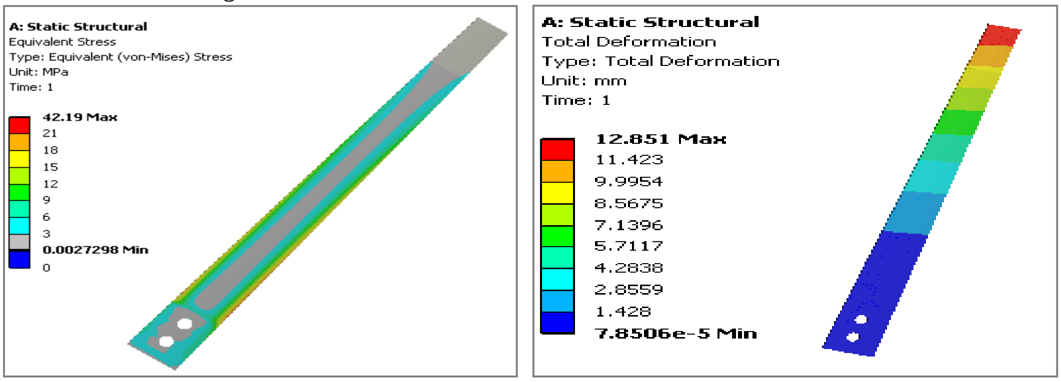

Fig. 4: Equivalent stresses and deformation occurred in the blade at a load of 10N

3.3 Structural deformation occurred in the trapezoidal blade

Figure 4 also shows deformation under the point load on the blade for 10N. The result shows that the deformation of blade sections increase from the foundation to the top, the maximum deformation happens as growth in the factor load at the blade; in the meantime, the minimal deformation role locates at the blade root, which meets the characteristics of the cantilever. A linear relationship among load and tip displacement, the deformation of the blade linearly increases with the rise in load, which once more suggest the blade is still linear and safe.

3.4 When the uniformly distributed load (UDL) is applied to the trapezoidal blade model

The blade geometry is modeled in CATIAV5R19, the figure shows the (UDL) is applied on the blade surface. For acting UDL on the blade, it required fixed support at the one end, therefore, the centre part which consists of the nacelle is in a static position. Whereas at the time of applying a load of 10N, one end of the blade is fixed with the nacelle and another end is free as shown in figure 5. Thus the condition of the cantilever model is satisfied, for calculating deformation and stress generation on the blade surface.

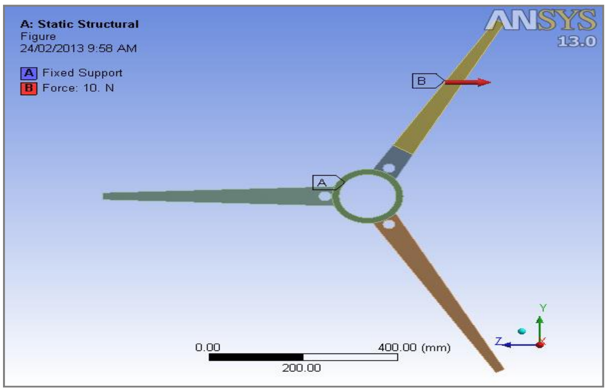

Fig. 5: Developed trapezoidal shape blade model

3.5 Structural deformation occurred in the trapezoidal blade

Deformation may be caused by external loads, body forces (such as gravity or electromagnetic forces), or temperature changes within the body. The strain is a description of deformation in terms of relative displacement of particles in the body. To find the deformation of the trapezoidal blade in FEA, have to choose the condition of the static structure of the blade. So as per decide diameter of blade model developed CATIA and converted in suitable format and import into the geometry of ANSYS for the FEA. By considering 10N load applied on the blade when the blade is in static position the static structural deformation happens in blade surface, the result of deformation occurred in the X direction, Y direction and Z direction. According to uniformly distributed load (UDL) applied on the blade, total maximum deformation occurs in the blade is 0.079mm, as shown in Fig.6a,As seen in above fig.4a Point load is applied on trapezoidal blade, the deformation is more because load acting at the top portion of the blade so only upper part of blade is deform for given load. In the case of uniformly distributed load (UDL) the distribution of force is according to the overall length of the blade hence automatically deformation is less as compared to the point load condition.

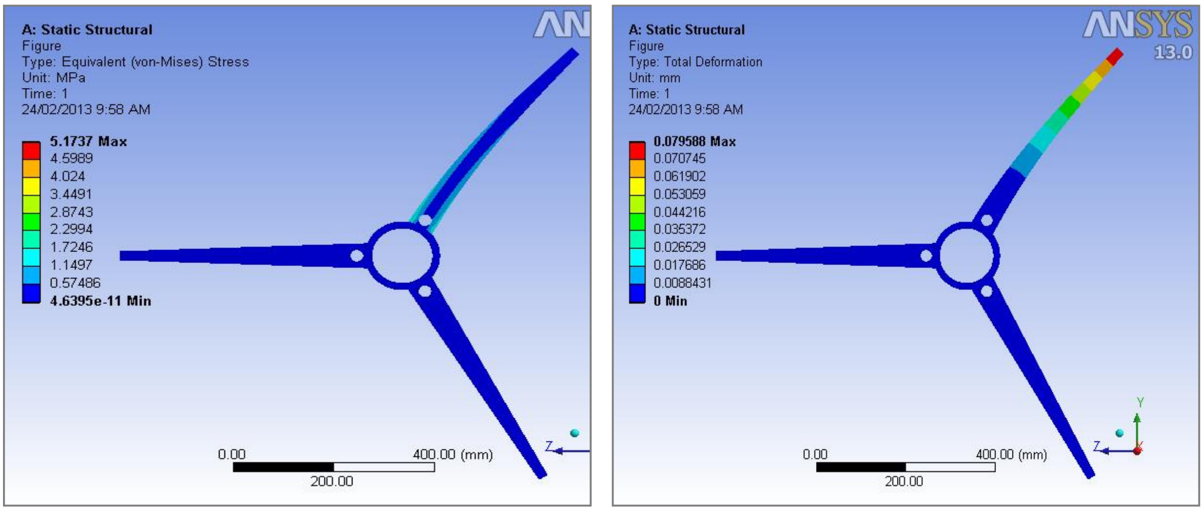

Fig. 6: (a) Maximum Deformation in blade (b) Equivalent stresses for 10N UDL

Figure 6 (b) shows when 10N Uniformly Distributed Load (UDL) applied on the trapezoidal blade. It generates maximum stresses on the root of the blade where the blade is attached with the fixed part. Figure 6 shows the von-Mises stress in the blade is 5.17 Mpa, which indicate the maximum stress occurred in the aluminum blade. The equivalent stress is again less compare with point load applied on a trapezoidal blade. The ultimate strength of aluminum is 40-50 Mpa, Hence the maximum von-Mises stress found in the blade is below the ultimate strength of aluminum so; the blade will not fail for the uniformly distributed load (UDL) of 10 N.

By considering the above results for point loading and Uniformly Distributed Load (UDL) applied on the trapezoidal blade. Realize that at the point loading condition amount of equivalent stresses generate in the blade is always high as compared to Uniformly Distributed Load (UDL). And the same condition is satisfied for deformation in the blade in case of cantilever loading. Hence for getting minimized stresses in the blade, consider the Uniformly Distributed Load (UDL) applied on the surface of the blade is more useful than point load applied on the surface of the blade. Therefore micro shape blade analysis considers only (UDL) is applied to the geometry. The wind velocity strike on the blade is always uniformly distributed loading type. Above analysis of stresses and deformation is directly given the indication that by increasing (UDL) on the blade surface equivalent stress and deformation is automatically increased.

4. STRUCTURAL ANALYSIS OF MICRO BLADE PROFILE MODEL

For the condition of the static structural arrangement of the blade, the blade geometry is modeled in CATIA, figure 7. Shows the (UDL) is applied on the blade surface. For acting UDL on the blade it required to fixed support at the one end as like trapezoidal blade centre part which consist of generator in micro shape for generating electricity according to rpm of the blade thus condition of cantilever model is satisfied, so as to use (UDL) for calculating deformation and stress generation on the blade surface. So developed CATIA model of micro shape blade is converted in a suitable format and shifted into the ANSYS for the FEA as like above blade analysis. For developing the model, dimensions are selected according to the power requirement.

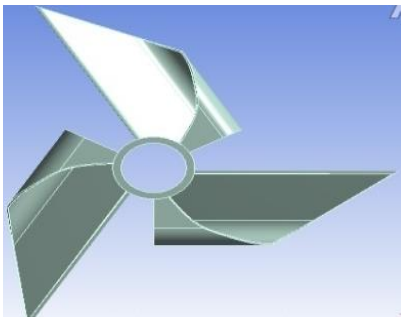

Fig. 7: Model of micro shape blade in CATIAV5R19

4.1 Meshing

The concept of the usage of only nearby mesh refinement for a convergence takes a look at may be prolonged. If a version is required to provide correct stresses most effective at positive areas of interest, the position of all elements faraway from those regions is considered one of best representing geometry and transmitting load. This needs a much decrease degree of mesh refinement than for accurate stress prediction. Hence, those elements can be notably large, a challenge to the limitations of allowing each reasonable pleasant transitions and geometry illustration. One in all 3 methods is used to solve the approximate model of the machine of equations: finite volumes, finite factors, or finite differences. Care ought to be taken to ensure proper continuity of solution throughout the common interfaces among two sub domains, in order that the approximate solutions inside diverse quantities can be prepared to give a whole picture of pressure go with the flow in the complete domain. The sub domains are often referred to as elements or cells, and the collection of all factors or cells is known as a mesh or grid. For different loading, condition analyzes the stress flow by meshing on the blade surface.

As a part of design after selection of the material directly get the total weight of the blade in the ANSYS. Define the Element size of the blade on the basis of the blade thickness and aspect ratio. Generally, the aspect ratio is approximately 1. Fine meshing is helpful for getting exact stresses in the blade.

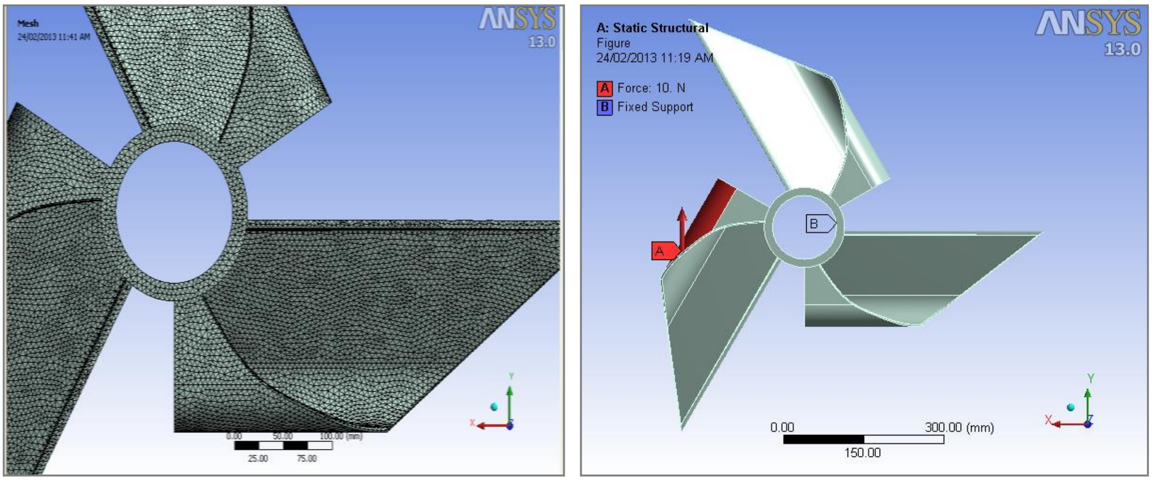

Fig. 8: Fine mesh model of micro wind blade and ANSYS model for loading condition

Total maximum deformation occurs in the blade by applying a load of 10N is 0.0144mm, which is negligible as shown in figure.9 as seen in above results, for UDL of trapezoidal blade deformation is more than micro shape model. The deformation is more because load acting on the surface of the blade from root to tip but in micro shape load only act on the swept portion of the blade and having more area. So in trapezoidal blade deformation occurs with respect to the overall dimension of the blade and in micro shape deformation found only in swept portion and tip of the blade.

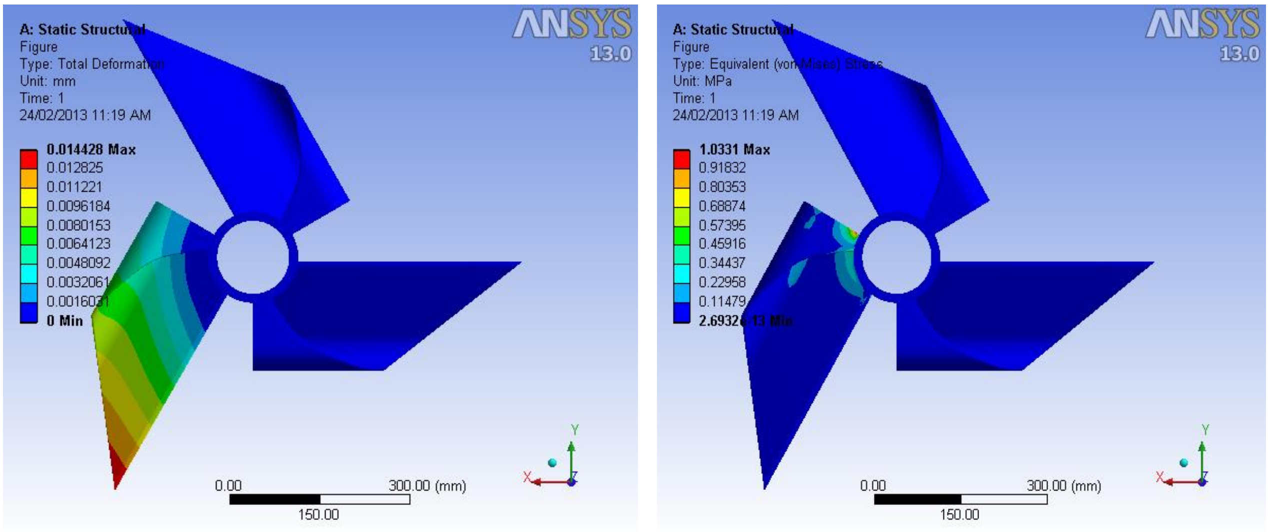

Fig. 9: Maximum deformation and equivalent stress analysis of micro shape blade

5. CONCLUSION

The present paper describes the structural evaluation by ANSYS for factor and uniformly dispensed loading. A parameter looks at is achieved wherein advances on this subject have allowed the fee of wind electricity to be competitive with extra traditional sources. The blades are a vital component of wind mills and lots of studies have been achieved in this location. Optimization of the blade doesn't forget for analysis where wind speeds common 7m/s. identify its suitability for its software on wind turbine blades and top settlement is made between outcomes. In -dimensional aerofoil modeling, the contrast among the two kinds of blades in structural evaluation by using ANSYS consequences is a dependable benchmark. Stress and deformation of the blade performances of different aerofoil's had been compared. It is discovered that the swept edge geometry continues maximum performance at decrease oncoming wind speeds and in a boom in strength at higher oncoming wind speeds. An airfoil of different shape blade for a horizontal axis wind turbine is designed based totally on structure, its miles concluded that the structural evaluation is efficient in predicting rotor aerodynamic traits. The structural analysis is done to evaluate the proposed design configuration by means of the usage of the modeling method at the intense wind situations. In this have a look at,

- The developed model of trapezoidal shape first checked for point load condition in ANSYS 13 and the same model checked for UDL. In uniformly distributed load stresses and deformation developed in the blade is low as compared to point load. So it describes fewer stresses are generated in UDL.
- According to the above results, UDL is used instead of point load on the surface of the blade.
- Then in case of micro model use UDL directly for analysis of stress also evaluate the blade for different loading condition. Out of two blades, the micro shape blade gives better equivalent stress analysis result than a regular trapezoidal blade for the selected diameter of the blade. Furthermore, ANSYS end result provides a higher correlation with theoretical information for power output prediction. Primarily based on its greater ability, analysis can be run below a specific variety of wind speeds. In keeping with the extraordinary wind speeds, the foremost rotational pace may be done to preserve the electricity output.
- A newly developed micro shape blade model gives better results than Trapezoidal one as shown in Table 1.

Table 1: Result comparison of blade forms

S no.	Form of blade	Load Carried (N)	Total Deformation (mm)	Equivalent Stresses (N/mm^2)
1.	Trapezoidal Blade	Point Load 10N	12.85	21 N/mm^2
		UDL of 10N	0.07	5.17 N/mm^2
2	Micro Shape Blade	UDL of 10N	0.014	1.03 N/mm^2
		UDL of 15N	0.021641	1.54 N/mm^2
		UDL of 20N	0.028855	2.06 N/mm^2

5. REFERENCES

[1] H. Erich, Wind Turbines: Fundamentals, Technologies, Application, Economics, 2nd edition edn. Springer, 2006.
[2] Report of the World Commission on Environment and Development: Our Common Future
[3] Wind Power Blade design, 1998.
[4] B. Tony, S. David, J. Nick, B. Ervin, Wind Energy Handbook. John Wiley & Sons Ltd, 2001.
[5] J. Manwell, J. McGowan, J, Wind energy explained: theory, design and application second edition, John Wiley & Sons Inc, 2009.
[6] D'Angelo S, Timmer W.A., "Two wind turbines dedicated airfoils tested in two Different wind tunnels: comparison and results", Windpoer'95 Conference, Washington D.C.USA, 1995, March 26-30.
[7] Tangler, K.J. David, "Wind Turbine Post-Stall Airfoil Performance Characteristics Guidelines for Blade-Element Momentum Methods", NREL/CP-500-36900, 2004.
[8] Ladean R. McKittrick, Douglas S. Cairns and John Mandell, etc. "Analysis of a composite blade design for the AOC1550 wind turbine using a finite element model[R]". California: Sandia National Laboratories, 2001.
[9] Hermann-Josef Wagner, Jyotirmay Mathur, "Introduction to Wind Energy Systems- Basics, Technology and Operation", Springer Series in Green Energy and Technology ISSN 1865-3529, Page 1-4, 2009.
[10] Meghan Lockington, Eric Martin, Helen Tsai, "Wind Power Preliminary Study", Queen's University Physical Plant Services.
[11] Laursen J, Enevoldsen P, Hjort S. 3D CFD rotor computations of a multimegawatt HAWT rotor. European wind energy conference, Milan, Italy; 2007.
[12] Schmitz, F. W., Aerodynamics of the model airplane. Part I. Airfoil measurements, NACA TM X-60976, 1967.
[13] A. Kasmin and C. Masson, "An extended k-e model for turbulent flow through horizontal-axis wind turbines", Journal of Wind Engineering and Industrial Aerodynamics, Vol. 96, pp. 103-122, 2008.
[14] Shur M, Spalart P, Strelets M, Travin A. A hybrid RANS-LES approach with delayed-DES and wall-modelled LES capabilities.International Journal of Heat and Fluid Flow 2008; 29: 1638e49.
[15] Schreck S. The NREL full-scale wind tunnel experiment. Introduction to the special issue. Wind Energy 2002; 5:77e84.
[16] Landahl MT, Stark VJE. Numerical lifting-surface theory-problems and progress. AIAA Journal 1977; 6:2049e60.

APPENDIX

ρ: Density of air
A: Swept area of the blade
V: Wind speed
Cp: Efficiency of conversion

