Different Analysis on Wind Turbine Blade: A Review

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Abstract— Renewable energy is basically defined as the energy that generate from the natural resources. Energy produced by wind is the type of renewable energy. Wind turbine is the thing which is used to convert the kinetic energy of moving wind into electric power. Wind energy depends upon several factors of wind like Wind power density, Wind speed, Aerodynamics, Turbulence, Forces, Loads, etc. All these parameters are equally applied on turbine blade to produce power. But sometimes the improper amount of these parameters creates inefficiency for turbine and cause damages, failure and some other serious problems in wind turbine blades. In this paper these problems are studies. A paper contains review on different previous journals base on mathematical, experimental, and analytical analysis. We also consider a study of different analysis done with the help of ANSYS. Work on blade material and new concepts were also reviewed in our work.

Key words: Wind Turbine Blades, Damage Detection, Experiments, New Concept, Ansys, Materials

I. INTRODUCTION

India is fifth largest country in installed capacity of wind power in the world. Wind energy is the type of most widely used renewable energy now a day. The study here is related to wind turbine which is used for generating energy from wind. Wind turbine is made up of assembly of different parts such as Tower, Shaft, Rotor, Generator, Gears, and Blades etc.

But the main part of turbine is its blade. Turbine blades are the key components of wind turbine and needs special care. Blades are designed according to they used and for achieving better efficiency. Some special methods and ideas are used in past for the analysis of blades which are reviewed in this work.

Mathematical models and calculations are used for vibration analysis on Damage detection, Performance evaluation of turbine blades. Experimental methods are used for investigation of actual Failure, Damages and their causes. A new concept used on turbines for applying experiments to get more efficiency. Analysis on software (ANSYS) is a better selection for doing an easy, better and accurate study on different Experiments, Designs, and also for actual blade profiles. Material plays an important role for better work of turbine and need attention. All these parameters are studied in this paper briefly and concluded for future work. The detail study about these topics was conducted in literature survey shown below.

II. LITERATURE REVIEW

The paper gives the review of different work and analysis done on wind turbine blades for increasing overall performance. We explain our study here by dividing the matter into different categories deeply discussed below.

A. Analysis of Wind Turbine Blades With the help of Mathematical and Numerical methods

Yanfeng Wang et.al [1] Damage in turbine blade caused by various reasons and creates serious problems. The paper consist of study of damage detection methods for which a dynamic analysis done on the actual model for calculation of mode shapes. The methods used for blade damage detection based on finite element method (FEM) for modal analysis and mode shape difference curvature (MSDC) for damage detection. A comparison is done with experimental data for design and modification of finite element model. Their numerical solution is able to detect the location of damage for wind turbine blade. The method also provides a low cost and efficient non-destructive tool for wind turbine blade condition monitoring. A blade of 1.02m of fiber-glass material is used for actual experimental work, and 3D models of blade of 5.5m multi-layer composite for work on software are taken as examples. The frequencies of both the blades at different node with and without damage are studied and compared for further work. Fig.1 shows the result comparison of first node frequency of blades.

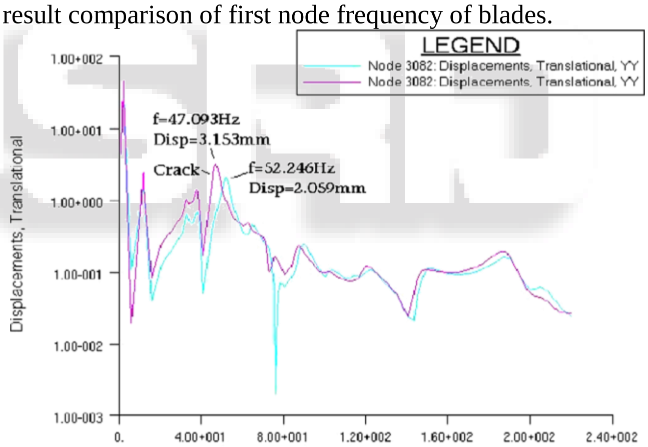

Fig. 1: Displacement magnitude vs. frequency of blade with and without failure at node 1. [1]

Ahmad Sedaghat et.al [2] flow of wind is variable at different regions here in this paper Aerodynamic performance of wind turbine blade at continuously variable speed is studied. A compact BEM (blade element momentum) analysis is use to derived a perfect design for continuously variable speed horizontal axis wind turbine blades. A generalized quadratic equation for calculation of different forces, force coefficient and tip loss are verified in paper. They also calculation values of power coefficient for optimal blade geometry at different tip speed ratio and drag to lift ratio at variable speed. The paper also concluded results for further use like power performance of variable speed wind turbine is higher than the constant speed wind turbine. Three bladed horizontal axis wind turbine with RISO airfoil sections are used and compared for the wind turbine operation under constant and variable speed.

Irshadhussain I. Master et.al [3] the paper consists of evaluation and comparison of Aerodynamic performance of wind turbine blade with the help of computational and experimental method. The study in paper considers by the use of NACA 4420 airfoil profile. The lift and drag forces on wind turbine blade and their effect on angle of attack ob blade were studied. 0^0 to 20^0 is taken an example for calculation. The mathematical calculation and their results of lift to drag ratio are shown in fig.2. They also carried a CFD analysis at various section of blade. The work in paper concluded that the blade show high Lift/Drag ratio at angle of attack ok 6^0. Different analysis and their results based on mathematical and experimental analysis shown briefly in the work, with the help of figure and charts. The CFD analysis is used to calculate various pressure and velocity profiles at different angle of attack for better results.

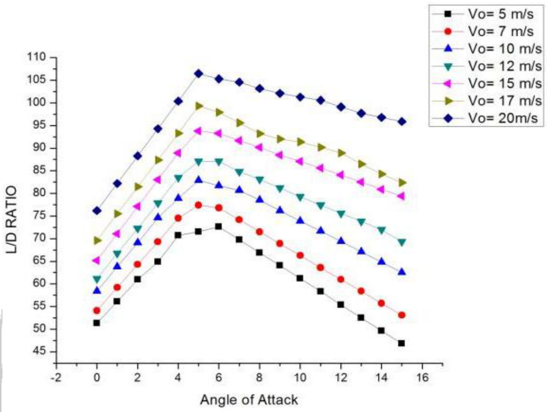

Fig. 2: Correlation between L/D ratio and angle of attack [3]

A Sharif et.al [4] as we know the manufacturing cost of blade stands for 15 – 20% of total cost of wind turbine, so the wind turbine blade needs special attention. In this paper the production of electrical energy of horizontal axis wind turbine with fixed rotor speed is studied. A mathematical formulation and equations are proposed here for selection of best pitch angle along wind turbine blade that corresponds to the maximum power extraction in site. The experimental data is taken from NREL phase II, and code is developed on blade element moment (BEM) theory for various corrections. They also validate a result of mathematical solution with actual experimental parameters, shown in TABLE 1. The work concluded that this mathematics is effective for increase in total power which makes blades economically reasonable.

Site	Electric power new turbine (KW)	Electric power original turbine (KW)	Relative boost in electric power (%)
1	14.42327	11.8206	22.018
2	6.183454	6.05512	2.119
3	2.089542	1.31438	58.974
4	6.291105	5.17845	21.486
5	3.061421	2.37075	29.133

Table 1: Comparison between Mean Electric Power of New and Actual Turbine [4]

B. Experimental Analysis of Wind Turbine Blades on actual models

Yan Li et.al [5] wind turbine placed at very cold places faces a serious problem of icing on turbine blade. In this paper a characteristic of surface icing on blade was studied with the help of actual test. The study applied on standard profile of NACA 7715 airfoil of wind turbine blade with proper arrangement of apparatus shown in Fig.3. The test conducted in wind tunnel on a blade of 0.22m chord at 0.2m height. The water is sprayed on the blade with nozzle to supply fog at different flow of discharge.

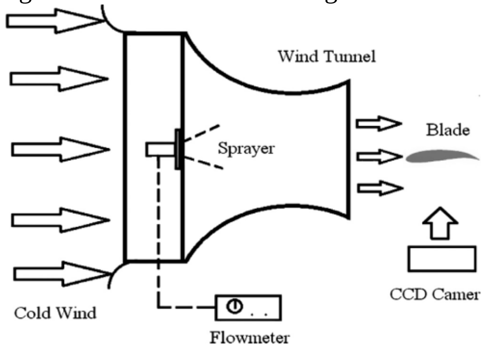

Fig. 3: Schematic diagram of experimental system. [5]

The icing distribution of blade under different wind speed and angle of attack were obtained with the help of camera placed at different position. The result of experiment concluded that the maximum icing rate is 6.6% and maximum icing area ratio is 21.8% at angle of attack -80^0.

Xiao Chen et.al [6] a wind turbine blade comprises of different weight and forces on it. These continuous loads create failure on blade. So a test conducted on 52.3m glass/epoxy composite wind turbine actual blade model, a static load is applied on blade to simulate extreme load conditions and a flap wise bending load is applied to enumerate failure, shown in Fig. 4. The failures were examined with the help of visual inspection and study various conditions. The work also concluded that the test is not applicable for analysis of large blades.

Fig. 4: Blade under Flap wise Bending [6]

Jinshui Yang et.al [7] the paper consist of actual test performed on composite blade model for investigation of failure arise due to static loads. The study concerned with an actual collapse testing under the flap wise loading on large full scale composite wind turbine blade. In this study a video metric technique is adopted to measure the deformation as well as the proper location of failure. The research also considers a validation of results through tensile and compressive test perform on software for same blade design. The result concluded that the displacement of blade tip is up to 11 m at ultimate load which is 160% of the extreme design load for the tested blade. Their results also show that the aerodynamic shells de bonding from adhesive joints is the initial failure mechanism causing a progressive collapse of the blade structure.

Sabbah Ataya et.al [8] wind turbine blade is the combination of different parts like leading edge, trailing edge, spar etc. Here in this paper an overall damage in trailing edge of wind turbine blade is analyzed with the help of actual model. The study in the paper is completely based on visual scanning of blades trailing edge in number of 81 blades of 100 KW and 18 blades of 300 KW and having a working life ranging between 6.5×10^7 and 1.1×10^8 cycles. The analysis based on actual model and different damages were allocated on the blade according to the length. The study concluded the result as three main cracks are appeared. Longitudinal crack found along the blade trailing edge from blade root to tip. Traverse cracks were found either in simple or in repeated form with the ranging of 20 to 50 mm. Edge damage were detected in the form of edge cut or crushing. Fig. 5 shows the details of result and different values.

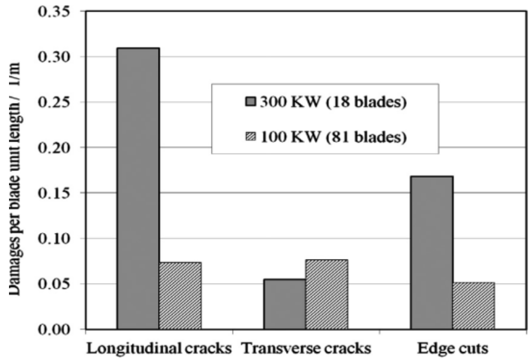

Fig. 5: Number of damage per blade unit length in the total inspected 100 KW and 300 KW wind turbine blades. [8]

C.P. Chen et.al [9] wind speed is an important factor which helps turbines to achieve better efficiency. But sometime a wind speed more than requirement creates failure. In this paper a theoretical and experimental approach is used for the analysis of small composite sandwich turbine blade at extreme wind loading. The strength of two type of composite sandwich wind blade of length 1 and 2.5 m will be analyzed in the study. In theoretical study a Finite Element Analysis based on ANSYS is used in which the failure location is studied and also the material at failure location is modified with the help of material degradation rule, and then changes in blade and the stiffness matrix analyzed again. In the experimental test a Wiffle-tree approach is used to simulate the wind load on blade. The experimental result also shows that the proposed method is best in 1m long blade for applying load and failure detection. The result of these methods is useful for the reliability design of composite sandwich wind blades.

Yu-Chung TSENG et.al [10] in this paper a small turbine blade of Glass-Fiber/Epoxy is used to verify actual torsion responses. The experiment actually based on torsion load at long straight members like root. The material here for a test comprises of combining a Glass-fiber/Epoxy and an aluminum shaft and applied on 1KW wind generator system. The composite shaft placed in torsion testing machine and a strain gage monitor. The result shows the mechanical properties and relation between applied torque and angle of twist. Location of failure and torsion loading in blade root also verified. The result also provides a reference for analysis and designers of small wind turbine system.

C. Study and Analysis of Wind Turbine based on New Concept

Qunwu Hung et.al [11] many research and work is under process for making wind turbine more efficient and effective. Here in this paper a new concept of Multi-turbine wind solar hybrid system is arise and experimentally verified with traditional method. The concept of multiple small wind turbines in place of bigger one is analyzed in the paper with the help of simulation on TRNSYS software. Two actual model of wind solar hybrid system are installed at Tianjin for measurement and simulation. The paper also concluded result at low speed the efficiency of multi turbine is better as compare to bigger one. The simulation also shows that turbine used at three different places give increased power of 18.69%, 31.24% and 53.79%, as compared with the reference system. TABLE 2 explained the proper distribution and comparison of outcome power.

CITY	New system/Wh		Reference system/Wh	
	P_w	P_{pv}	Pw	P_{pv}
City 1	98,143	523,115	63,818	523,115
City 2	189,816	477,444	144,638	477,444
City 3	239,945	211,978	202,152	211,978

Table 2: Yearly Wind Power Output of the Two Systems in Different City [11]

Daryoush Allaei et.al [12] the paper comprises of new concept used for the purpose of achieving better efficiency. The work done on new concept shown in Fig.6 in which a tower is eliminated and an INVELOX is used to capture wind flow. The concept also eliminates a use of yaw mechanism. A venture section is used for better wind speed. The new system face some challenges due to its complicated shape of path for wind flow and wind delivery system, as compare to traditional method in which flow path is not defined.

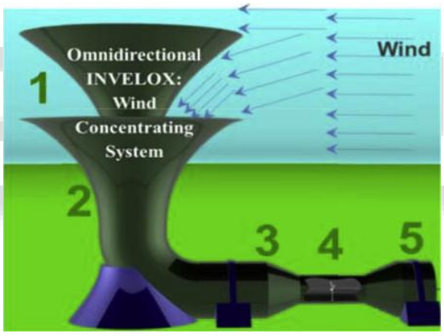

Fig. 6: Design of New Concept [12]

The result in this new concept shows that it is possible to capture, accelerate and concentrate the wind. Increase wind velocity result in significant improvement in power output.

The result and significant power increase is verified with the help of actual data.

D. Design and Analysis of Wind turbine Blades on Software's

Aravind kumar. N et.al [13] the paper considers the study on small wind turbine blade. The study is based on the experimental comparison done on bade with and without winglet (a small portion at the tip end of blades). The work done with the data of 2.0 KW of turbine designed in ProE and analysis done on ANSYS software. The result concluded that the power output is increase about 2.01% and noise level reduce at 25% in the winglet blade as compare with without winglet blade. The study of results and different analysis in paper are conducted with the help of graphical representation. The method is adopted for complete study of voltage and current at different wind speed and also for noise level distribution.

N. Manikandan et.al [14] the main object of this work is to increase the reliability of wind turbine through development of airfoil structure and also to reduce the noise produced during the running of turbine blades. In this paper ProE, Hyper mesh software has been used to design a blade and a blade of NACA 63215 is considered for study. The study also considers design of winglet at the tip end of the blade to achieve better efficiency and also for the purpose of reducing noise. TABLE 3 shows the distribution of different parameters used in paper for design a model. The result concluded with the help of comparison between the modified blade with winglet and the existing turbine blade.

X (m)	x/R	Twist angle (deg)	Chord length (m)
0	0	0	0.192
0.18	0.474	2.5	0.172
0.36	0.643	5.0	0.151
0.54	0.730	7.5	0.131
0.72	0.783	10.0	0.111
0.90	0.818	12.5	0.091
1.08	0.844	15	0.070

Table 3: Airfoil Distribution for Blade Design [14]

Fangfang Song et.al [15] analysis of blade in running and stable condition helps us to modify and design blade better than previous one. Here in this paper a design, modeling and dynamic analysis of composite wind turbine blade is considered. An example of 20KW horizontal axis wind turbine blade is taken. MATLAB tool is used for aerodynamic calculation based on Wilson method (space coordinate transformation theory). The study combines Solid work and ANSYS to establish the blade model so to describe actual shape and layer structure of composite blade precisely. The dynamic performance of the blade was checked by modal analysis as shown in Fig 7, for the calculation of frequencies at different modes.

Fig. 7: Model analysis at first three modes. [15]

The overall study has been successfully applied to a blade model. TABLE 4 shows the results of frequencies at 6 different modes on blade.

Mode order	1	2	3	4	5	6
Frequencies	5.6309	13.696	19.417	41.257	58.805	68.704

Table 4: Frequencies at Six Modes [15]

Mahmood M. Shokrieh et.al [16] fatigue failure is one of the most serious problem faces by wind turbine blades. In this paper a fatigue failure is studied in full composite wind turbine blade. 3D finite element method is applied to perform a Static analysis on blade. A study also comprises of a wind flow loading, stochastic approach is employed to develop a computational code to simulate wind flow with randomness using a Weibull wind speed distribution. The paper also comprises of study and evaluation of life of turbine blade. The result are bounded between 18.66 years in a worse situation and 24 years in the best situation an lower and upper limits.

Ashwani Kumar et.al [17] the main objective of this study is based on analysis of blade through software. An actual working design of a blade is taken under test with the help of some modification. Finite element method or finite element analysis is used for the study of wind turbine blade of uttarakhand region by some modification done on its material. The material used in this research is AL 2024. The main part of the research is related to identify the natural frequencies and natural vibration modes of AL 2024 wind turbine blade. The results at different modes of frequencies are shown in TABLE 5. In this work solid edge software is used for design of blade and analysis is done on ANSYS. The analysis results were also verified with the experimental results available for future use.

Vibration Modes	Natural Frequency (Hz)
1	73.685
2	125.45
3	456.58
4	851.44
5	928.02
6	1104.8

Table 5: Vibration Modes V/S Natural Frequency of Al2024 Wind Turbine Blade [17]

E. Analysis based on Wind Turbine Blade Material:-

J. Zangenberg et.al [18] material plays a very important role in life of wind turbine blade. The paper describes a study and design of blade and blade components on the basis of their material composition. The composite perform used for the load carrying main laminate of wind turbine rotor blade was analyzed here. The survey can be used as an information source on composite performs manufacturing. The paper provides us the basic knowledge of wind turbine blade technology and composite used.

A. Rashedi et.al [19] as we know wind power is increasingly receiving attention because of clean energy technology. But the cost, life cycle, and structural rigidity are some challenging parameters. Here the study at the outset, aim to establish blade and tower material selection indices on the basis of inherent constrains and potential design objective. They also highlight entire blade and tower material selection aspect for small and large scale horizontal axis wind turbine both for onshore and offshore application. The profile and loading of blade which is use is shown in Fig 8. The study can be deployed to hardness massive scale wind energy from structurally more promising, economically more competitive and environmentally more clean turbines.

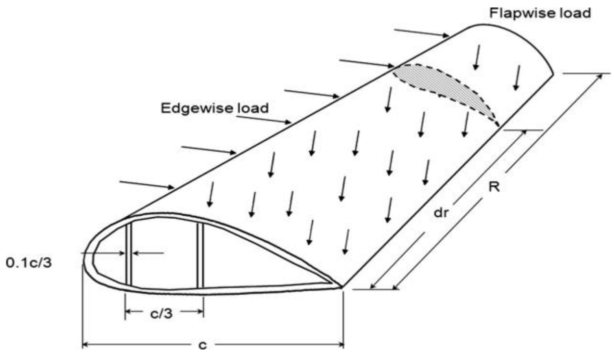

Fig. 8: Schematic diagram of a blade [19]

Ece Sagol et.al [20] as we know installation of wind turbine takes place at open areas where the wind speed is high. This high wind speed and some other parameters create some problem also. High wind also produces heavy flow of dust and dirt. At the place near to water creates water absorption and icing on blade. One more serious problem is created by insects, birds. All these agents develop a serious problem a roughness on wind turbine blade, which is discus in this paper. The paper gives the deep review on these agents and an irregularities and problems created due to these agents. Finally solution and conclusion are provided on material of blade, effect of roughness and power production.

III. Conclusion

This paper contains a study of different analysis and modification done on wind turbine blade in previous paper for achieving better efficiency and high power. As from the study of past papers we analyze many results. These results help us to clarify the overall working concept of turbine and provide better ideas for future work. Some work and results in paper gives us great thoughts for analysis and work. As from the conclusion point the previous journals work on very effective process. We observe Mode shape difference method (MSDM) for mathematical calculation for damage detection and it may be possible to use this method for actual modal in future.

Many standard airfoils used in these papers for analysis, for future aspect these results were helpful for us for validate results from another airfoils. Lots of work done on the survey of different actual wind turbine and their blade profile in laboratories were also specified in the paper. Analysis based on different blade damages, problems and failure was also pointed in the study with the help of design and analysis softwares like ProE, Solidwork, Ansys, and Trnsys etc. Various problems due to material and on material were also figure out. The study is very helpful and effective in future we see these parameters were also applied on other type of airfoils. A complete simulation of various journals is provided in this paper which is very effective for improvement and finishing.

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