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Review of Frequency Test of Windmill Blade with the Help of CAE Tools and its Brief Study for Further Development

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***Abstract*: When the windmill blades rotate with its maximum speed, the vibration may occur due to the unbalancing if blades. The effect of these vibrations on windmill blade for a long duration is dangerous. Hence windmill blades are designed with maximum precision and sustainability. Designer has to focus on blade profile to avoid friction with air. Most of the researchers have suggested the effective methods for balancing of blades. We can avoid failure of blade with these methods. But the practical implementation of such methods is not so costly. Hence a cost-effective method is required to balance the windmill blade. Second important parameter on which we need to focus is the vibrations occurred for long time span. If vibration range is more than the natural frequency of a windmill blade then the stability of blade affects and blade may fail due to its unbalancing. Some of the researchers have focused on this point also. But more concentration is required to achieve the maximum natural frequency of blade. In this paper the reviews of different research papers have been taken. For that purpose, the research papers are studied and their work is explained. Conclusion is drawn on the basis of papers study.**

***Keywords*: windmill blade, vibration, natural frequency etc.**

1. Introduction

Wind turbine (WT) blades capture energy from wind and convert it to mechanical energy for electricity power generation. They are therefore one of the most critical components in a WT system. However, WT blades are exposed to direct harsh environment, suffering constantly varying loads, experiencing temperature and humidity changes, erosion, and corrosion in operation. They are also the most vulnerable component in a WT. The long-term practice has shown that blade failures account for about 10% of all WT failures that have been reported. These blade failures lead to over 15% of total downtime, which means a significant revenue loss to the operator. Moreover, a catastrophic failure of blade could result in the loss of the whole turbine or even casualty and damage to neighboring facilities in the wind farm. Thus, blade failures have a profound impact on the cost of energy from wind. For this reason, to detect the failure of blade as early as possible and take measures to protect those being defective is of great significance in increasing the availability and therefore the economic return of WTs. Recently, there has been a noticeable increase in interest for wind power generation as a new and renewable energy. The size of a horizontal axis wind turbine (HAWT) has become larger for the multi-megawatt wind power class. Since this multi-megawatt wind power system is operating under unpredictable situations such as varying wind speeds, wind shear, blade-tower interactions, turbulence, and surface roughness of the blades in various external environments, possible uncertainties that can occur under operational conditions, have to be considered in order to design the best wind turbine blade and analyze its performance. The most important factor that influences the lifetime and reliability of a wind turbine system is the aerodynamic load on the blade, which is dependent on the operating environment, especially wind conditions. Consequently, research on aerodynamic load and fatigue analysis of wind turbine blades

2. Literature review

Yang W, Lang Z, Tian W.: Incipient defects occurring in long wind turbine (WT) blades are difficult to detect using the existing condition monitoring (CM) techniques. To tackle this issue, a new WT blade CM method is studied in this paper with the aid of the concept of the transmissibility of Frequency Response Functions (FRFs). Different from the existing CM techniques that judge the health condition of a blade by interpreting individual CM signals, the proposed method jointly utilizes the CM signals measured by a number of neighboring sensors. This offers the proposed technique a unique capability of both damage detection and location. The proposed technique has been experimentally verified by using the real CM data collected during the fatigue and static tests of a full scale WT blade [1].

Jihoon Jeong, Kyunghyun Park: In order to analyze the unsteady aerodynamic load of a wind turbine, FAST code was used as the analysis code. To consider turbulent wind as the wind input model in FAST, TurbSim was used as a turbulent wind simulator. For effective geometrical representation of the aerodynamic shape of a wind turbine blade, the shape modeling function was used to represent the chord length and twist angle. The fluctuating unsteady aerodynamic load in the optimized blade was reduced within the operating range of the wind speed. With the optimized blade shape, the wind turbine can be operated with decreased fluctuating aerodynamic loads and have a longer life in turbulent wind [2].

M. EL-Shimy: Due to its advantages, doubly-fed induction generator (DFIG) based variable-speed wind turbines (VSWT) are recently the most widely used topology of wind energy conversion systems (WECS). This study provides a steady-state modeling and analysis of DFIG systems. A steady-state model for DFIG is derived based on a wound-rotor induction machine 3rd order model with a stator flux-oriented control scheme. A fundamental steady-state stability criterion based on DFIG power-slip characteristics is used to study the steady-state stability of the system considering the entire maximum power-tracking characteristics. Also, the solo effect of the rotor voltage d-q components on the doubly fed induction machine (DFIM) steady-state performance and stability is analyzed. The results illustrate the steady-state stability limitations, as well as causes of steady-state instabilities of DFIG system as affected by the stator power demanded and the rotor-impressed variables. [3]

Koji FUKAMI, Kai KARIKOMI: This study deals with aeroelastic stability analysis of offshore wind turbine blades at standstill condition considering unsteady aerodynamics focusing on the stall flutter of a coupled flapand- edgewise bending motion. Taking an example of a 7MW offshore wind turbine, it was investigated that dynamic stall effect on the aeroelastic damping covering the whole regions of angle of attack and direction of blade vibration. To conduct the analysis, state space modeling, was applied, which consists of linearized unsteady aerodynamic model as well as 1 DoF blade vibration model. According to the analysis, it was revealed that unsteady aerodynamics could alleviate aeroelastic instabilities to different but great extents for each region defined based on angle of attack and direction of blade vibration [4].

V. A. Riziotis: Wind turbine blades in parked position can experience extremely high flow angles of attack in the region of ±900, depending on the direction of the incoming wind. Under such conditions the flow is massively separated over the entire blade span and therefore stall induced vibrations are likely to occur with obvious implications on loads and stability. Hysteresis effects. In this study a vortex type stall model is used in order to predict the stability characteristics of the Up Wind project reference blade. Damping assessment is performed by analyzing the transient response of the time series of blade deflections [5].

Jess, Graduate Engineer, power renewable: In this article the calculations to find windmill power is obtained. With the knowledge that it is of critical economic importance to know the power and therefore energy produced by different types of wind turbine in different conditions, in this exemplar have calculated the rotational kinetic power produced in a wind turbine at its rated wind speed. This is the minimum wind speed at which a wind turbine produces its rated power [6].

Qiyue Song: A small wind turbine blade was designed, fabricated and tested in this study. The power performance of small horizontal axis wind turbines was simulated in detail using modified blade element momentum methods (BEM). Various factors such as tip loss, drag coefficient, and wake were considered. The simulation was validated by experimental data collected from a small wind turbine Bergey XL 1.0. A new blade was designed for the Bergey XL 1.0 after comparing three types of aerodynamic blade structures and their related performance, and then the detailed blade structure was determined. The performance of the new rotor at different additional pitch angles was simulated and compared with the original Bergey XL 1.0 rotor. To fabricate prototypes of the new blades, a resin transfer moulding (RTM) system was designed and built. Three blades were fabricated successfully and installed on the hub of an existing Bergey XL 1.0. In a vehicle-based test system, the new blades were tested at the original designed pitch angle, plus at additional 5° and 9° pitch angles. The +5° rotor reached maximum power of 1889 W at wind velocity 13.6 m/s. The +9° rotor performed over a wider wind velocity range and output slightly lower power than the original Bergey XL 1.0. The new blades have better aerodynamic performance than original Bergey XL 1.0. [7]

SAMBIT SARANGI: Wind turbines provide an alternative way of generating energy from the power of wind. At windy places, wind speeds can achieve scintillating values of 10-12 m/s. Such high speeds of wind can be utilized to harness energy by installing a wind turbine usually having 3 blades. Rotational speed of the blades is usually 6 times that of wind speed. In this study, validation of a beam (a geometrical approximation of a blade) in vibration analysis is taken up first. The natural frequencies are matched with a published research paper and then an actual blade geometry is taken up to validate its 1st 3 natural frequencies with a published research paper and then a CFD analysis is taken up to find the lift and drag forces on the blade and subsequently these forces are used to calculate the fatigue life of the blade. Suitable materials for different parts of the blade are taken to see which combination of materials gives better results. [8]

S. Derakhshan and A. Tavaziani: Design of wind turbine blades strictly depends on high precision, reliable and robust numerical predictions of its performance in all of operation conditions. This study aims to simulate the flow around horizontal wind turbine blade with

Computational Flow Dynamics (CFD) using a validated 3D Navier–Stokes flow solver. The main objectives of this study are investigating of different turbulence models and aerodynamic performance of wind turbine blades. The NREL Phase VI rotor used for CFD simulations and testing. Three different turbulence models included of Spalart-Allmaras, k-epsilon (Launder Sharma) and k-ω SST tested and the best model for prediction of wind turbine performance is provided. Since Mach number is less than 0.3, the flow around wind turbine blade is incompressible and precondition used. For all cases the structure grid used for Fluid reticulation grid. For results more accuracy, use of preconditioning is necessary. Outputs of flow solver are t power and pressure coefficients for each section [9].

Dan PREDICĂ: The authors present the development of a consistent modeling and simulation approaches to correctly describe the realistic behavior of wind turbines. The Hybrid Engineering allows simulation and optimization of the performance of mechanical systems for structural integrity, noise and vibration, acoustics, system dynamics and durability, from the initial concept to the complete modeling and simulation of components and the full wind turbine. MBSE Engineering lets to create and run multi-physics simulation models to analyze and design the associated complex control systems. The following wind turbine problems are briefly presented: Multibody simulation, Durability simulation, Acoustics simulation [10].

John Arrigan: The aim of this study is to study the variation in natural frequency of wind turbine blades due to centrifugal stiffening and the potential use of semi-active tuned mass dampers (STMDs) in reducing vibrations in the flapwise direction with changing parameters in the turbine. The parameters considered were the rotational speed of the blades and the stiffness of the blades and nacelle. Two techniques have been employed to determine the natural frequency of a rotating blade. Numerical simulations have been carried out to study the effectiveness of the STMDs in reducing flapwise vibrations in the system when variations occur in certain parameters of the turbine. Steady and turbulent wind loading has been considered [11].

Bo ZHOU: As the wind turbine generator is located in more remote areas and poor environment, up construction and installation is very difficult. Therefore, to ensure the normal operation of the wind turbine, based on the analysis of wind turbine blades and the wind turbine blade by finite element model is established using the finite element theory and Abaqus software, then the modal analysis of the wind turbine blades was carried out, and the modal parameters of the wind turbine blades, the frequency and the vibration type of the first ten orders of the blade are obtained, results show that the wind turbine blade to reach the safety of use, must have to meet the requirements of strength, stiffness and stability. [12]

Gunjit S. Bir: This study examines the elasto mechanical stability of a four-bladed wind turbine over a specific rotor speed range. Stability modes, frequencies, and dampings are extracted using a specialized modal processor developed at NREL that post-processes the response data generated by the ADAMS1 simulation code. The processor can analyze a turbine with an arbitrary number of rotor blades and offers a novel capability of isolating stability modes that become locked at a single frequency. Results indicate that over a certain rotor speed range, the tower lateral mode and the rotor regressive in-plane mode coalesce, resulting in a self-excited instability. Additional results show the effect of tower and nacelle parameters on the stability boundaries [13].

Kunduru Akhil Reddy: This study describes about the principle and working of wind turbine as they are becoming popular in the renewable energy world. Primary objective in wind turbine design is to maximize the aerodynamic efficiency, or power extracted from the wind. The blade is designed using different types of airfoils which are oriented at different angle of attack and the blade design is responsible for the efficiency for the wind turbine. The designs of blades are done using Q-BLADE software, the power output is also determined using this software which uses Blade Elemental Theory. The comparative study is done considering the power output of the designed wind turbine blades and the existing wind turbine blade. Structural analysis is performed by ANSYS software [14].

E. Muljadi: The objective of this study is to analyze and quantify the inertia and frequency responses of wind power plants with different wind turbine technologies (particularly those of fixed speed, variable slip with rotor-resistance controls, and variable speed with vector controls). The fundamental theory, the operating range, and the modifications needed for the wind turbine to contribute to the inertial and primary frequency response during the frequency drop will be presented in this study. The approaches are based on the inclusion of frequency error and the rate of change of frequency signals in the torque control loop and pitch control actions for wind speeds below and above its rated value. Detailed simulation models in the time domain will be conducted to demonstrate the efficacy of the approaches [15].

Jørgen Jensen Tande: The objectives for the thesis were, (i) make a Computer Aided Design, CAD, model out of a set of coordinates given by PhD candidate Lars Frøyd of a blade of approximately 70 m length and designed for a 10 MW Offshore Wind Turbine, (ii) develop a mesh (a set of grid points) surrounding the blade so that CFD calculations can be performed on the blade, (iii) validate performance of the rotor in question by previously performed wind turbine CFD calculations and Blade Element Method results for the rotor in question, (iv) develop a guideline for drawing a CAD model of the blade, describing the procedure for meshing and how to run CFD calculations. The first task was successfully completed while the second and third task proved to be more demanding than anticipated. Many meshes were made in ANSYS 12.1 and several validation methods were attempted. For each mesh and validation attempt, new insight was gained in the complexity of fluid flow analysis software. In order to secure that the results obtained are physically correct and viable for the 10 MW wind turbine blade three validation methods mwere attempted. Because none of the validation methods were successful, the CFD results for the 10 MW offshore wind turbine blade was not possible to validate [16].

3. Outcomes of literature survey

- Vibration analysis of windmill blade defines the stability of windmill blade; hence it is necessary to perform it.

- Very less research work has been done on windmill blade behavior for vibrations.
- Different modes of vibrations are not much discussed in all above research study.
- Authors have focused on blade stability, while blade life is also is an important.

4. CAD modelling

CATIA offers a solution to shape design, styling, surfacing workflow and visualization to create, modify, and validate complex innovative shapes from industrial design to Class-A surfacing with the ICEM surfacing technologies. CATIA supports multiple stages of product design whether started from scratch or from 2D sketches (blueprints).

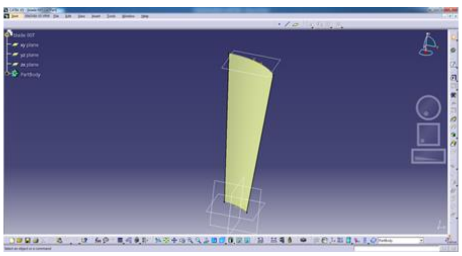

Fig. 1. CATIA model of Windmill blade

5. ANSYS as a CAE Tool

Ansys software is used to design products and semiconductors, as well as to create simulations that test a product's durability, temperature distribution, fluid movements, and electromagnetic properties.

Ansys develops and markets finite element analysis software used to simulate engineering problems. The software creates simulated computer models of structures, electronics, or machine components to simulate strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Ansys is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, Ansys software may simulate how a bridge will hold up after years of traffic, how to best process salmon in a cannery to reduce waste, or how to design a slide that uses less material without sacrificing safety.

6. Result

Table 1
Modes, frequency and displacement obtained

S. No.	Mode	Frequency (Hz)	Displacement (mm)
1	Mode 1	72.482	59.71
2	Mode 2	192.13	45.018
3	Mode 3	456.68	88.90
4	Mode 4	534.28	66.424
5	Mode 5	681.18	68.175
6	Mode 6	1111	77.619

Actual Displacement of windmill blade with ANSYS software:

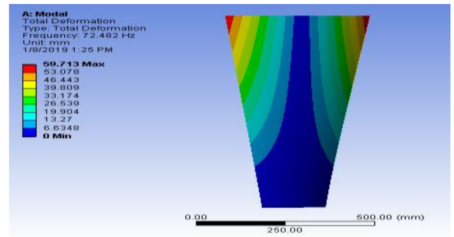

Fig. 2. Deformation in Mode Shape 1

7. Conclusion

- Study of research available on windmill blade is done.
- Further work is needed on frequency test.
- Balancing of windmill blade is most important task.
- More the natural frequency, safer the object.

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