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Design and CFD Analysis of Vertical Axis Ocean Turbine Blade

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ABSTRACT:

The success of harnessing energy from ocean current will require a reliable structural design of turbine blade that is used for energy extraction. In this study we are particularly focusing on the different blade foil of a ocean current turbine blade. The blade consists of sandwich construction having polymeric foam as core, and aluminium metal. Repetitive loads (Fatigue) on the blade have been formulated from the randomness of the ocean current associated with turbulence and also from velocity factor. In this project we are going to modelling general present day ocean turbine blade by using CATIA and in addition, finite element software blade, configuration when subjected to general boundary conditions and loads to examine its velocity flow reliability. Results from the CFD FLUIENT analysis revealed that the best design provides adequate pressure and produce the proposed velocity without any back pressure failure.

INTRODUCTION:

Oceans cover more than 71% of the earth's surface. They offer a large and renewable energy resource that is capable of producing large amounts of sustainable power. Florida's cleanest and most abundant source of renewable energy is its oceans. The two most significant and sustainable forms of renewable energy are through ocean thermal energy conversion (OTEC) and kinetic energy conversion (KEC). OTEC uses the thermal gradient produced as a result of the heat absorbed by the sun at/near the surface and the much cooler water far beneath the surface to produce energy; KEC is associated with the waves, currents and tides, producing energy using a turbine or wave buoy. As the price of fossil fuel increases alternative forms of energy become more and more attractive. South Florida is the closest major load center to a large ocean current; the Gulf Stream [1]. By harnessing energy from the Gulf Stream, Florida can relieve itself of its dependence on fossil fuels. The Gulf Stream Current flows northward past the southern and eastern shores of Florida, funneling through the Florida Straits with a mass transport greater than 30 times the total freshwater river flows of the world - over eight billion gallons per minute. It has an annual average flow velocity of 1.56 m/s in its core, with a summer average of 1.69 m/s and a winter average of 1.42 m/s. The blade designed under his thesis will be proposed for use in a KEC system, which will be installed in Florida's Gulf Stream Current the long term reliability of tidal turbines is critical if these structures are to be cost-effective. Optimized design requires a combination of material durability models and structural analyses. Composites are a natural choice for turbine blades but there are few data available to predict material behavior under coupled environmental and cycling loading. This

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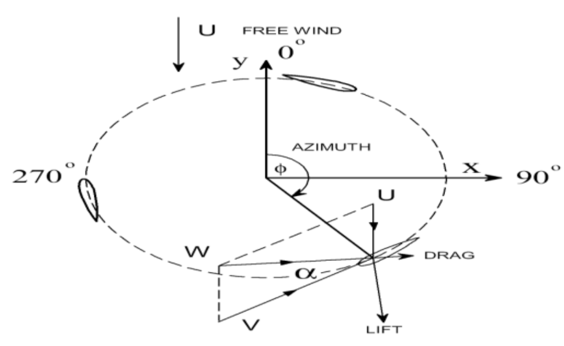
paper addresses this problem, by introducing a multi-level framework for turbine blade qualification. At the material scale static and cyclic tests have been performed, both in air and in seawater. The influence of ageing in seawater on fatigue performance is then quantified and much lower fatigue lives are measured after ageing. At a higher level flume tank tests have been performed on three-blade tidal turbines. Strain gauging of blades has provided data to compare with numerical models

The main aerodynamic models that have been used for performance and design analysis of straight-bladed Darrieus-type for VAWT briefly described by Islam [4]. Batten, et al. [5] also conduct a numerical model of a typical 3D rotor to demonstrate parametric variations of the design parameters and the use of alternative blade sections for ocean current turbine. Calcagno [6], presenting results on experimental and numerical approaches to the development of a prototype vertical-axis turbine types of ocean currents, and Kobold is an application that was first performed using 3-straight NACA 0015 series. Although studies have been conducted on the NACA 0018, information and performance of characteristics for vertical axis ocean current turbine for passive variable-pitch need to be more closely examined.

In this study, prototype of vertical-axis ocean current turbine test was constructed to determine the effect of a fixed-pitch and passive variable-pitch application using NACA 0018. Changes in rotation and tip speed ratio resulted at the speed variation between 1 - 3 m/s are presented. The dynamics of blades position on azimuth of rotation due to pitch-type application was analyzed as more in-depth information about the characteristic of turbine.

1.1 Lift and Drag of VAT

A distinction is made between vertical axis turbines that operate using the drag force of the flow on its rotor and those that employ lift forces to generate torque. Drag type devices employ a blade shape that has a higher drag coefficient with flow incident on one side than on the other. In this way the downstream drag force on the retreating blades is greater than the retarding force on the blades advancing in flow on the other side of the rotor. A net torque is thus generated. It is a limitation of drag type turbines that higher speeds and higher peak efficiencies cannot be attained due to the speed of the rotor is inherently limited because the blades on the retreating side will never travel faster than the current. In addition, relatively large amounts of material are required for a given swept area. However construction is typically simple and inexpensive compared to other types of turbine. Lift type turbines, such as the Darrieus turbine, employ aerofoil-section blades to generate lift. Such turbines are able to convert this lift into positive torque when the blades are traveling sufficiently fast relative to the free-stream flow. Consider the two-dimensional case of a blade moving in a circular path. as shown in Figure 1. As the blade rotates, it experiences a changing relative flow, which is the vector sum of the local flow speed and the blade's own speed. Both the angle of incidence of this relative flow and the magnitude of its velocity vary with the orbital position of the blade, called the azimuth. In general, the relative flow always comes from the upstream side of the blade: that is the outer side of the blade on the upstream pass and the inner side on the downstream pass. Thus, the angle of attack swings through positive and negative values each revolution. At small non-zero angles of attack the lift force generated by the blade has a tangential component in the direction of rotation. Provided



that drag is small, the blade then contributes positive torque to the rotor on which it is mounted. This torque is used to drive a load, thus extracting energy from ocean-current. In the absence of a free stream, the angle of attack is at all times zero and no lift is produced.

2.CURVE FITTING

Manuel et al. (1999) continued the work that Winterstein et al. had presented in their 1994 study on fitting curves. The program used in this paper is known as the FITS routine. The program automatically fits a set of empirical data to a variety of distributions as well as computes the firste distribution. The concept is to generate the equation of a line that will best match the first four statistical moments of the empirical data. The authors went through two examples: a wave height and a wind turbine load example. The wave height example had 19 data points, meaning 19 various wave heights. The data points were entered and the desired distributions were selected. The distributions used in that example were the Gumbel, shifted exponential above H = 8m, and shifted exponential above H = 8.5m. The program computes the first four statistical moments of the actual data and of the three distributions selected. It was found that the Gumbel distribution overestimated the chances of larger wave heights. The wind turbine example was slightly different in that it not only contained tress amplitude data points, but a corresponding number of occurrences with each stress range. The Weibull, quadratic Weibull, and cubic Weibull distributions were used in that example. The quadratic Weibull produced a much better fit than the standard Weibull distribution based on visual observation. The cubic Weibull distribution matched more statistical moments than the quadratic, but didn't turn out to be a significantly better fit. The cubic Weibull would be significantly better than the quadratic Weibull if the data displayed double curvature features. Overall, the quadratic Weibull distribution turned out to be the best pick to best represent the data when considering both computation time and the best fit. Winterstein et al published work on statistical moment-based fatigue load models for wind energy systems. Distributions of rainflow-counted range data were characterized by a limited number of statistical moments. In the study, several models were used that depended on these statistical moments. These models include a two-parameter Weibull model, quadratic Weibull model, and a damage-based model. The two-parameter model depends on the first two statistical moments while the quadratic model depends on the first three statistical moments. The damage-based model fits the irst two statistical moments with a power-law transformation that directly reflects the damage. The damage-based model was found to be the best fit while the quadratic model gave a good fit as well, as long as the lower, non-damaging low-amplitudes were excluded.

2.1.PARTIAL SAFETY FACTORS

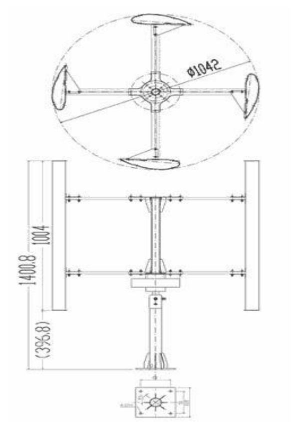
Ronold et al. (1999) used the results of the first-order reliability method in order to calibrate the partial safety factors. The characteristic bending moment range distribution as described in section 2.2 was used in order to represent the characteristic long-term bending moment range distribution over the design life of 20 years. The curve was used to determine the number of cycles occurring at a given bending moment range. The characteristic ε-N curve was then obtained by shifting the fitted ε-N curve to the left by two standard deviations of the residuals. This is a standard procedure for ε-N curves that yields a 95% confidence level. The design point ε-N curve was calibrated during the first-order reliability method but the damage was based on the expected values that were originally calculated. The ideal design ε-N curve (characteristic ε-N curve with an applied material factor) is the one that matches the design point ε-N curve. The material factor was calculated so as to set the design ε-N curve to the design point ε-N curve. The sought-after choice for the load factor is the one that will lead to a cumulative damage exactly equal to one by using the design load distribution (characteristic load distribution with an applied load factor) and design ε-N curve. Toft et al (2010) has shown the calibration of partial safety factors for fatigue design of wind turbine blades. The stochastic models for the physical uncertainties of the material properties are based on constant amplitude fatigue tests. The uncertainty in the Miner"s rule for linear damage accumulation is determined from variable amplitude fatigue tests. The partial safety factors are calibrated for different variations of the stochastic models. The load and resistance factors were calculated to be1.00 and 1.37, respectively.

2.2. Hydrodynamics of Blade Design

HAWT blades are significantly larger than those thought to be used for a MCT, 30 to over 100 m in diameter compared to 3 to 22 m in diameter [2, 4]. The rotor diameter of a MCT does not need to be as large as a VAWT in order to produce similar amounts of power due to the large density difference. Similarly the free stream velocity can be lower, yet allow for significant power production. For example some VAWT systems cut in when the free stream is 4 m/s, whereas most MCT's are not even designed for currents that fast [2, 4, 8, 9]. In order to design a rotor that will produce power related to theoretical predictions, hydrodynamics must be applied correctly. This begins by calculating the design rpm. By plotting the power coefficient (C_P) verses various tip speed ratios, the rpm allowing for most efficient power production can be extracted. This procedure was done by Batten [13], and from his plot it was decided to use a TSR of 5. The rpm was calculated using the following equations:

2.3.Blade Element Theory

This method assumes the blade is composed of hydrodynamically independent, narrow strips, or elements. Each differential blade element of chord (c) and width (dr) located at a radius from the rotor axis is considered as a hydrofoil section [16]. BET is an iterative method which can be used to find an efficient hydrodynamic shape of a blade and the corresponding forces that act on it. Eight blade elements, or sections, of width 0.3 m were used for designing the proposed rotor blades. Figure 2-2 contains an illustration of the loads that act on a local blade section



Blade characteristics

CONCLUSION

Thus this software's such as CATIA and ANSYS are used for modelling and analysing the normal ocean turbine blade which further helped in developing prototype of it. The design brings out the correct view of the blade which working for the pressure acting under the ocean when it is installed.

The analysis on ocean turbine blade was done in ANSYS 14.0. A comparative study has been made between different blades under different conditions:

1} single blade analysis)(mh62,mh82,s1010)

2}set of three blade analysis (mh62,mh82,s1010)

3}hybrid blade which consist of above three blades

From results it is observed that **MH82** the ocean turbine blade(among single blade) has relatively low pressure and high blade velocity and more suitable than the conventional ocean turbine blade with similar design.

Among single triple blades **MH62** has relatively low pressure and high blade velocity and more suitable than the conventional ocean turbine blade with similar design

And the main aim of our project CFD analysis in hybrid blade we conclude that it has comparatively good relative blade velocity but failed in pressure coefficient factor which may lead unwanted vibration forces .

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