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Design and Analysis of Vertical Axis Wind Turbine

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Abstract— *Simple drag type vertical axis wind turbine has proven to be greatly advantageous in the history of wind energy technology and the first successful electrical power generating wind turbine was built by Professor James Blyth of Scotland IN 1887.This research work focuses on computational study of the boundary layer control of a vertical axis wind turbine by modifying the geometry of the blade that is to be used in wind energy conservation. The control method used is passive method which will be consisting of implementation of tubercles geometry on leading edge inspired from a humpback whale flipper. The baseline design is an H-type three bladed Darrieus turbine consisting of NACA0015 cross-section.*

For CAD modelling SOLIDWORKS software is used whereas finite-volume based software ANSYS Fluent will be used for simulation purposes. Three dimensional, unsteady, turbulent, simulations for the modified blade geometry will be carried out in order to see for the achievable improvement on the performance.

Keywords*— *ANSYS, computational study, energy conservation, tubercles, vertical axis wind turbine.

I. INTRODUCTION

Wind turbines is the technology working on aerodynamic principals of lift and drag that extracts energy from wind. After reaching TSR of 1.6 it is observed that as the C_P (i.e coefficient of performance) reaches a value close to 0.3 and decreases due to the elevation in the magnitude of drag force acting on each of the turbine blade at high speed[2] (research paper on tunnel testing). This results in decrease in power generation of turbine.

Hence in order to eliminate the above causes, the aerodynamics of the turbine blades has to be improved. Now the of this study is to analyze the unsteady as well as the complex aerodynamic flow corresponding with wind turbine functioning. The all–around objective of this study is the comparison of the performance between baseline model and modified model. The tubercle along the leading edge may drive the boundary layer to higher extent which may prevent the flow separation for longer time and therefore delaying the stall.

II. OBJECTIVE

- To increase the power coefficient of VAWT
- Increasing the values of lift-to-drag ratio.

III. LITERATURE REVIEW

Chi-Jeng Bai, Yang-You Lin, San- Yih Lin, Wei-Chong Wang, 2015 [1] Studied performance of vertical axis wind turbine using Semi Implicit Method for Pressure Linked equations algorithm to solve incompressible Navier-Stokes equation. The k-omega SST model was selected for the turbulence flow simulations. The study was carried out for Angle of attack 00 to 400 were first validated with the experimental data in order to confirm the simulation accuracy, overall, the values of thrust were lowered than the ones with straight blade.

IV. PROBLEM IDENTIFICATION

There are lot many factors to be considered while designing aerodynamic shape of the turbine with tubercles on the leading edge. Namely, interaction of blades at certain Angle of Attacks, chord length , height of blades, rotor diameter and Tip Speed Ratio. The area of rotor through which air is passing plays role of absorbing wind energy which is impinged on blades from every possible direction. This defines the coefficient of turbine to be either maximum and minimum. In conventional vertical axis turbines, this is the matter of concern, "the act of absorbing power which wind is carrying". Most of the available power is used

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to reduce the drag which decreases the lift-to-drag ratio of each blade in flow field. Role of this research is to design an aerodynamic tubercles blade which satisfies the law of conservation of energy and direct the available power to maximise the lift-to-drag ratio.

V. PROPOSED METHODOLOGY

In order to overcome problems mentioned in previous chapter a brief experimental study was executed and with the help CFD analysis it was stated that the performance of H-type VAWT can be improved. In order to validate the methodology, a baseline design was modeled and simulated based on the experimental performance testing given by Bravo et al. [4]. The baseline turbines blades had a constant cross section with a NACA 0015 profile. This procedure was followed by the implementation of the leading edge tubercles on the turbine blade of baseline model.

5.1 Sizing of baseline model

A two dimensional model based on experimental performance test was build using Computer Aided Design Software, SOLIDWORKS. The turbine is three-bladed H-type Darrieus with diameter of 2.5m and a height of 3m. The blades have a NACA0015 profile with a chord of 0.4m. In the simulations of baseline geometry, the k – omega SST turbulence model is used [3]. Various turbulence models would be studied further in order to achieve more precise results as those of experimental.

5.2 Sizing of modified model

The leading edge tubercle two dimensional model is created in Computer Aided Design Software, SOLIDWORKS by maintaining the purity of tubercle on leading edge as it would cause the same effect when manufactured. As this research is focus mainly on H-type VAWT, therefore the turbine with diameter of 2.5m and a height of 3m is created. Initially the height is neglected in 2-D simulations. The constraint in design methodology is to conserve the turbine blade area. Tubercle profile will consist of amplitude that equals to 2.5% of mean chord length of blade profile as well as wavelength that equals to 25% of the mean chord length of the blade profile.[6]. In the simulation of modified geometry, the k-omega realizable is used, as the k-epsilon would yield same results but as compared to k-epsilon, k-omega would give us better results [1].

5.3 Numerical technique

5.3.1. Two dimensional domain and Meshing techniques

A. Domain configurations

In this section the geometrical features of 2D domain is discussed. Initially, controlled volumes and the corresponding boundary conditions are adopted [2].

TABLE 5.1
Domain Specifications

SR NO.	GEOMETRICAL FEATURES	DESCRIPTION
1	L_X =100R	Length of control volume along free-stream.
2	L_Y =60R	Width in y-direction
3	D_R =3m	Circular rotating domain diameter
4	D = 2.5m	Rotor diameter

The specification of the simulation domain is shown in Figure5.1. The outlet pressure is set equal to 101,325 Pa. and the no slip boundary conditions is applied on turbine wall blades. An interference wall is introduced between the rotating and fixed domain. And center of the rotor will be the origin of reference.

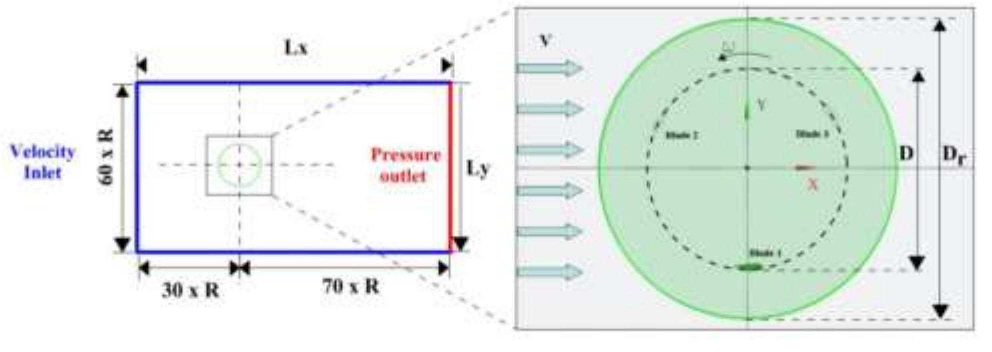

FIGURE 5.1 Two-dimensional computational domain

B. Meshing techniques

Since, there exists interaction between solid and fluid, the fluid meshes surrounding a solid can slide each other to accommodate a rotational motion of the solid, and a fluid mesh outside the sliding interface can translate through a background fluid mesh. The solid geometry is created in SOLIDWORKS and imported into a mesh component system in ANSYS WORKBENCH to create the mesh model. The mesh generation specifications for fixed and rotating entities are adapted accordingly.

VI. CONCLUSION

Simple blade of turbine consumes available power to overcome the drag generated at high velocities which indirectly affects turbine's coefficient of performance by decreasing it after reaching certain tip speed ratio. Our study is based on bio mimicry of whales tubercle which helps to produce more lift. A study from Fish and Battle [5] stated that modifying the leading edge of the airfoil with tubercles helps in achieving as well as maintaining the lift at high AOAs. Therefore by implying tubercles on blade leading edge the available power from wind can be used to generate more power rather than using it to decrease drag which increases the CP of our turbine.

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