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Re-Design and Numerical Analysis on Vertical Axis Wind Turbine Blade Profile

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Abstract: *Wind energy is a promising renewable and clean energy source and wind turbines are the common devices to harvest this energy. Vertical-axis wind turbines (VAWTs), one kind of wind turbine, are concerned because of their congenital advantages of easy maintenance. However, one main issue of VAWTs is that the aerodynamic phenomenon of dynamic stall typically occurs under low tip-speed-ratio conditions, which negatively affects their power extraction performance. This study focuses on exploring a better blade design to improve the power coefficient of VAWTs. The study of cambered NACA2412 and symmetric NACA0018 aerofoil is designed in Q blade software and analyzed. For computational analysis Ansys space claim, ANSYS workbench software is used to carry out 2D analysis to study the understanding of performance of blade and then 3D analysis is carried out to learn modelling of blades rotation and distance from shaft or center of VAWT plays very important role in increasing the efficiency and power outcome of the system.*

Keywords: NACA, QBlade, VAWTs, HAWT, etc.

I. INTRODUCTION

As the world continues to use up non-renewable energy resources, wind energy will continue to gain popularity. A new market in wind energy technology has emerged that has the means of efficiently transforming the energy available in the wind to a usable form of energy, such as electricity. The cornerstone of this new technology is the wind turbine. A wind turbine is a type of turbo machine that transfers fluid energy to mechanical energy through the use of blades and a shaft which converts that form of energy to electricity through the use of a generator. Depending on whether the flow is parallel to the axis of rotation (axial flow) or perpendicular (radial flow) determines the classification of the wind turbine.

There are two major types of wind turbines exist based on their blade configuration and operation. The first type is the horizontal-axis wind turbine (HAWT). This type of wind turbine is the most common and can often be seen littered across the landscape in areas of relatively level terrain with predictable year-round wind conditions. HAWTs sit atop a large tower and have a set of blades that rotate about an axis parallel to the flow direction. These wind turbines have been the main subject of wind turbine research for decades, mainly because they share common operation and dynamics with rotary aircraft.

The second major type of wind turbine is the vertical axis wind turbine (VAWT). This type of wind turbine rotates about an axis that is perpendicular to the oncoming flow, hence, it can take wind from any direction. VAWTs consist of two major types, the Darrieus rotor and Savonius rotor. The Darrieus wind turbine is a VAWT that rotates around a central axis due to the lift produced by the rotating aerofoils, whereas a Savonius rotor rotates due to the drag created by its blades. There is also a new type of VAWT emerging in the wind power industry which is a mixture between the Darrieus and Savonius designs. The selection of aerofoil, blades, their computational analysis and their performance parameters is very important. The study gives an outcome of power generated by VAWT for both profiles using Ansys Fluent and QBlade software.

II. LITERATURE SURVEY

Our world has been powered primarily by fossil fuels such as coal and natural gas for years. Plants powered by these fuels produce plenty of hazardous substance including sulphur dioxide and nitrogen oxides, which can lead to acid rain and potentially cerebrovascular effects. Different from the traditional power source, wind power represents a promising renewable energy resource that can help reduce pollution. Wind power is usually harvested by wind turbines which can be classified into two major categories based upon their axis of rotation: horizontal-axis wind turbines (HAWTs) and vertical-axis wind turbines (VAWTs), as shown in Figure 1. (In Figure 1 Wind turbines: left picture-HAWT, right picture-VAWT 2). The axis of HAWTs is parallel to the incoming flow. HAWTs capture power through the whole rotation, which is usually more efficient than VAWTs.

The Vertical Axis Wind Turbine (VAWT) gives economical reliable energy solution for remote areas. The use of VAWT should overcome the problems associated with the various patterns i.e., poor self-starting and low initial torque etc. The advancement in the wind turbine design have been possible due to development in technology. The features such as choice of wind generators, wind velocity, site, height, wind power potential have been considered as an important function of feasible models. Further, choice of the windy site for wind power generation needs meteorological data for installing the wind turbines. The noise detection in the Aerofoil is detected by using aero acoustics tests. The wind field modelling and aerodynamic modelling has been performed for structural analysis and aerodynamic forces. Also, controlling system modelling has been performed to check the operating parameters of the wind turbines are within desire limit. With the assumption of installing the wind turbine at location with moderate wind speed with optimized blade design, high power output generation is achieved with VAWT and can be used to provide energy to remote areas.

The world is facing lots of problems in the future due to lack of non-renewable energy sources. They are moving towards the use of renewable energy sources like wind, solar energy etc. This paper provides detail information about design, types and future trend of vertical wind turbine. The vertical wind turbine can be placed and remote areas where electricity not reached yet and generate the electricity using wind power which is easily available. The researchers are going on in order to develop vertical axis wind turbine with better efficiency.

However, the major disadvantage of HAWTs is that they are very sensitive to directions of wind, so a group of yaw control systems must be set to keep the blades perpendicular to the incoming flow. In addition, the maintenance of HAWTs is a significant extra cost compared with VAWTs. Unlike HAWTs, VAWTs' rotation axis is perpendicular to the incoming flow, so they are not sensitivity towards robust flow direction. They are often considerably smaller than HAWTS so they can bring the advantages of easy installation and maintenance irrespective of terrain. Additionally, VAWTs usually produce less noise than HAWTs, so they are more feasible to install in urban and suburban areas.

The VAWT performance is influenced by rotor performance and aspect ratio was investigated and some empirical relations were figured out for the experimental design. Below figure2 gives the nomenclature of cambered aerofoil having upper surface known as upper chamber, lower surface known as lower chamber, the centreline for aerofoil is called mean camber line, the straight line joining leading edge of an aerofoil with the trailing edge is called chord line.

III. IMPLEMENTATION

The majority of wind turbine research is focused on accurately predicting efficiency. Various computational models exist, each with their own strengths and weaknesses that attempt to accurately predict the performance of a wind turbine. However, it is important to note that predicting the performance of a wind turbine using CFD typically requires large computational domains with additional turbulence modelling to capture unsteady affects; therefore, CFD can be computationally expensive. The mass, momentum and energy conservation equations are solved computationally using fluent software for converging results.

CFD is technique of replacing governing fluid flow algebraic equations with Partial Differential Equations. Finite element method is discretization technique used to convert practical differential equation of fluid to algebraic equations. Thus, numerical methods of Newton Raphson's are used to solve the algebraic equation. Governing equations used are continuity, momentum, energy equation. There are three basic forms of governing equations i.e., algebraic, integral and differential.

CFD Modelling in ANSYS Fluent:

Geometry Modelling:

Following is the geometry modelling for VAWT analysis for NACA 0018 symmetric aerofoil:

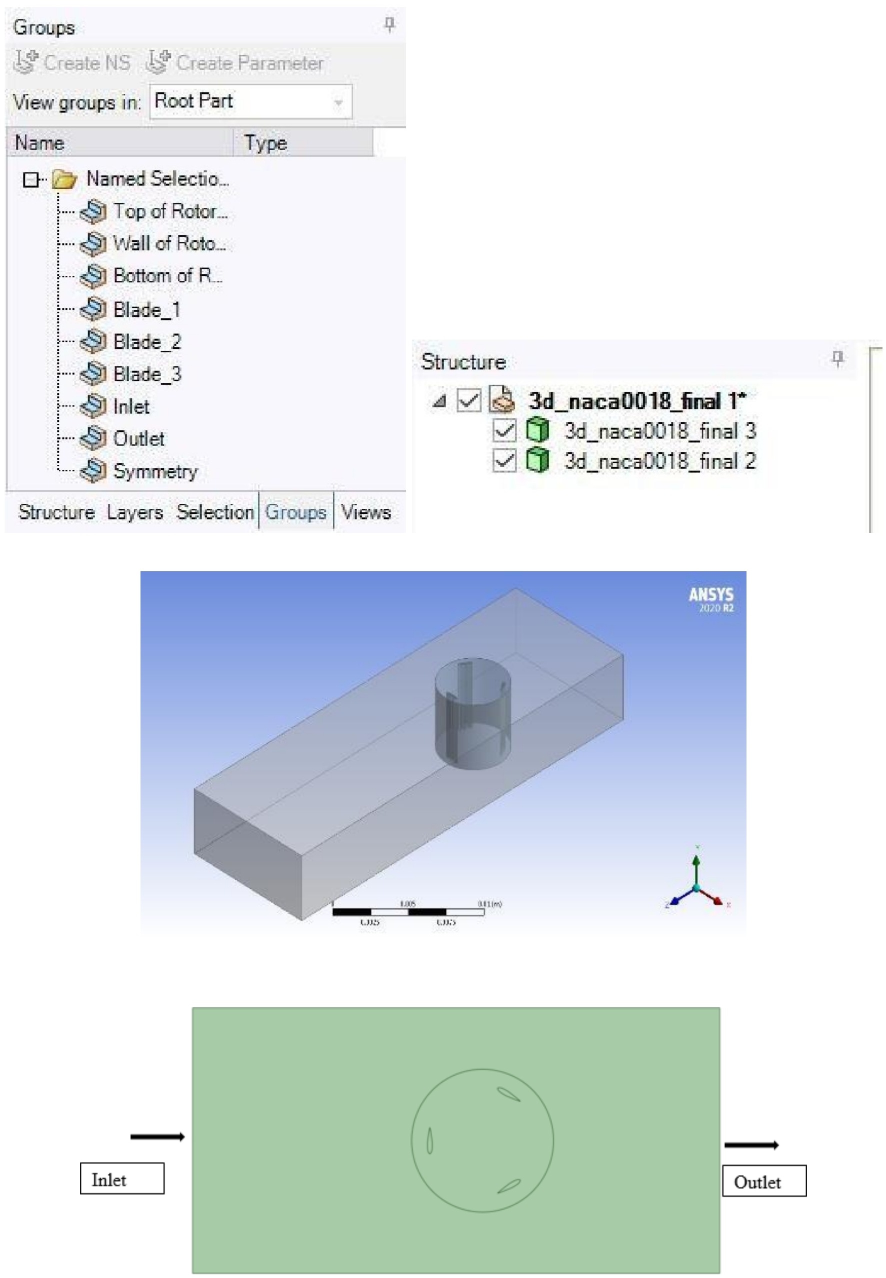

Figure 1: Geometry Modelling and details

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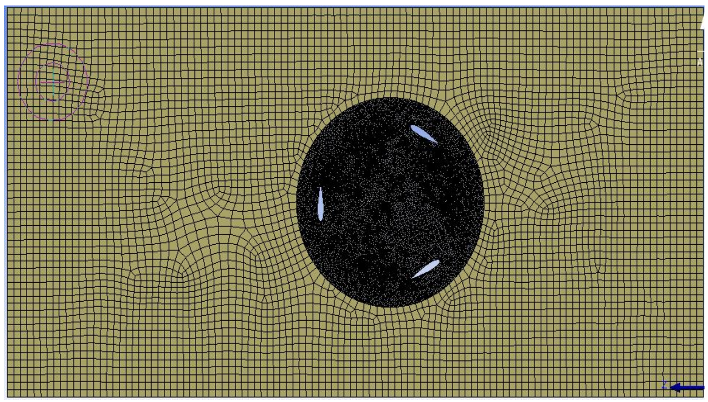
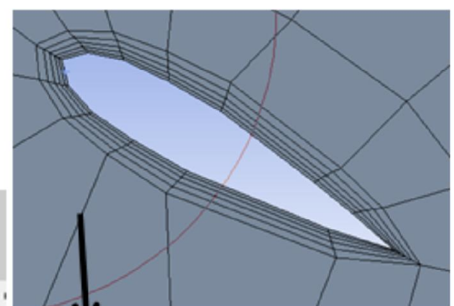
Mesh Modelling:



No of prism Layers: 7

Statistics	
Nodes	55218
Elements	110035



Prism layer near aerofoil wall

Setup and Solver settings:

1] Settings of fluent:

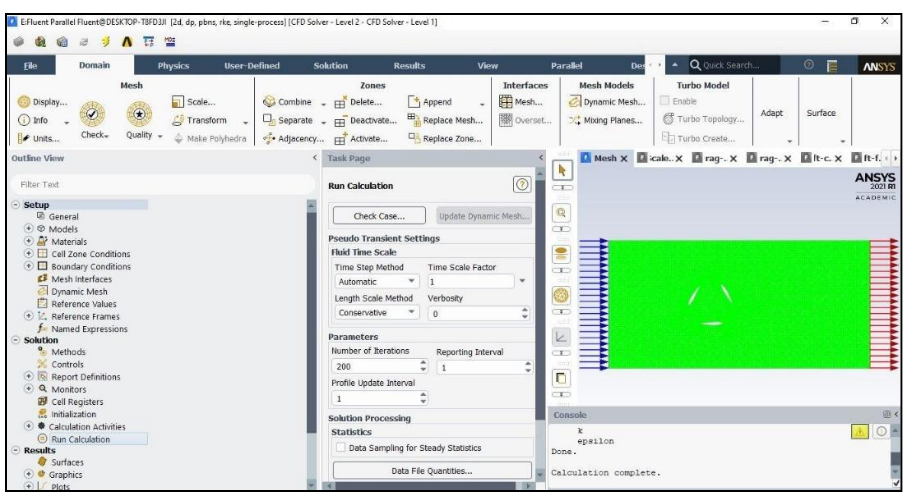


Figure 3: Taskbar and interface of fluent

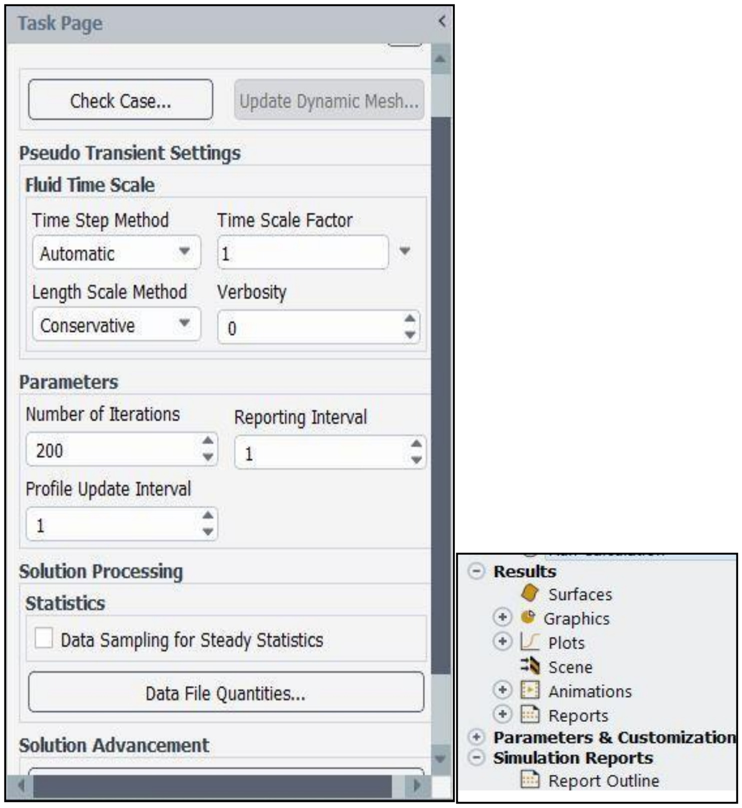


Figure 4: Setup details

IV. CONCLUSION AND DISCUSSION

1. The analysis of VAWT, HAWT specifies the advantages of VAWT over HAWT with better stability and performance for same velocity. The cambered airfoil performance changes with increase in velocity it undergoes dynamic stall and the performance is affected leading to reduction in stability and efficiency. The symmetrical airfoil has increased velocity increasing the RPM and thus the power output.
2. The contour plots and vector plots give the pressure distribution with recirculation zones over the blade profiles.

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