Blade Shape Design and Analysis on the Optimal Direction of Impact for Vertical Axis Wind Turbine

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Abstract—Wind energy as a viable renewable is reliable and economical for stand-alone systems. Vertical Axis Wind Turbine is getting popular due to the fact Malaysia is lacking of cut-in speed, is viable methods used to harvest wind energy for a low power generation. The power production is highly dependent on the blade shape with respect to the wind flow. In order to increase its output power, the design and optimize the blade design using Computational Fluid Dynamic modelling through different standard blade shapes. Based on the analysis the blade with the highest lift coefficient is chosen. It is observed that NACA4518 have a higher lift coefficient compared to others at an angle of attack at 15°.

Keywords—CFD, NACA, VAWT

1. Introduction

The advantage of implementing Vertical Axis Wind Turbine (VAWT) is the ability to generate electricity at low wind speed. However, the design and the position can be highly influential on the output of VAWT. Therefore, the objective of this research is to design and optimize the blade for a VAWT model based on five different NACA profile. These profiles are chosen based on past research done [1-4]. The background of this work is due to the limitations on the choice of the NACA profile [1-3]. Therefore, addition of different NACA profiles into this research to determine the suitable NACA profile to be implemented into the VAWT design. The simulations of these NACA profiles are tested with a numerical tool to determine the drag and lift coefficient which will be discussed in Methodology part. Besides that, the computer aided tool is used to design the prototype integrated with the NACA profile chosen based on the results from the CFD simulation. This paper would report the simulation results at the Results session.

2. Design Methodology

Based on the lift force equation given as in Equation (1)

\[ L = \frac{1}{2} \rho u^2 A C_L \]  

where \( L \) is the lift force, \( C_L \) is the lift coefficient, \( \rho \) is the air density in kg/m\(^3\), \( u \) is the wind speed in m/s and \( A \) is the area of blade in m\(^2\).

From the equation, it can be observed that the air densities, wind speed, the size of the blade and lift coefficient are the factors affecting the lift force of the wind turbine. Therefore, CFD tool is used to obtain the lift coefficient of the NACA profiles selected and modelling tool is used to design the blade. Project flowchart is shown in Figure 1. The NACA profiles are simulated under CFD 2-D model and it is solved using pressure-based ANSYS Fluent 14.0 using the setting as shown in Figure 2. The NACA profile coordinate is imported into geometry and a basic airfoil shape is constructed. Then, a mesh surface is created around the airfoil to simulate the surrounding of the airfoil as shown in Figure 3. The accuracy of the results is depending on the mesh size. The more define the meshing, the more accurate the result is. The solver is launched to define the boundary condition for the simulation. Spalart-Allmaras model is used as the setting of boundary condition to give accurate results as this model is normally used to analyze the airflow. After the boundary condition is set, the solution is needed to be initialized to ensure the value is as inputted.

After the confirmation, it is ready to run the calculations after the number of iterations is changed to 3000. The higher number of iterations can provide high accuracy results. Once the setting is done, the calculation is then started until the results are converged. The results of five NACA profiles at angle of attack 15° are shown in Figure 4.
3. Results

Five different NACA profiles are simulated using numerical tool and are compared for lift coefficient. The NACA profiles are namely NACA0012, NACA0018, NACA4612, NACA8612 and NACA4518. The blade lift force and lift coefficient can be obtained by simulating the NACA profiles. Figure 5 shows the graph of angle of attack versus the lift coefficient. Based on the simulation, it is noticed that profile NACA4518 produces highest lift coefficient at attack of angle of 15° compared with the other four NACA profiles. Table 1 shows the lift coefficient of the NACA profiles selected.

<table>
<thead>
<tr>
<th>NACA Profile</th>
<th>Lift Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>NACA0012</td>
<td>0.7383058</td>
</tr>
<tr>
<td>NACA0018</td>
<td>0.7147175</td>
</tr>
<tr>
<td>NACA4612</td>
<td>1.1804521</td>
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<tr>
<td>NACA4518</td>
<td>1.587083</td>
</tr>
<tr>
<td>NACA8612</td>
<td>1.804521</td>
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</tbody>
</table>

4. Conclusions

It can be observed that NACA4518 have higher lift coefficient compared to others at an angle of attack at 15°. Therefore, it is chosen as the blade profile for the VAWT prototype. Experimental data would be able to collect once the VAWT prototype is developed.

References