Performance and aerodynamics study on wind turbine

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Abstract. The importance of vertical axis wind turbine is developing due to their compactness and simple design among the researchers on renewable energy development. Some performance improvement techniques are famous in the field of Darrieus H – Rotar wind turbine. This paper is focusing to find out the efficiency of the wind turbine by adding flap and corresponding optimum position and angle of it. The numerical approach is used in this article using Computational Fluid Technologies (CFD) in the 2D domain. The k-ε SST 2 equation model is used for simulation purpose for obtaining its coefficient of momentum and performance. The validation of the result has been done using a grid-independent test by changing the element size. The performance parameters are obtained using simulation techniques and plotted in a standard manner to optimize them.

Keywords: Wind turbine, aerodynamics, drag, computational fluid dynamics, angle of attack

1. Introduction

Vertical Axis Wind Turbine is used to produce the wind energy at the low cost and has fewer components, require less maintenance, easily transportable when compare to the HAWT because of which we choose the VAWT. In the low tip speed ratio, VAWT’s aerodynamic characteristic is complex when we compare it with a horizontal axis wind turbine [1]. Flow separation follows up on the two sides of the blade which leads to an increase of drag and decrease of lift force. So the efficiency also accordingly decreases. Unsteady loads were caused on the local and downstream blades due to the vortex shedding [2-6]. Therefore, decreasing the load fluctuation and the power efficiency can be increasing done with mitigating flow separation. Decreasing the angle of attack is the only answer to alleviate the flow separation. Many control methods are available in nature to alleviate the flow separation. For example, dolphin skin is used for the transition between the laminar and the turbulent boundary layer [7]. The same principle is used in the golf ball. By creating the leading-edge serrations on VAWT’s blade. Studied the performance improvement at the low tip speed ratio of the VAWT.

Rather than disturbing the main flow, we can introduce a flap in the VAWT, which is inspired by the bird's wing feather. Also experimented with different flap sizes and positions with aerodynamic characteristics. He observed that the flap with ore length helps for the flow separation. A few birds are found to have highlighted at the wing upper surface toward the end via air to respond to the blast. Here, the feature was followed by the flap corresponding angle and position of the flap where it will give
maximum efficiency and the design of a flap is also very simple [8]. Experimented on the aircraft by modifying the wings with the addition of a flap. It found that 11% increase in lift force in the airfoil.

![Figure 1. Design of Flap](image)

In the present study, to improve the efficiency of the VAWT, the flap with fixed angles are studied and results are presented. Finally, three modified blades with the flap are studied and the performance coefficient and torque coefficient using experimental techniques are presented.

2. Method of Study

This study aimed to make the modified blade with the addition of flap in the corresponding position. Few steps should be achieving in it are design of the 3D model of the modified blade. Next step of our work is the CFD simulation of the modified blade using ANSYS fluent software.

First we have chosen the NACA0015 series blade according to the literature survey. After that the rotor, and the three blades are designed and the domain is modelled using the CATIA V5 software. Then the models were imported into the ansys and the necessary input parameter were added to that. And the CFD were done by using the ANSYS software. Finally the fabrication were done by using the 3D printing machine.

3. System Design

Using the CATIA V5 software, 2D modeling is done for the rotor, blade, and rectangular domain. First NACA0015 profile points have been imported to Catia software. Then the NACA0015 series blade (as shown in figure 2 is done. According to the blade size, the rotor is modeled (as shown in figure 4. A domain is modeled according to the literature survey as shown in figure 3. The modeling of NACA0015 blade flap (as shown in figure 1) has been done.
Figure 2. Design model of Rotor

Figure 3. Design model of Domain

Figure 4. Design model of NACA0015 Blade
Table 1. Geometry of turbine.

| Geometry of turbine | Dimensions |
|---------------------|------------|
| Airfoil blade selected | NACA0015 |
| Chord length (C) | 78mm |
| Turbine radius (R) | 250mm |
| Number of blades (N) | 3 |
| Solidity (NC/D) | 0.78 |
| Height | 350mm |

Table 2. Boundary conditions in domain.

| Wall | Boundary condition | Condition |
|------|--------------------|-----------|
| Inlet | Velocity | 6 m/s |
| Outlet | Pressure | 0 Pa |

Table 3. Different zones and assumed conditions.

| Zone | Condition |
|------|-----------|
| Turbine | Rotating |
| ODGV | Stationary |
| Domain | Stationary |

Figure 5. Schematic representation of domain size.
3.1 Study of mesh

The flow field is analyzed and geometry, mesh, stimulation were carried out by using Ansys fluent. Then import the model which is created by using the CATIA V5 software. The triangular method is chosen for the meshing. Stimulation is done after applying the all necessary and required conditions. Edge sizing is done for all the components (blade, rotor, domain). Then the after choosing the triangular method. Face sizing is also done for all the components. After the inflation, interfaces are done, Mesh parameters are defined. Mesh is generated. Hence the meshing model is shown in figures 6-7.

![Meshing of the domain](image1)

**Figure 6.** Meshing of the domain

![Meshing of Rotor](image2)

**Figure 7.** Meshing of Rotor

| Parameter     | Value                |
|---------------|----------------------|
| Nodes         | 120418               |
| Elements      | 142836               |
| Mesh Metric   | Orthogonal Quality   |

**Table 4.** Mesh Details
4. Results and Discussion

The contour of the pressure and velocity are took by using the software called Tecplot 360 + chorus and from the values of Cm which is exported from the result of the CFD stimulation. By keeping the values of the Cm and TSR we can find the value of the Cp by using the equation $C_p = C_m \times TSR$ which is shown in the tables 5-6. For the profiles in the presence and absence of flap, Cp and Cm values are tabled in the tables 5-6 and plotted in the graph in which blue line indicates the value of Cp after and green line indicates the values of Cp before modification in the figure 8 and also brown line indicates the value of Cm after and blue line indicates the values of Cm before modification in the figure 9.

| TSR | $C_p$ | $C_m$ |
|-----|-------|-------|
| 1   | 0.34  | 0.34  |
| 2   | 0.37  | 0.185 |
| 3   | 0.4   | 0.133333 |
| 4   | 0.33  | 0.0825 |

| TSR | $C_p$ | $C_m$ |
|-----|-------|-------|
| 1   | 0.46  | 0.46  |
| 2   | 0.48  | 0.24  |
| 3   | 0.49  | 0.163333 |
| 4   | 0.45  | 0.1125 |

Figure 8. TSR Vs $C_p$ graph before and after modification
5. Conclusion

Considering the performance of Vertical Axis Wind Turbine of the NACA0015 blade, animation of the pressure and velocity shows a lot of difference. The stimulation is done and the contour of both velocity and pressure which is obtained is a nice contour. Therefore addition of flap in NACA0015 series blade shown some improvement of $C_p$ value when plotted the graph against TSR. After number of simulations an optimum value of $C_p$ is obtained for the TSR from 1 to 4. Before modification we got $C_p=0.4$ at TSR 3, but after the modification we got the $C_p$ as 0.49. From this observation, we can conclude that performance has slightly improved. Fabrication of the VAWT with the NACA0015 series blade was done with the help of the 3D printing machine and also experimental testing will be done as our future work. Then we can attempt NACA0015 series blade wind turbine with low cost for wind application and also do the experimental analysis.

Nomenclature:

| Symbol | Description |
|--------|-------------|
| C      | Blade chord length (mm) |
| CFD    | Computational fluid dynamics |
| $C_m$  | Torque coefficient |
| $C_p$  | Power coefficient |
| HAWT   | Horizontal axis wind turbine |
| VAWT   | Vertical axis wind turbine |
| $N$    | Number of blades |
| $L$    | Length of the blade |
| $R$    | radius of the wind turbine (mm) |
| TSR    | Tip speed ratio |
| $P$    | Power (W) |
| $\theta$ | azimuth angle (°) |
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