EFFECT OF PITCH ANGLE ON BLADE - TOWER INTERFERENCE ON HAWT

N. I. Haroon Rashid¹, S. Nadaraja Pillai², C. Senthil Kumar³.
¹Research Scholar, Department of Aerospace Engineering, MIT Campus, Anna University Chennai, TN, India, aeroharoonrashid@gmail.com
²Department of Aeronautical Engineering, J. J. College of Engineering & Technology, Tiruchirapalli, TN, India, aeropillai@gmail.com
³Department of Aerospace Engineering, Madras Institute of Technology, Anna University, Chennai, TN, India, cskumar@annauniv.edu

ABSTRACT

In the wind turbine, the distribution of wind is altered by the presence of the tower. For upwind rotors, the flow of wind in front of the tower is redirected thereby reduces the torque at each blade. The performance of the wind turbine is affected by such influence of interference. Hence, it is important to understand the flow interference between blade and tower. In this research, the wind turbine blade with various pitch angles has been studied both computationally and experimentally. The result shows that the influence of interference leads to negative pressure region on the tower where the blade interference occurs. Hence this leads a slowdown of rotor locally for every 120 degree, this in turn affect the power performance and decrease the structural stability.

Keywords: Tower Shadow, Interference, HAWT, pitch angle

Introduction

For horizontal axis wind turbine, the interaction between the tower and the blade creates flow complexity and leads to reduced power performance. Even though various unsteady effects in the wind turbines such as atmospheric boundary layer, turbulence intensity of the upstream flow, yaw effect of the nacelle, wake of the neighboring turbines, upstream blockage effect dominates; this has been discussed by many researchers. However the interference between the wind turbine blade and its tower and also the influence of the blade pitch angle interaction needs further more research attention. This effect is discussed widely as tower shadow and most of the effect on downwind turbine wake model is discussed by Wang and Coton. Also they concluded that the discrepancies arise when the angle of attack of the blade experiences higher value. Experimental study by Orlando et al., found that there is 35% of velocity reduction in the anemometer reading the anemometer is in the downstream of the turbine tower.

Chattot studied with vortex model for the simulation of the tower shadow and its effect on the blade working conditions as analyzed with the blade root flap bending moment. The importance of rotor in the upwind and downwind configurations and its importance is discussed by chattot. Amada et al., showed the decrease in power output by around 6% due to the various effect including tower shadow. Dolan and Lehn discussed about the normalized power output and its effect in terms of wind shear and the tower shadow effect. They found that the tower shadow and wind shear combine reduce 6% of the power output. In this research wind turbine model has been made both computationally and experimentally in order
to study the interaction between tower and blade. Leishman studied about the induced velocity field produced by the vortical wake behind the turbine, the various unsteady aerodynamic issues associated with the blade sections, and the intricacies of dynamic stall. Anemometer in the wind turbine is kept in the nacelle part where the most of the blade rotation wake influences. Lubitz studied about the tower shadow influence on the anemometer data. Various research has been done in wind turbine and the component influence on aerodynamics of wind turbine, however there are limited study carried out in the area of interference or the effect of rotor with various parameters needs a extensive study. The issue on pitch angle of the blade and its influence on interference between blade and the tower is discussed in this paper.

**Computational Model Geometry and Flow conditions**

The computational domains for the blade, hub, and tower are created and meshed. Mesh is carefully checked so that there is no discrepancy which leads to the discontinuity. To generate the volume mesh for the three bladed rotors, the 120 degrees periodicity of the rotor is exploited by only meshing the volume around the blades. The computational domain created using tetrahedral elements, extending in the axial direction roughly 4 diameters upstream and 8 diameters downstream of the turbine.

In the plane of the rotor, the domain diameter is 4 times that of the turbine. Second stage involves creating the meshing element. One of the major difficulties in CFD modeling is to mesh the flow domain near the rotor. The grid should be fine enough to capture the details of geometry and flow field at these locations, but not too large to handle and then the succeeded meshing models are exported for the analysis.

HAWT geometry with 108m tower height and 46m blade height has been created computationally. The model is surrounded by the fluid elements of tetrahedral shape with more than 1 million elements. The model rotor boundary condition is set as rotating reference frame in order to create the required rpm. The rotor has been rotated to 5, 10, 15, 20, 25 rpm corresponding to the wind speed. The computational turbulence model used is $k – \varepsilon$, because it is more general and predicts well in general. The model made computationally and the domain created for flow analysis is shown in Figs. 1 & 2.
Experimental Study

The experiments were carried out using low speed wind tunnel at MIT for the test section velocities of 10 m/s, 20 m/s and 30m/s. The size of the test section is 3 ft x 4ft x 6ft, where the turbine model is scale down to 1:333. 64 channel pressure scanner is (DTC-Initium) used to measure the pressure on the tower surfaces of the wind turbine model. There were 32 pressure tapings in the wind turbine model tower and it is shown in fig. 3. The pressure tapings are connected to the pressure scanners and to capture the pressure distribution on the surface of the tower.
Fig-3 Experimental Model in Wind Tunnel

Fig. 4 Coefficient of Pressure (Cp) at various cross section of the blade.
Fig. 5 Coefficient of Pressure (Cp) at various cross section of the Turbine tower

Fig. 6 Schematic representation of Wind Turbine with pressure tapings at different levels

Fig. 7 Experimental Pressure distribution (Cp) value at different levels of fig. 6
Results and Discussions

From the computational study the results for the coefficient of pressure has been obtained for the various blade cross section at the locations 10, 20, 30m from the blade root shown in Fig. 4. The pressure distribution for the aerofoil on the pressure side and suction side are shown in the Fig 4. The suction side pressure is very well constant and this could be due to the influence of tower. In the other case where the pressure coefficient for various locations of the tower geometry from 10, 20, 30, 40, 70m has been obtained and shown in Fig. 5. For 70m location there is no influence of the blade and tower interaction, hence the pressure distribution looks like normal circular cylinder. For other cases like 10 to 40m tower height from the hub height, the influence is clearly shown. Here the pressure difference created is small and also all are in the negative pressure region. Even though the pressure difference causes a force but it is very small.

Fig. 6 shows the schematic representation of the wind turbine model kept in the wind tunnel with pressure tapings. The pressure distribution (Cp) of the different levels shown in Fig. 7. It shows that the effect of the tower is visible at the levels 4, 5 and 7. In the levels 1, 2, 3 shows the similar value or pattern whose value is different from levels below. Cp affected by the blade influence in the tower and the one which is not affected from the interference is shown in fig.7. The extensive study in the wind tunnel is needed much more to get the information about the interferences.

References

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