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ACOUSTIC COMPARISON OF WIND TURBINES

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ABSTRACT

The efficiency of a wind turbine is directly related to the generated power. The power varies depending on the torque occurring in the rotor. Additionally, the noise levels of wind turbines are as important parameter as their efficiency. Hence, in this study, torque and acoustic values of three different wind turbines were calculated using aerodynamic analysis. Two horizontal and one vertical type wind turbine models were used for analyses. When the torque results are investigated, it is seen that turbine 3 gives the highest torque value of 37,32 Nm and turbine 2 gives the lowest torque value of 9,48 Nm. However, turbine 3 has the lowest noise level of 58,2 dB and turbine 2 has the highest noise level of 63,3 dB.

Keywords: Wind turbine, Aerodynamic analysis, Acoustic.

1. INTRODUCTION

Aerodynamic analysis is a crucial step in the development phase of a wind turbine. After an aerodynamic analysis is carried out, the torque value can be determined. Also, the noise level can be determined and some modifications can minimize it. There are various works on the subject of aerodynamic performance (AP) of wind turbines in the literature.

The flow structure of a circular open jet was evaluated. Theory and experimental correlation were joined to expand our knowledge of fully developed turbulent jets. Mathematical correlations were reproduced to obtain the actual power of the jets. The corresponding increase in power generation from small wind turbines was discussed [1].

An air-scale wind turbine model with active single-blade motion and torque control was described. The model was managed by a control and monitoring system similar to a real wind turbine and can simulate steady-state and transient motion at the Boundary Layer Research Unit of Politecnico di Milano for Wind [2].

The importance of measuring wind turbine efficiency was emphasized by two experiments that use experimental measurement methods and complement existing scientific results [3].

A new wind turbine control system that provides precise power during transitions between different controllers. The study presented a predictive control method using a linear model for the application of an offshore wind turbine control system [4].
Yearly energy generation, load analysis, variable structural design, and wind farm operational modeling to perform non-standard system-level optimization was integrated [5].
The development of wind turbines for electricity generation from the late 19th century to the present and some key features were reviewed. Today's commercial turbines were not the giant prototypes of the 1970s-1980s that were built from government-sponsored wind programs [6].
A brief description of composite material for wind turbine designs was investigated. Evaluates needs for existing wind turbine equipment, installations, and equipment. Apart from traditional wind turbine blade composites (glass/epoxy composite), natural composites, hybrid composites, and nanoengineered composites have been investigated. It reviews production technology for wind turbine composite, as well as testing and modeling methods [7].
To determine the impact of wind shear and turbulence on wind turbine performance, the wind profile of flat land up to 160 meters in height was analyzed. The shape of the profile extends to wind shear without any breaks, and in many cases, local dominance was also observed in the profile [8].
The wind turbine load simulation of the NREL 5 MW reference wind turbine was performed in diabatic mode. The diabatic mode was included in the inlet wind field in the wind and rotation profiles. The simulation was performed at the height of the turbine hub with an average wind speed of 3 to 16 m/h. Loads were considered as sums of equivalent damage loads at different wind speeds weighted by wind speed and stability distributions. Four locations with several wind speeds and stability distributions were used for comparison [9].
Mountain passes can be potentially useful locations for wind farms due to the connectivity of roads and energy transfer infra-structure. However, little is known about wind behavior and turbine response in these regions. The paper used altitudinal wind data from a mountain pass in Switzerland to describe the observed wind factors and overall wind turbine performance under these conditions [10].
Two-Dimensional Lift Airfoil an airfoil optimization expression was a parameter of drag and lift. Since takeoff height was proportional to wing thickness, aerodynamic optima were shown in thick wings, which were structural advantages. The performance of the objective function in a vertical axis wind turbine using a genetic optimization algorithm was calculated using the field potential flow solution and two-dimensional columns calculated by XFOIL to create an airfoil [11].
The aerodynamic calibration programs carried out in wind turbines over the last decade were reviewed. It was largely based on the results of four projects under the International Energy Agency (IEA), namely IEA Tasks 14, 18, 20 and 29. Five field organizations (IAA missions 14 and 18), NASA's Level VI Turbine Energy Laboratory at Ames, a wind tunnel (IAA mission 20), and a Mexican turbine were installed at a large low-speed wind farm in Germany and the Netherlands. DNW (IAA Study 29) [12].

The space requirement of the rotor and the number of rotor blades were examined in terms of torque, power, and thrust concepts. Three-dimensional flow analysis was performed using SolidWorks flow simulation [13].

Aerodynamic optimization of an airfoil was carried out using computational fluid dynamics (CFD) analysis to improve the AP of the wing. The widely preferred NACA0012 aerofoil was optimized for several AoA values using CFD software [14]. The AP of NACA 4412 and S809 airfoils was investigated. For comparison, CFD analysis of two-dimensional (2D) flow over NACA 4412 and S809 airfoils was used. Lift and drag forces were used as performance parameters [15].

Velocity distribution and turbulence energy were studied for the bullets on different shapes of the tips. Three different bullet nose shapes were used in the analyses [16]. The thrust distribution along a propeller diameter section with the gradual increase of the hub diameter was investigated. It was shown that the max. thrust of a propeller was obtained in the region between 75% and 85% of the propeller length [17]. At the end of the literature survey, it was observed that different studies exist related to wind turbines, and many different studies on AP of wind turbines were performed in the literature.

2. ANALYSES

All analyses are performed using the SolidWorks Flow Simulation program. Three different wind turbine models are given in figure 1, figure 2, and figure 3. Wind speed is taken as 13 m/s which is the operating speed level of wind turbines. Diameter of the Model 1 and Model 2 is chosen as 2m, model 3 is chosen as 0,6m, and height of the Model 3 is 0,6m.

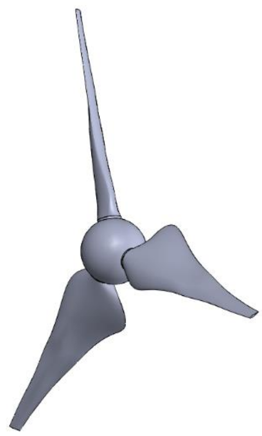

Figure 1. Solid model of wind turbine 1 [18]

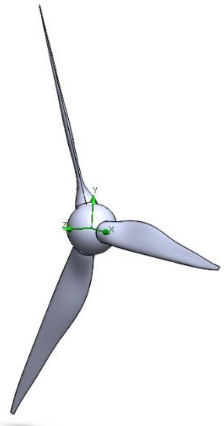

Figure 2. Solid model of wind turbine 2 [19]

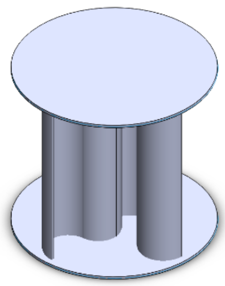

Figure 3. Solid model of wind turbine 3 [20]

3. RESULTS

Flow trajectories of velocity on wind turbine 1 are given in Fig. 4. When flow trajectories were investigated, it was seen that turbulent regions occur around and behind the propeller. The acoustic power level of Wind Turbine 1 is given in Fig. 5.

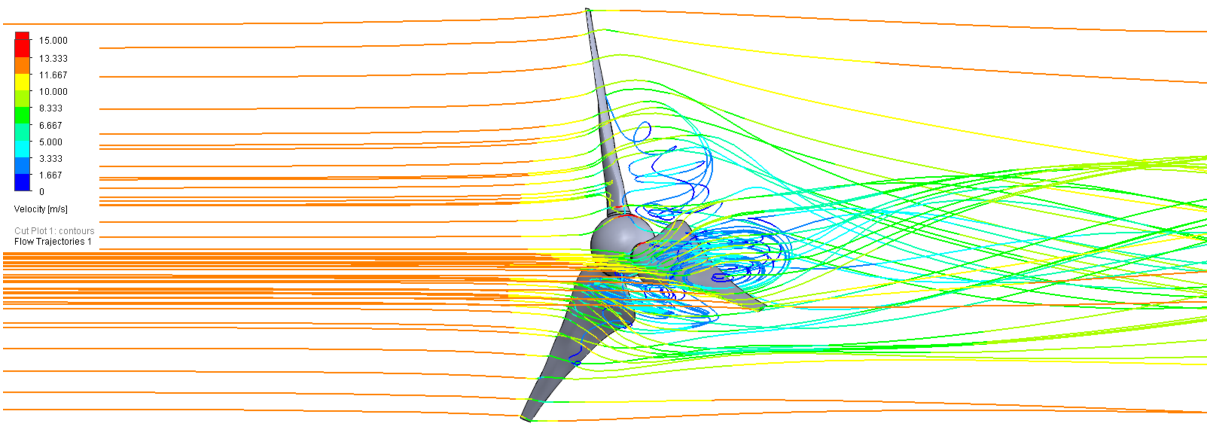

Figure 4. Velocity distribution of wind turbine 1

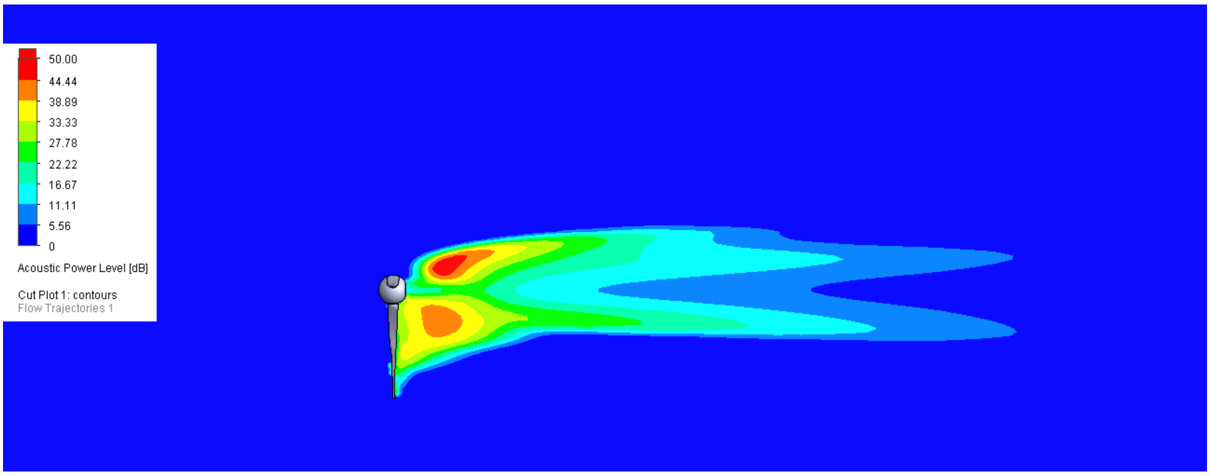

Figure 5. Acoustic power level of wind turbine 1

Flow trajectories of velocity on wind turbine 2 are given in Fig. 6. When flow trajectories were investigated, it was seen that turbulent regions do not occur around and behind the propeller. The acoustic power level of Wind Turbine 2 is given in Fig. 7.

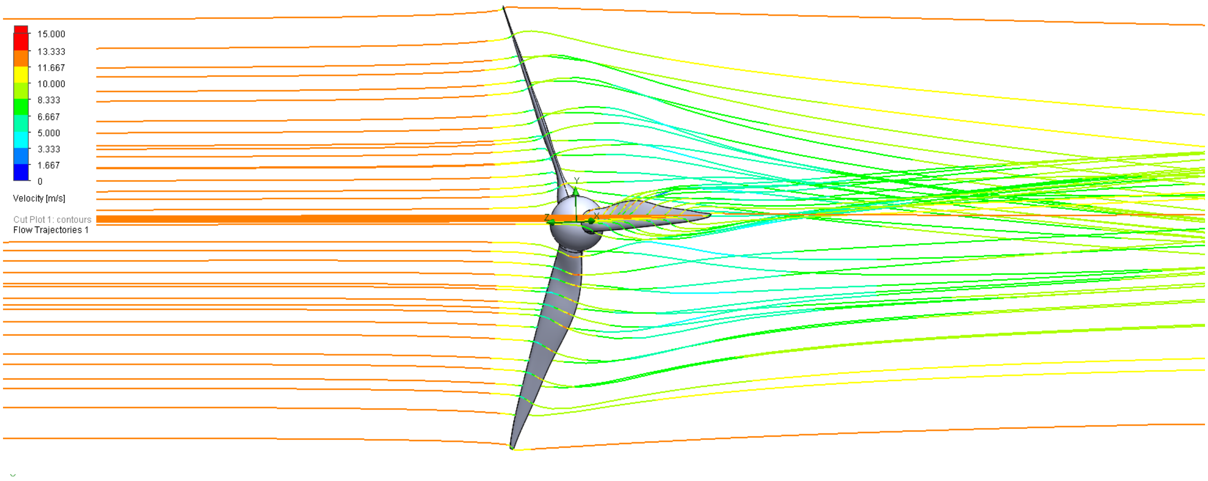

Figure 6. Velocity distribution of wind turbine 2

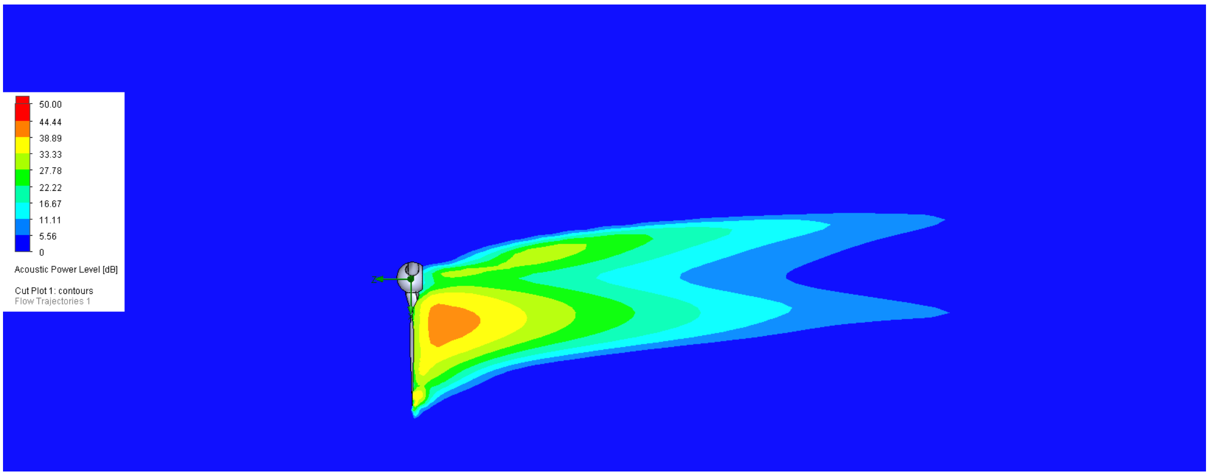

Figure 7. Acoustic power level of wind turbine 2

Flow trajectories of velocity on wind turbine 3 are given in Fig. 8. When flow trajectories were investigated, it was seen that turbulent regions occur around the propeller. The acoustic power level of wind turbine 3 is given in Fig. 9.

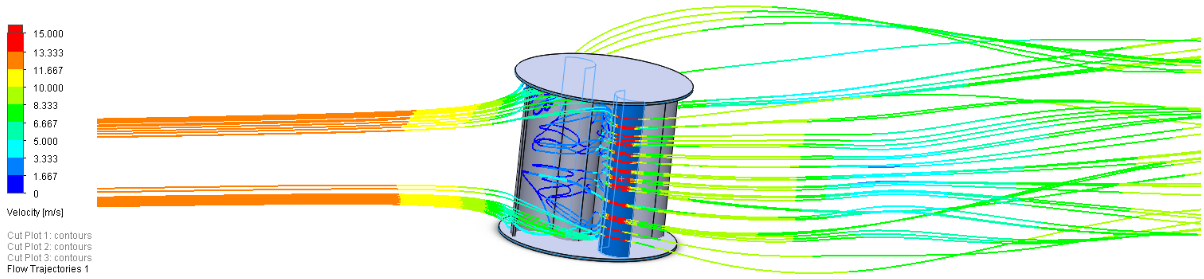

Figure 8. Velocity distribution of wind turbine 3

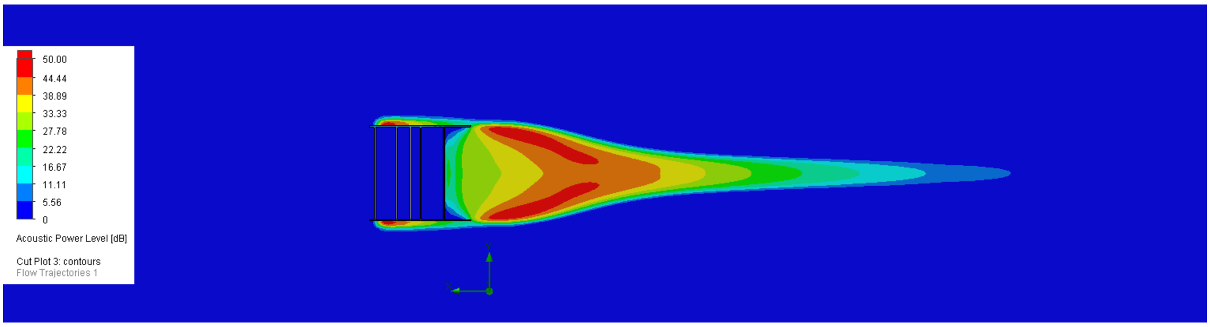

Figure 9. Acoustic power level of wind turbine 3

The torque results of three different wind turbines are listed in Table 1.

Table 1. Torque Results

	Torque (Nm)
Wind turbine 1	18,64
Wind turbine 2	9,48
Wind turbine 3	37,32

The acoustic power level results of three different wind turbines are listed in Table 2.

Table 2. Acoustic Power Level Results

	Acoustic Power Level (dB)
Wind turbine 1	61,4
Wind turbine 2	63,3
Wind turbine 3	58,2

4. CONCLUSIONS

In this study, torque and acoustic values of three different wind turbines were calculated using aerodynamic analysis. Two horizontal and one vertical type wind turbine models were used for analyses. When the torque results are investigated, it is seen that turbine 3 gives the highest torque value of 37,32 Nm and turbine 2 gives the lowest torque value of 9,48 Nm. But when the flow distribution is investigated turbine 2 was the model that disrupted the wind flow regime the least. However, turbine 3 has the lowest noise level of 58,2 dB and turbine 2 has the highest noise level of 63,3 dB. These mean that the environmental effect of turbine 3 is minimal level.

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