International Journal of Scientific Modern Research and Technology
(Volume: 11, Issue: 3, Number: 1)
ISSN: 2582-8150

Analysis of Vertical Axis Wind Turbine Blades

Ashish Patil[1], Mahendra Prajapati[2], Prof. N. V. Saxena[3]
[1]Research Scholar,[2]Assistant Professor, [3]Head and Professor
[1, 2, 3]Department of ME, MIT, Bhopal, India

Abstract: Aerodynamic noise generated by wind turbines has gained significant attention due to its potential impact on human health and well-being. Tip noise is produced by the vortices shed from the blade tips as they rotate through the air. Leading-edge inflow noise arises from the interaction between the incoming wind and the blade's leading edge. Understanding and mitigating these noise sources are crucial for improving the acceptance and sustainability of wind energy systems. Mitigation techniques for trailing edge noise have witnessed substantial progress in recent years. The implementation of serrations or novel trailing edge designs has been effective in reducing noise levels. Serrated trailing edges create small vortices that interact with the larger turbulent structures, effectively diminishing noise generation. Active flow control methods, including boundary layer suction or blowing, have shown potential in altering the flow characteristics and mitigating noise at the leading edge. Developments in noise mitigation techniques include the application of porous materials on blade surfaces to absorb sound and the use of active noise control systems to counteract noise emissions. Porous materials placed strategically on the blade surface can attenuate noise by absorbing and dissipating sound energy. Active noise control systems employ sensors and actuators to detect and counteract noise in real-time, providing an active noise reduction mechanism. Addressing the aerodynamic noise sources in wind turbines is essential to minimize the impact of wind turbine noise on human health and enhance the acceptance of wind energy systems.

1. INTRODUCTION

Numerous academics have done studies to determine the relationship between wind turbine noise and its potential effects on the mental and physical health of adjacent inhabitants in response to noise complaints made by communities where these wind turbines are situated. An expert panel investigating the effects of wind turbine noise on human health (Bolin &Åbom, 2013) found enough data to prove a connection between wind turbine noise and displeasure. The panel also discovered scant support for a causal link between wind turbine noise and disturbed sleep. Studies on wind turbine noise perception and annoyance by Pedersen and Waye (Pedersen & Persson Waye, 2004) revealed that, at the same A-weighted Sound Pressure Level (SPL), more respondents were irritated by wind turbine noise than by community noise sources, and that the proportion increased quickly with rising SPL as can be seen in Figure 1. The problem of irritation is shown to be more prevalent in rural landscapes than in urban settings, and it can cause sleep disturbances and obstruct psycho-physiological recovery (Pedersen & Persson Waye, 2007). These studies show that wind turbine noise can be annoying and, in some cases, can interfere with sleep. Due to the negative effects on adjacent towns that have been mentioned above, there is a need to further address the issue of wind turbine noise.

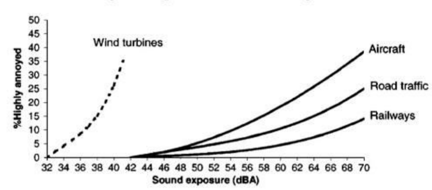


Fig. 1. A comparison between dose-response relationship of perception of wind turbine noise and transportation noise

The sole force that is exerted on the blades of a Darrieus turbine is tension, as the blades are supported in a manner that minimizes the amount of bending stress that they are subjected to. These turbines have two or three blades that are either curved or straight and have a cross section that is similar to an airfoil or a constant chord length. Their low initial torque can be attributed to the fact that Darrieus turbines cannot start their rotation without the assistance of an external power source. At the University of Reading in the United Kingdom, Musgrove (Musgrove,1987,) carried out an exhaustive investigation of the cross-section of blades. The research conducted by Musgrove resulted in the development of the H-blade shape utilized by Darrieus, which included a blade that was straight. The design and production process of H-blades is significantly less complicated than that

 ISSN: 2582-8150

of curved blades; in addition, the performance of H-blades is significantly higher than that of designs that are more traditionally used. Musgrove's designs have seen significant development over the past few decades, transitioning into fixed-pitch straight-bladed H-rotors. These H-rotors come in a variety of configurations, including articulating, tilted, and helical H-rotors. However, the acceptance of Darrieus depends on how cost-effective they are ($/kWh), how dependable they are, and how easily they can self-start even when the wind speed is low.

Lift type (Darrieus)

For a given same size of VAWT Lift type produces more power than Drag type. So, the focus of this study will be on Lift type wind turbines as the aim to harness maximum power from the turbine but at low noise levels. VAWT can be of very different shapes like:

1) H-type Turbines

2) Helical Shape Turbines

3) Egg- Beater type with curved blades

Darrieus type VAWT This device was conceived by and patented by a French engineer named G.J.M. Darrieus in the year 1931. In comparison to the Savonious, the Darrieus possesses higher aerodynamic performance, a more straightforward design, and a lower price point. Since these machines are based on the lift force, they are designed to harvest more energy from the wind per unit of swept area than other comparable machines. The aerofoils of the Darrieus move forward in a circular path through the air, and the relative motion between the direction of wind flow and the airfoil of the blade provides a small net force in the forward direction, which imparts a positive torque to the rotor.

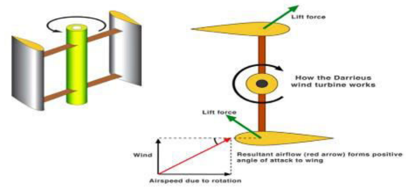


Figure 2: A design of Darrieus turbine with the direction of lift force on the blade surface. (Jin at al.)

II. PROBLEM IDENTIFICATION

Mechanical Noise Sources

The nacelle of a wind turbine has a number of moving parts, such as the gearbox, the generator, and the cooling fans, all of which contribute to the generation of mechanical noise. The majority of mechanical noise is tonal, which indicates that it has peaks at particular frequencies; this type of noise is more annoying to the human ear than wideband noise. Despite this, it is possible to drastically reduce the amount of mechanical noise by properly isolating the nacelle with sound-absorbing materials and vibration suppression (Wagner et al., 2012)**.**

Aerodynamic Noise Sources

The term "aerodynamic noise" refers to the flow-induced noise that occurs as a result of the interaction between flow structures and the blade wall. Aerodynamic noise from wind turbines can be broken down into two distinct categories: inflow turbulence noise and airfoil self-noise. The relative contribution of individual noise sources is illustrated in Figure 2, which may be found here. These noise sources and the strategies they use are going to be looked at in greater detail in the next sub-sections.

III OBJECTIVES

Based on the above information design modifications will be done on the turbine blades and analyze them on Solid works flow simulation to get the perfect shape with low noise.

a) Design using Solidworks Software

b) Proper material Selection

c) Performing CDF analysis on the VAWT Blades to

IV. METHODOLOGY

The primary objective of the primary objective of designer is to maximize the aerodynamic performance or efficiency that is power extracted from wind. But this objective should be met with other mechanical strength criteria and economical aspects.

1)Blade shape**:** One of the biggest factors affecting the performance of wind turbine is shape and orientation of blade cross section. A wind turbine gives maximum performance when lift slash drag ratio is maximum and this is called an optimum angle of attack. Even though the flow velocity is uniform along the length of the blade, blade velocity increases as we move towards the tip of the blade. The amount of trailing edge noise that is produced by a particular aerofoil is highly dependent on the aerofoil's shape.

2) Blade length: The length of the blade is another key factor of wind turbine as the power extracted by wind turbine is directly proportional to the square of length of the blade. But with increase in blade length deflection of blade tip due to axial wind force also increases. So blind increase in the length of blade only lead to the unreasonable swing of blades. For this project the length of the blades are taken as five feet and the width is considered as one feet.

3) Number of blades**:** As the number of bleeds of wind turbine increases the efficiency increases. But when we move from 2 to 3 blade design there is an increase in the efficiency of wind turbine by approximately 3%.

4) Blade materials**:** The performance of wind turbine blade also depends on the material used to build them. Nowadays many wind turbine blades made up of glass fibres and therefore this research is done by considering that the wind turbine bleeds a made up of glass fibres.

Blade Design No.1**.**The below mentioned design is the modified form of blade of the wind turbine since the purpose of this study is to minimize the noise generated by the trailing edge so brushes are attached to the trailing edge of the blade.

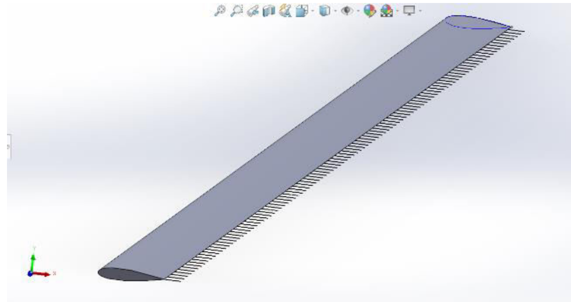


Figure 3: Modified wind turbine blade 1

Blade Design No.2**.**

The NACA 0012 wind turbine blade has been reimagined as the design that will be shown in the following paragraphs. The trailing edge of the blade in this design has a tapered and helical shape, and the noise that is created by this design is evaluated using the flow simulation in Solidworks.

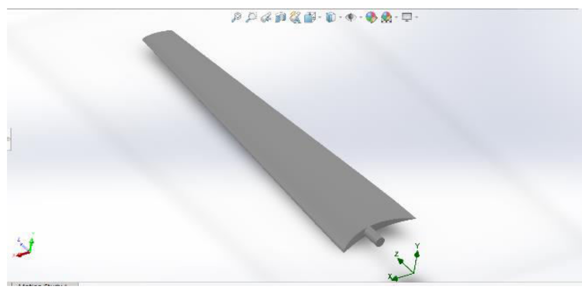


Figure 4: Modified wind turbine blade 2

Vertical Axis wind Turbine Blade Materials
In this research we have analyzed the different shapes of blades made up of glass fibres and on porous medium.

Glass fibre Material
Glass is a fibrous non-metallic material that is used extensively in a variety of modern industrial applications. A method that dates all the way back to 1713, spinning glass into yarn that can then be used in clothes is a very old technology. The gown consisted of bundles of spun glass fibre that had been bound together with silk threads. Despite this, the fabric was not flexible enough to be draped and was too heavy to be worn. The principal forms of silica that are utilized in the manufacturing of glass fibres include sand, limestone, stone ash, and borax.

Porous Medium:

Application to an aerofoil raises a number of research-based questions. How is the surface applied to be porous? By material selection for the trailing edge region, post-manufacturing machining, or another method? What is the configuration of the trailing edge's internal structure - a single cavity separating the upper and lower porous surfaces, two divided and sealed cavities, or something else?

V. RESULTS AND DISCUSSION

Simulation set on Solidworks flow simulation:
The above mentioned two blades are analysed for the noise generated by blade at 25m/s as inflow air speed with zero angle of attack.

In case of blade design 1 it is divided into two main sections one is the blade itself and the other is the brushes which are attached to the blade, the blade and brushes are considered to be made up of glass fibre material, but porous medium is applied on the brushes is isentropic in nature.

The following CFD analysis is carried out assuming the following assumptions:

1) The flow of air is steady state.
2) The angle of attack is zero.
3) The air is flowing with the constant velocity of 25m/s.
4) The blades of vertical axis wind turbines are made up of Glass fibre.

Analysis of blade Design No.1.

Considering that the blade is made up of glass fibre and the porous medium is applied at the brushed applied at the trailing edge.

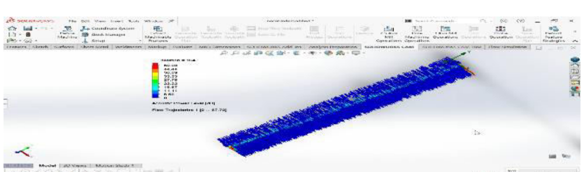


Figure 5: CFD Analysis of noise - modified blade design 1

above shows the overall noise produced by the blade.

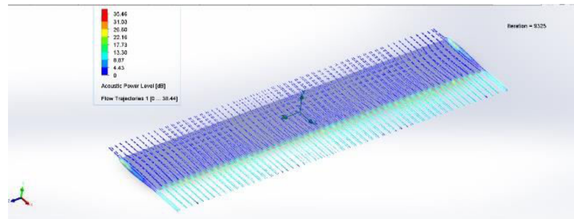


Figure 6: NACA 0012 Blade simulation on Solidworks flow simulation.

The above shows the noise generated by original NACA 0012 aerofoil when the angle of attack is zero and with air speed of 15 m/s. It is clearly evident from the simulation result that it is generating noise along the edges of the blade whereas the noise generated by the modified blade is less along the edge of the blade, which clearly shows that the brushes at the end of the blade edges has reduced the eddies collision which is the main cause of vibration and noise generation in wind turbine blades.

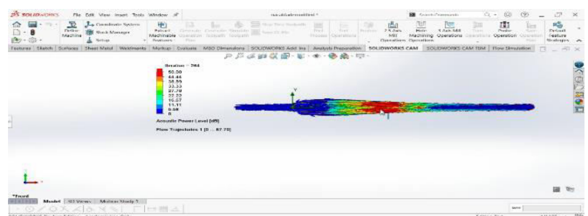


Figure 7: Top view of modified blade design.

Also, from the above it is evident that though the modified blade is not generating much noise along the edges of the blade, but it is generating noise at both the ends of the blade and to suppress this noise the blade design needs to be optimized. One way to reduce such noise is to make the top and bottom ends of the blade in curve and smooth shape so that the sharp edges can be removed.

Findings of the CFD Analysis:
From the CFD analysis of the which is made up of glass fibre and the porous medium is applied at the brushes at the trailing edge, it has been observed that there is not much change in the noise at the trailing edge and the leading edge of the blade, this is because of closely spaced fibres that have a brush-like appearance which reduce the noise produced by a trailing edge. An additional theory proposes that the porous nature of the brushes is responsible for

reducing the turbulent fluctuations in the boundary layer, which are the root cause of trailing edge noise.

Analysis of Blade Design No.2.

In the CFD Analysis of blade design no.2 i.e. Tapered, and helical blade two cases are considered

1) when the blade is made up of Glass fibre material and second is when the porous medium is applied on the whole blade which is made up of glass fibre.

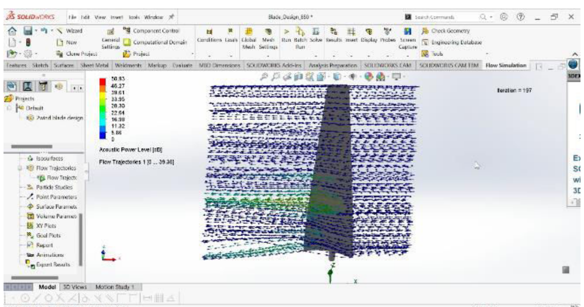
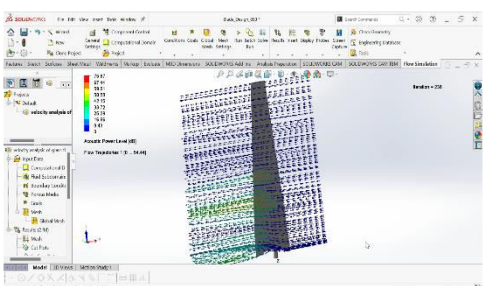


Figure 8: CFD Analysis of when porous medium is used:

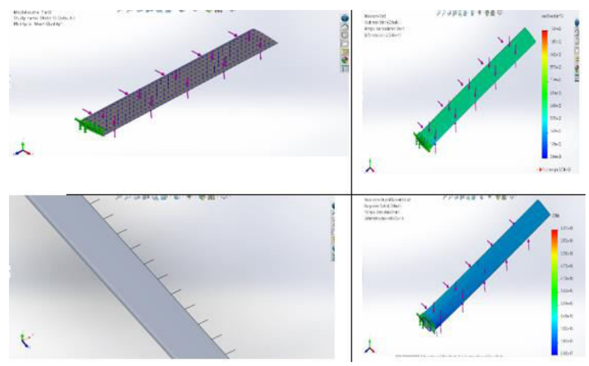


Findings:

1) In case of tapered helical blade, it has been seen that as the width of the blade increases the noise level of the blades increases.
2) The second most important observation from the CFD analysis is that when the porous medium is used on the entire blade length the overall noise of the blade has been increased. The noise generated by the porous aerofoil's is significantly louder than that generated by the non-porous aerofoil. This may be because the porous aerofoil's have a higher roughness noise level, which is associated with boundary layer turbulence scattering over a non-smooth surface. The aerodynamic performance of porous aerofoil's is degraded, as measured by a loss of lift and an increase in drag, both of which are inversely proportional to the resistivity of the porous material. This results in a poorer overall performance.

Stress Analysis of the modified blades:

On performing the stress analysis of the blades, it has been found that the stress developed in the modified blades are under limits so not any structure failure developed in the blades. Since the focus of this project is to understand the techniques of noise mitigation from the vertical axis wind turbine blades due to air flow only not much detailed analysis has been performed.



VI. CONCLUSIONS

A review of the different approaches to lowering the noise at the turbulent boundary layer's trailing edge reveals that several of these methods have been either considered or used in previous research. Because they disperse the impedance mismatch over a greater distance in the direction of the flow, trailing edge brushes, and porous surfaces can all, in some way, lessen the intensity of the turbulence that is caused by the interaction between the edge and the turbulent flow. Low noise aerofoil shapes work to modify the properties of the boundary layer that forms along the trailing edge in such a way that there is a reduction in the amount of noise that is scattered along the edge.

Out of the above two ways to reduce the noise produced by the trailing edges the brush fibre with porous medium on it is the best way to reduce trailing edge noise. However, there is a need to do the detailed experimental setup for optimizing it so that there will be no loss in the performance of the vertical axis wind turbine as the main aim of it is to produce the electricity. The make the blade design or manufacturing processes also need to be address as it may be complicated and can be very costly and therefore increase the coast of the whole vertical axis wind turbine, which may not be feasible even if they are low-noise aerofoils and very appealing option for noise reduction.

Also, the maintenance of the blades of vertical axis wind turbine can be an issue as the clogging of the porous surface by dirt and debris presents a potential problem in practical application. When we talk about wind turbines the biggest limitation is no matter how much efficient the wind turbine blade is, it is also important to see how much the energy in the wind is available in order to produce the electricity from it, this is the biggest limitation in harnessing the energy form the wind and to overcome this problem we need to find out the ways to increase the velocity of wind and at the same time try to minimize the turbulence associated with it. So much more work needs to be done in this area as this is not much explored.

Future Recommendations

To establish the ideal spacing between brush fibres, it is necessary to determine the optimal relationship. Furthermore, there is a need to optimize the designs of brush fibres in order to further reduce noise levels.

The redesign of the aerofoil shape at the trailing edge is essential. This redesigned section can then be designated as a porous medium. By adopting this approach, we can explore the potential benefits of incorporating different lightweight materials into the construction of wind turbine blades. Subsequently, an analysis should be conducted to evaluate the effects of these modifications. The ultimate goal is to achieve an optimal design for vertical axis wind turbine blades that not only minimizes noise but also maintains high efficiency.

In summary, the establishment of an optimal spacing between brush fibres and the optimization of brush fibre designs are crucial steps. Additionally, the redesign of the aerofoil shape at the trailing edge and the introduction of a porous medium can offer potential advantages. By considering different lightweight materials and conducting thorough analyses, it is possible to attain a vertical axis wind turbine blade design that significantly reduces noise while preserving efficiency.

REFERENCES

[1] Global wind energy policy and development. (2015). Wind Energy Essentials, 405-428. https://doi.org/10.1002/9781119040934.ch22

[2] Ahmed, N. A., & Cameron, M. (2014). The challenges and possible solutions of horizontal axis wind turbines as a clean energy solution for the future. Renewable and Sustainable Energy Reviews, 38, 439-460. https://doi.org/10.1016/j.rser.2014.06.004

[3] Bolin, K., &Åbom, M. (2013). Wind turbine wind turbine noise emissions wind turbine noise emissions. Renewable Energy Systems, 1843-1860. https://doi.org/10.1007/978-1-4614-5820-3_376

[4] Kinzie, K., Drobietz, R., Petitjean, B., &Hanhoff, S. (2013). Concepts for Wind Turbine Sound Mitigation. AWEA Windpower.

[5] Kinzie, K., Drobietz, R., Petitjean, B., &Hanhoff, S. (2013). Concepts for Wind Turbine Sound Mitigation. AWEA Windpower.

[6] Roy, S., &Saha, U. K. (2013). Computational study to assess the influence of overlap ratio on static torque characteristics of a vertical Axis wind turbine. Procedia Engineering, 51, 694-702. https://doi.org/10.1016/j.proeng.2013.01.099

[7] Akwa, J. V., Alves da Silva Júnior, G., & Petry, A. P. (2012). Discussion on the verification of the overlap ratio influence on performance coefficients of a Savonius wind rotor using computational fluid dynamics. Renewable Energy, 38(1), 141-149. https://doi.org/10.1016/j.renene.2011.07.013

[8] Wagner, S., Bareiß, R., &Guidati, G. (2012). Wind turbine noise. Springer Science & Business Media.

[9] Aslam Bhutta, M. M., Hayat, N., Farooq, A. U., Ali, Z., Jamil, S. R., & Hussain, Z. (2012). Vertical

axis wind turbine – A review of various configurations and design techniques. Renewable and Sustainable Energy Reviews, 16(4), 1926-1939. https://doi.org/10.1016/j.rser.2011.12.004

[10] Barone, M. (2011). Survey of techniques for reduction of wind turbine blade trailing edge noise. https://doi.org/10.2172/1029824

[11] Oerlemans, S. (2011, April 15). Wind turbine noise. Primary noise sources (Technical report) | Etdeweb. OSTI.GOV | OSTI.GOV. https://www.osti.gov/etdeweb/biblio/22144104

[12] D'Alessandro, V., Montelpare, S., Ricci, R., &Secchiaroli, A. (2010). Unsteady aerodynamics of a Savonius wind rotor: A new computational approach for the simulation of energy performance. Energy, 35(8), 3349-3363. https://doi.org/10.1016/j.energy.2010.04.021

[13] Finez, A., Jacob, M., Jondeau, E., & Roger, M. (2010). Broadband noise reduction with trailing edge brushes. 16th AIAA/CEAS Aeroacoustics Conference. https://doi.org/10.2514/6.2010-3980

[14] Afungchui, D., Kamoun, B., Helali, A., & Ben Djemaa, A. (2010). The unsteady pressure field and the aerodynamic performances of a Savonius rotor based on the discrete vortex method. Renewable Energy, 35(1), 307-313. https://doi.org/10.1016/j.renene.2009.04.034

[15] Geyer, T., Sarradj, E., &Fritzsche, C. (2009). Measurement of the noise generation at the trailing edge of porous aerofoils. Experiments in Fluids, 48(2), 291-308. https://doi.org/10.1007/s00348-009-0739-x