Trailing Edge Thickness Effect on Tonal Noise Emission Characteristics from Wind Turbine Blades

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DOI: 10.13111/2066-8201.2021.13.4.9

Received: 14 June 2021/ Accepted: 17 November 2021/ Published: December 2021

Abstract: *Broadband noise generation from wind turbine blades is one of the fundamental aspects of flow-induced noise. Besides the turbulent boundary layer flow over the blades, factors such as the angle of attack, the turbulence intensity, the trailing edge thickness of the blade and their shapes strongly influence the overall sound power levels at high frequencies, i.e. f > 8 kHz. In large operating wind farms, a trade-off between noise generation and power production is considered by power utility firms to maximize the return on investment (ROI) and minimize the fatigue damage on wind turbine components. The present work deals with the analysis of the thickness effect on trailing edge bluntness noise level at hub height average wind speeds of 7 m/s, 10 m/s. A semi-empirical BPM model was used to predict the sound pressure levels from the 37 m blade length of a 2MW wind turbine. The receiver configuration was fixed at a distance of 120 m from the source height of 80 m. The results demonstrated that as the trailing edge height increased from 0.1 % to 0.5 % of the local chord, the sound power level increased by ~ 17 dB for frequencies > 200 Hz, but decreased by 16 dB when the thickness is 0.1 % local chord. The computed results of the sound power level using the BPM model have been validated using experimental data and showed a good agreement for the tonal frequencies, f ~ 10 kHz, where the trailing edge bluntness noise becomes dominant.*

Key Words: *Sound power level, blade, wind turbine, turbulent boundary layer, wind speed*

1. INTRODUCTION

Wind power is growing at an exponential rate, with installed wind power capacity reaching over 500 GW globally. By far, the cheapest source of energy generation among all renewable energy technologies is wind power. As more wind power projects are installed, a growing concern of noise emissions from wind turbine blades is increasing due to adverse health effects on inhabitants living near wind farms. [1] Many policymakers are considering this issue seriously as noise generated from wind turbines is an impediment to the growth of wind energy growth. Modern megawatt-scale turbines have a large rotor diameter of size 100 m and above which contribute to the overall noise levels and cause annoyance for people living near wind farms. Fig. 1 depicts the wind turbine sizes for rotor diameter ranging between 17 m and 250 m. It can be seen clearly that large wind turbines are becoming the future trend in the 21st century. Airfoil self-noise from wind turbines with longer blades has higher tip speeds and produces high aerodynamic noise. Studies by several researchers have found that most of the broadband aerodynamic noise emissions occur due to the trailing edge sources from rotating blades such as from helicopters, wind turbines and compressors [2-5]. However, when the blades become thicker, the trailing edge bluntness source also dominates between moderate to high-frequency range in noise spectra.

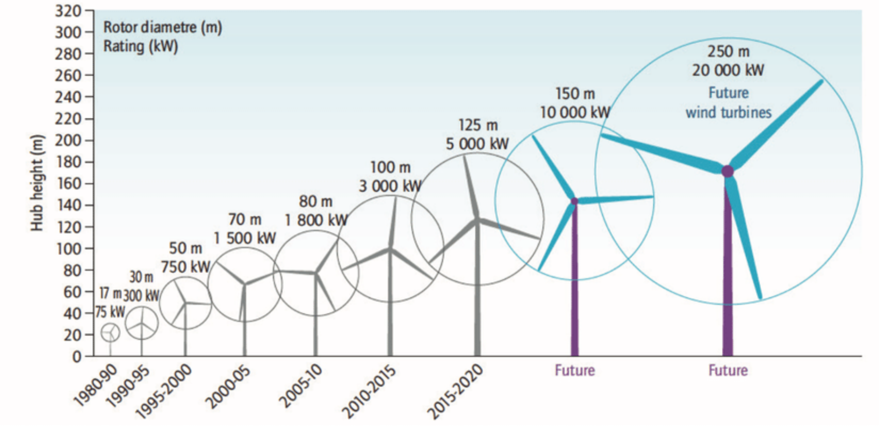


Figure 1. Illustration of horizontal axis wind turbine sizes with rotor diameter range between 17m and 250m

Airfoil self-noise prediction models developed by Brooks Pope and Marcolini (BPM) have been studied and improved by several researchers [6-8] One of the recent improvements in the trailing edge bluntness noise predictions was done by Wei et al (2016) who applied numerical techniques and correlated their results with field experiments measured for Siemens 2.3MW wind turbine blade. They also used computational aero-acoustic (CAA) method to compute the trailing edge bluntness noise level from NACA 0012 airfoil with finite thickness for consistent validation of results obtained from BPM semi-empirical noise prediction model and measured noise data. In addition, NACA 63-418 with two different variants of trailing edge shapes were studied to compare the noise spectra. They modified the generalized shape function proposed by the original BPM model and made it independent of the solid angle formed between the trailing edge surfaces of the airfoil, to investigate the effect of the shape function on the trailing edge tonal noise peak, produced in the high frequency region of sound spectra. In the present study, we investigate the shape function used by BPM model for predicting the trailing edge bluntness noise source but also apply regression approach to improve the bluntness peak at the high frequency region of noise spectra. In section 2, we describe the trailing edge bluntness noise method developed by BPM along with the present formulation. In section 3, the geometry model of the wind turbine blade used in study is described along with IEC 81400-11 standards for measurements of acoustic emissions for wind turbines. Computational assumptions are described for the generating aerodynamic flow field by means of the BEM which is coupled to the noise solver for predicting the sound power level. The noise solver for the trailing edge bluntness source is developed based on the original BPM model along with its improvements proposed by [9]. Overall, 1/3rd octave band sound power level for the 2MW wind turbine with a blade length of 38 m is computed using the BPM model and validated with experimental data of the GE 1.5sle, Siemens 2.3 MW 93 m, 95 m, and 101 m versions of turbines. Finally, the conclusions are presented based on the results obtained for the BPM model.

2. METHODS

2.1 BPM Model – Trailing Edge Bluntness Vortex Shedding

The flow around the wind turbine blades can be considered often as incompressible and low Mach number for the most utility scale wind turbines. Even though they operate in environments where the effects of the air density and wind shear on power production are significant, the aerodynamic noise generation from the wind turbine blades becomes important when the blade tip speed ranges between 0.1 and 0.3 Mach number. As the length of the blade is increased, the sound radiation from the blades depends not only upon the aerofoil geometry and the local angle of attack for the aerofoils but also on the rotational speed of the rotor. One of the noise mechanisms from blades occurs due to periodic vortex shedding from the suction side of the trailing edge surface when the turbulent boundary layer flow interacts with the blade surface and contributes to a monotonic peak in high frequency region of the noise spectrum. For a given flow condition i.e. Reynolds number and Mach number along the span wise direction of the blade strongly affect the overall noise levels as well as the tonal noise production. Typically, the noise amplitudes increase with an increase in flow Mach number and Reynolds number of order 3×10^6. Vortex shedding is the aerodynamic phenomenon observed on both streamlined and bluff bodies such as an aerofoil or a cylinder and becomes dominant when there exists an adverse pressure gradient within the boundary layer which causes a relative difference in the flow velocities between the surface and free streamflow conditions. According to the BPM model, the trailing edge vortex shedding occurs when the turbulent boundary layer displacement thickness is at least 30% higher than the characteristic dimension of the source [6,10]. In addition, flow conditions such as angle of attack, Reynolds number and Mach number affect the aerodynamic lift and drag force characteristics of an aerofoil. It can be noted that for the low angle of attack and attached flows, the vortex shedding from the trailing edge occurs rapidly and produces unsteady lift which often results in higher noise generation [11]. The lift and drag coefficient at a high angle of attack also increases rapidly but reaches maximum values near the stall angle of attack. For aerofoils with finite trailing edge thickness, and at stall angle of attack, the vortex shedding phenomenon is reduced due to turbulent boundary layer separation near the trailing edge. Beyond the stall angle of attack, a significant reduction of lift can be observed and hence the vortex noise from aerofoils is also reduced. BPM model predicts noise radiation from aerofoils using relative velocity and angle of attack as primary inputs and computes the turbulent boundary layer data for suction and pressure sides of the aerofoil. This datum varies according to the thickness of the aerofoil trailing edge as well as the chord length of the aerofoil. As the thickness to the chord increases, the turbulent boundary layer on the suction side of the aerofoil becomes less stable and tends to shed vortices rapidly. For a rotating wind turbine blade, the vortex shedding occurrence happens at a faster rate which leads to the massive flow separation near the tip of the blade due to centrifugal force acting on the flow. The separated flow appears as a wake which has lower velocity compared to free stream flow condition and contributes to aerodynamic noise. Further, according to this method, the strength of this source is approximated using the spectral functions, G4 and G5 which are functions of ratio of trailing edge thickness and average turbulent boundary layer displacement thickness from pressure and suction sides of aerofoil as given by Eq. (5). Hence, it is needed to compute the spectral functions G_4 and G_5 as given by Eq. (6)-(8). G4 represents the narrowband peak in spectra and G_5 is used to determine the broadband overall shape of spectra which is dependent on Strouhal number, St''' and St_{peak}'''. The two spectral functions $(G_5)_{\varphi=14}$ and $(G_5)_{\varphi=0}$ are solid angles which are determined using the symmetric NACA 0012 aerofoil experiments and given by Eq. from (76) to (82) in (Brooks et al, 1989). In this section, Eq. (76) to Eq. (82) are represented using Eq. (10) to Eq. (16). As mentioned by [6] and [10], the bluntness vortex shedding source appears as tonal peak in the overall noise spectra and becomes dominant near 10 kHz masking other self-noise mechanisms. It should be noted that the functional parameters in Eq. (1) are expressed in terms of angle of attack of the flow, bluntness ratio h/δ^*, for aerofoil at moderate to high Reynolds number; at the same time, they show the dependence of Mach number, $M^{5.5}$. The noise levels are also found to vary with the span segment length of the aerofoil, L and inverse square of the distance between source and receiver, r^2_e as given in Eq. (1) . The Strouhal number for this type of source is defined according to Eq. (2) where h is the height of the trailing edge. It should be noted that at moderate Reynolds number and for subsonic Mach number flows, the chord Reynolds number and turbulent boundary layer thickness and displacement thicknesses for zero and non-zero angle of attack are evaluated using Eq. (5) and Eq. (16), given in [6]. The 1/3rd octave sound pressure for this source is approximated using Eq. (1). The narrowband tonal peak is given by function G_4 and expressed using Eq. (6) and Eq. (7). The function G_5 is calculated using the ratio of the trailing edge thickness to the average boundary layer displacement thickness and sloping angle, φ between 0° to 14° given by Eq. (78) and Eq. (79) found in [6] where φ is the angle between the sloping surfaces near trailing edge of aerofoil and δ^*_p and δ^*_s are the pressure and suction side turbulent boundary layer displacement thickness, and h is the trailing edge height. The empirical equations used to determine the pressure and suction side displacement thicknesses for zero and non-zero angle of attack for symmetric aerofoils are given in [6]. They are found to be dependent upon the local angle of attack and chord Reynolds number. For an aerofoil, it is expressed in terms of turbulent boundary layer displacement thicknesses for the pressure and suction side. This source also uses the high frequency directivity function like turbulent boundary layer trailing edge noise and given by Eq. (9).

$$SPL_{\text{Blunt}} = 10\,log\frac{hM^{5.5}LD_h}{r_e^2} + G_4\left(\frac{h}{\delta^*_{\text{avg}}},\varphi\right) + G_5\left(\frac{h}{\delta^*_{\text{avg}}},\varphi,\frac{St'''}{St'''_{\text{peak}}}\right), \tag{1}$$

$$St''' = \frac{fh}{U}, \tag{2}$$

$$St'''_{\text{peak}} = \frac{0.212-0.0045\varphi}{1+0.235\left(\frac{h}{\delta^*_{\text{avg}}}\right)^{-1}-0.0132\left(\frac{h}{\delta^*_{\text{avg}}}\right)^{-2}}, \quad \text{for } \frac{h}{\delta^*_{\text{avg}}} \geq 0.2, \tag{3}$$

$$St'''_{\text{peak}} = 0.1\left(\frac{h}{\delta^*_{\text{avg}}}\right) + 0.095 - 0.00243\varphi, \quad \text{for } \frac{h}{\delta^*_{\text{avg}}} < 0.2, \tag{4}$$

$$\delta^*_{\text{avg}} = \frac{\delta^*_p + \delta^*_S}{2} \tag{5}$$

$$G_4\left(\frac{h}{\delta^*_{\text{avg}}},\varphi\right) = 17.5\,log\frac{h}{\delta^*_{\text{avg}}} + 157{,}5 - 1.114\varphi, \quad for\ \frac{h}{\delta^*_{\text{avg}}} \leq 5, \tag{6}$$

$$G_4\left(\frac{h}{\delta^*_{\text{avg}}},\varphi\right) = 169.7 - 1.114\varphi, \quad \text{for } \frac{h}{\delta^*_{\text{avg}}} > 5, \tag{7}$$

$$G_5\left(\frac{h}{\delta^*_{\text{avg}}}, \varphi, \frac{St'''}{St'''_{\text{peak}}}\right) = (G_5)_{\varphi=0^\circ} + 0.0714\varphi\left[(G_5)_{\varphi=14^\circ} - (G_5)_{\varphi=0^\circ}\right], \tag{8}$$

$$D_H(\theta, \phi) = \frac{2\sin^2\left(\frac{1}{2}\theta\right)\sin^2\phi}{(1+M\cdot\cos\theta)[1+(M-M_C)\cos\theta]^2}, \tag{9}$$

where θ, ϕ are the directivity angles between the source and receiver line aligned to blade span and chord direction with respect to the receiver position. M is the Mach number and M_c is the convective Mach number; h, is the trailing edge height.

The denominator term in Eq. (9) represents the Doppler Effect and convective amplification of acoustic waves produced at the trailing edge of the aerofoil [6, 10, 12, 13].

$$\begin{aligned}(G_5)_{\varphi=14^o} &= m\eta + k \text{ for } \eta < \eta_0 \\ &= 2.5\sqrt{1-\left(\frac{\eta}{\mu}\right)^2} - 2.5 \text{ for } \eta_0 \le \eta \le 0\text{-}2.5 \\ &= \sqrt{1.5625 - 1194.99\eta^2} - 1 \text{for } 0 \le \eta \le 0.03616 \\ &= -155.543\eta + 4.375 \quad \text{for } 0.03616 < \eta\end{aligned} \tag{10}$$

where

$$\eta = \log\left(St''' / St'''_{peak}\right) \tag{11}$$

$$\begin{aligned}\mu &= 0.1221 \text{ for } \frac{h}{\delta^*_{\text{avg}}} < 0.25 \\ &= -0.2175\frac{h}{\delta^*_{\text{avg}}} + 0.1755 \text{ for } 0.25 \le \frac{h}{\delta^*_{\text{avg}}} \le 0.62 \\ &= -0.0308\frac{h}{\delta^*_{\text{avg}}} + 0.0596 \text{ for } 0.62 \le \frac{h}{\delta^*_{\text{avg}}} \le 1.15 \\ &= 0.0242 \quad \text{for } 1.15 \le \frac{h}{\delta^*_{\text{avg}}}\end{aligned} \tag{12}$$

$$\begin{aligned}m &= 0 \text{ for } \frac{h}{\delta^*_{\text{avg}}} < 0.02 \\ &= 68.724\frac{h}{\delta^*_{\text{avg}}} - 1.35 \quad \text{for } 0.02 \le \frac{h}{\delta^*_{\text{avg}}} \le 0.5 \\ &= 308.475\frac{h}{\delta^*_{\text{avg}}} - 121.23 \text{ for } 0.5 \le \frac{h}{\delta^*_{\text{avg}}} \le 0.62 \\ &= 224.811\frac{h}{\delta^*_{\text{avg}}} - 69.35 \text{ for } 0.62 \le \frac{h}{\delta^*_{\text{avg}}} \le 1.15 \\ &= 1583.28\frac{h}{\delta^*_{\text{avg}}} - 1631.59 \text{ for } 1.15 \le \frac{h}{\delta^*_{\text{avg}}} \le 1.2 \\ &= 268.344 \text{ for } 1.2 \le \frac{h}{\delta^*_{\text{avg}}}\end{aligned} \tag{13}$$

$$\eta_0 = -\sqrt{\frac{m^2\mu^4}{6.25 + m^2\mu^2}} \tag{14}$$

$$k = 2.5\sqrt{1 - \left(\frac{\eta_0}{\mu}\right)^2} - 2.5 - m\eta_0 \tag{15}$$

$$\left(\frac{h}{\delta^*_{\text{avg}}}\right)' = 6.724\left(\frac{h}{\delta^*_{\text{avg}}}\right)^2 - 4.019\left(\frac{h}{\delta^*_{\text{avg}}}\right) + 1.107 \tag{16}$$

It should be noted that $(G_5)_{\varphi=0^o}$ is computed using Eq. (10) to Eq. (16) like $(G_5)_{\varphi=14^o}$ except that $\left(\frac{h}{\delta^*_{\text{avg}}}\right)$ is replaced with Eq. (16). Further, Eq .(1) to Eq. (9) are fundamental equations needed to compute the turbulent boundary layer vortex shedding noise mechanism given in the Brookes, Pope and Marcolini (BPM) empirical model [6]. The empirical curve fitted equations, *m, η, k and μ* are used to define the constraints for quantifying spectral functions in trailing edge bluntness noise production from an aerofoil. It has been proven that for high values of Strouhal number or for the order greater than 2, the flow is dominated by turbulent boundary layer thickness and results in small scale flow instabilities [6, 14-16]. The Strouhal number and the shape functions vary with the shape of aerofoil, inflow velocity conditions and local angle of attack. Experiments conducted by [6] used a reference chord length for testing the aerofoil which was 30.86 cm; boundary tripping was done with the help of 2 cm wide strip or grit applied at 15% chord length. Tripping of boundary layer resulted in reduction of the noise levels in certain frequency regions of sound spectrum [7, 8, 17]. For the present analysis, tripping of turbulent boundary layer has not been taken into consideration. The maximum trailing edge height in the BPM model aerofoil was 2.5mm which is ~ 0.8% of chord. For the present case of 38m blade, it is 3.22mm and corresponds to 0.1% chord, respectively.

3. SIMULATION ASSUMPTIONS

In the analysis of the sound pressure from the wind turbine blade, generalized blade element momentum (BEM) method was used to compute the relative velocity field along the blade span. The outputs of the BEM solver are relative velocity on the blade section, the angle of attack, normal and tangential force coefficients on every section of blade which can be used to compute the rotor loading forces and moments. The outputs from the BEM solver are coupled to the BPM noise prediction module for which, the sound pressure level computations are done at a given wind speed, blade pitch angle and rotational speed of the machine. In the BEM approach the total length of blade is discretized into several aerofoils at least 20 segments. Aerofoil can be assumed as half-infinite flat plate with finite thickness and aspect ratio. The flow over the flat plate was assumed to be 2D incompressible and quasi uniform along the blade length which means that flow behaviour varies from one span station to another along the blade span. The overall shape of the blade is approximated using selected aerofoils, viz. NACA 0012, NACA 6320 and NACA 63215 while the turbulent boundary layer properties on suction and pressure side of the aerofoils are computed from XFOIL module [19, 20]. The boundary layer data for the aerofoil serve as input to the noise prediction module. In the prediction of the sound pressure levels, each blade segment is treated as a point source in near field and rotating blade as line source. However, in the far field sound prediction, the blades act as point source where the sound waves propagate or spread themselves in spherical manner. The sound pressure level is thus calculated by logarithmic addition of individual sources relative to the observer position. For the present simulation work, the receiver height was fixed at 2m above the ground level and the source height was fixed at 80m. The distance of the receiver location was set at 110m, which is approximately the total turbine height ($HH + D/2$). This is in accordance with IEC 61400-11 regulations for measurements of acoustic emissions from wind turbines. HH is the hub height of the turbine, and D is the rotor diameter in m. A downwind scenario is considered as the worst case since sound waves bend in downward direction with respect to free stream wind and this results in amplification. Therefore, downwind receiver location is considered. The boundary conditions for the blade are Reynolds number, the angle of attack along the blade span.

It is implemented to verify that blade element momentum (BEM) computed values do not exceed predefined threshold values as given in [6, 21]. The blade pitch angle is set to 3.5° for sound pressure calculations and rotation speed for machine as 17RPM.

3.1 Geometric model of turbine

For the assessment of the trailing edge bluntness noise from horizontal axis wind turbine rotors, a geometric model for the blade has been developed using NuMAD software. The software allows user to input the aerofoil data at every span wise location of the blade. Table 1 shows the turbine design parameters along with the orientation of the rotor into wind.

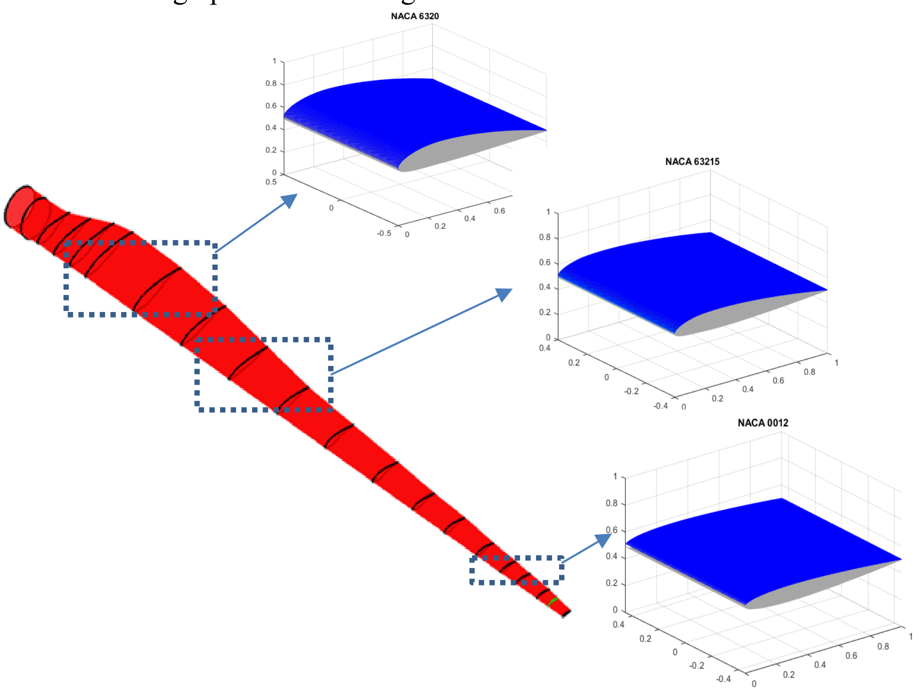


Figure 2. Isometric (3D) model of wind turbine developed using NuMAD software showing the airfoil sections used near the blade root, mid-span, and tip of the blade [18]

Figure 2 shows the isometric (3D) model of the 38 m blade for the 2MW wind turbine used for analyzing the trailing edge bluntness noise. Towards the inboard region, the airfoils have high thickness to chord ratio with at least 18 % t/c as well as high camber. In the present study, NACA 6320 airfoil data have been used with a trailing edge slope angle of 14°. In the mid span region, the airfoils have moderate thickness to chord ratio. The geometric properties of the blade are depicted in Fig. 3.

It is evident that the chord length and twist remain constant for the root section which connects the blade to the rotor hub.

Table 1. Turbine parameters for 2 MW machine

Parameter	Value
Cone angle	0°
Tilt angle	3°
Hub height	80 m
Blade Radius	37 m
Rotor speed	17 RPM
Max twist	13°
Max chord	3.22 m
Orientation	Upwind
No of blades	3
Rated power	2 MW

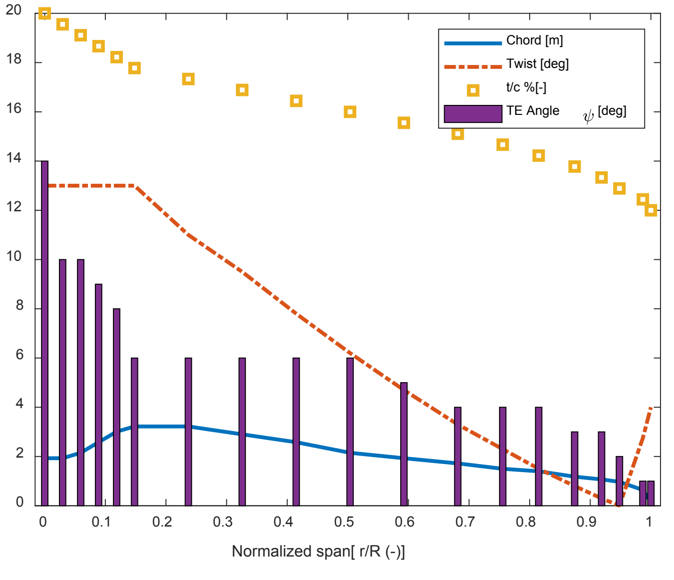


Figure 3. Geometric properties shown along the normalized blade span for a wind turbine blade having a length of 37 m.

3.2 IEC 61400-11 standard for the measurement of the sound level

The relative position of the receiver with respect to the aerofoil coordinate system is shown in Fig. 4. For a wind turbine blade, in addition to the shear within turbulent boundary layer responsible for the trailing edge vortex shedding noise, the sound levels also depend on the blades pitch angle operation.

Particularly for moderate pitch angles and at a low or positive angles of attack, the boundary layer on the pressure side of the aerofoil at the leading edge shows a laminar flow structure; however, the boundary layer on the suction side remains mostly in turbulent state near the trailing edge. Further, it is important to note that such a type of noise mechanism is dominant in mid span region of the blade where the trailing edge thicknesses are high for which maximum Strouhal number is found to be 0.15.

Below this value, the vortex shed from the trailing edge surface does not contribute significantly to the noise levels [8, 10].

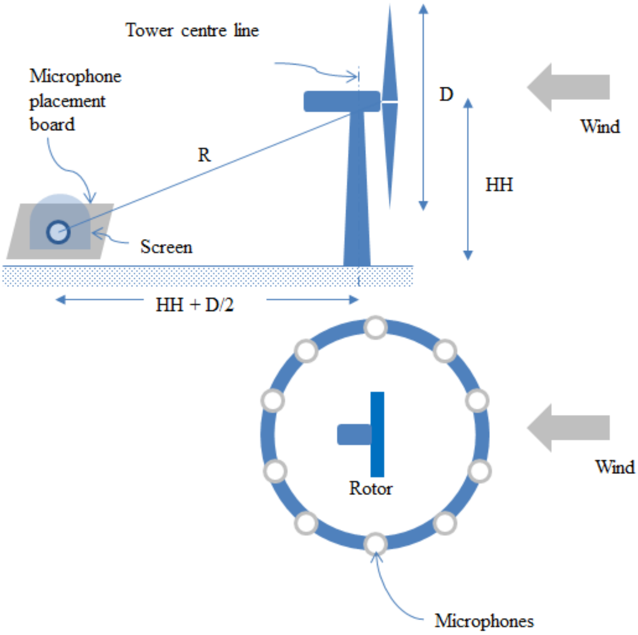


Figure 4. Illustration of microphone position surrounding the source located in center as well as the microphone measurement distances and position according to IEC 61400-11 standards with respect to source

4. RESULTS AND DISCUSSIONS

In this section we present the results for the turbulent boundary layer vortex shedding noise from a 2MW horizontal axis wind turbine blade, using original BPM model predictions and compare them with OSPL (overall sound power level) experiment data obtained for GE 1.5sle, Siemens SWT 2.3MW machines.

All the computations were done in MATLAB 2020b software, for a wind speed of 7m/s and 10m/s at blade pitch angle of 3.5º and trailing edge thickness taken ~ 0.1 % chord length. Fig. 5 shows the Strouhal number, St''' computed in terms of displacement thickness, δ^*, for wind speeds of 7 m/s and 10 m/s, respectively.

The maximum value for St''' was found to be 2.2 and 4.16 for wind speeds of 7 m/s and 10 m/s at frequency f ~ 10kHz, where the turbulent boundary layer trailing edge bluntness noise produces peak tonal amplitude. Figure 6 (a) and Fig. 6(b) show the trailing edge bluntness peak from the original BPM model as a broad band hump that agrees well within 5% of experiment validation data for GE 1.5sle, Siemens 2.3MW (Pedersen and Pieter) turbines for wind speed of 7m/s and 10m/s at trailing edge thickness of 0.1% local blade chord length. For frequencies below 1 kHz, the turbulent boundary layer trailing edge noise dominates with a peak value of 96 dB that is obtained using the measured data of the experimental turbines. The tonal peak of trailing edge bluntness noise computed from the original BPM model was found to be ~ 82 dB for wind speeds of 7 m/s and 96 dB for wind speeds of 10 m/s.

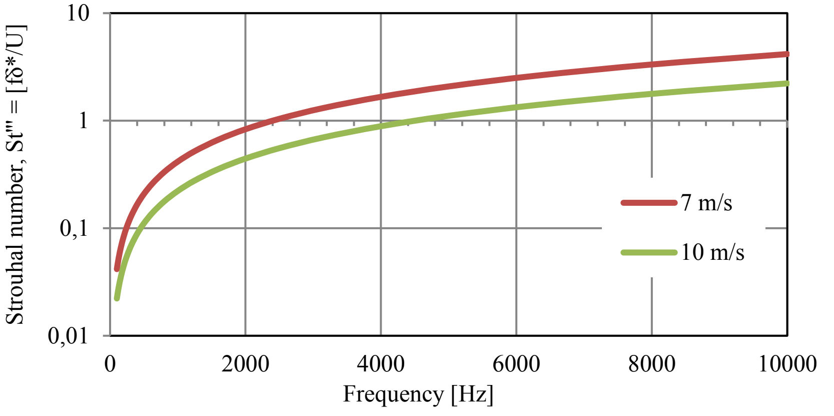


Figure 5. Illustration of Strouhal number, St''' as function of displacement thickness, δ^*, at wind speeds of 7 m/s and 10 /s

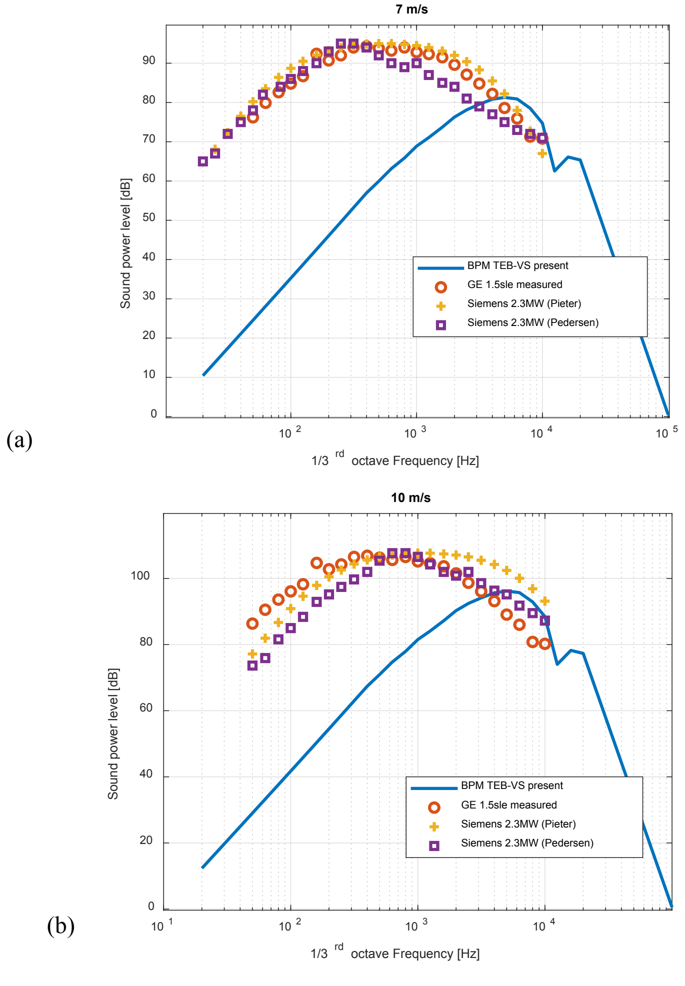
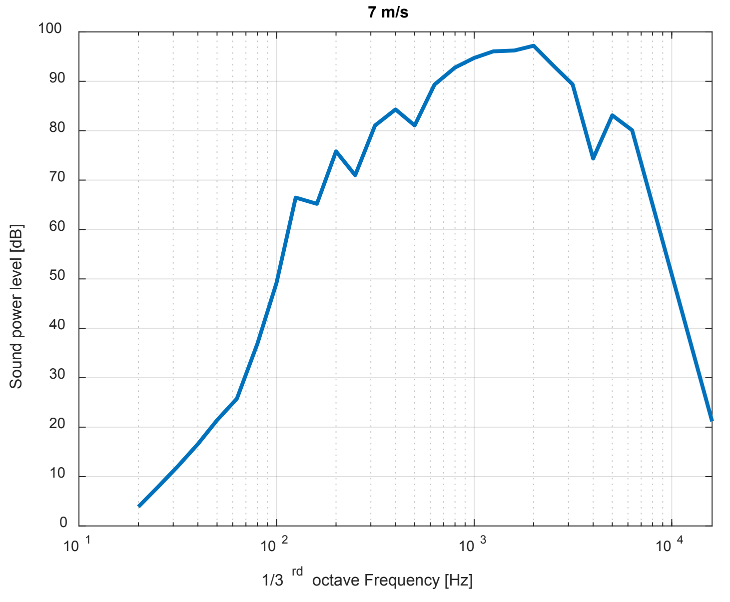


Figure 6. Validation of the computed BPM-Turbulent boundary layer vortex shedding noise (TEB-VS), for a blade length of 37 m, 2MW turbine having trailing edge thickness of 0.1%c with OSPL measured data of GE-1.5sle, Siemens 2.3 MW (Pieter), Siemens 2.3 MW (Pedersen) of blade length 47 m at two different wind speeds of (a) 7 m/s (b) 10 m/s

(a)



(b)

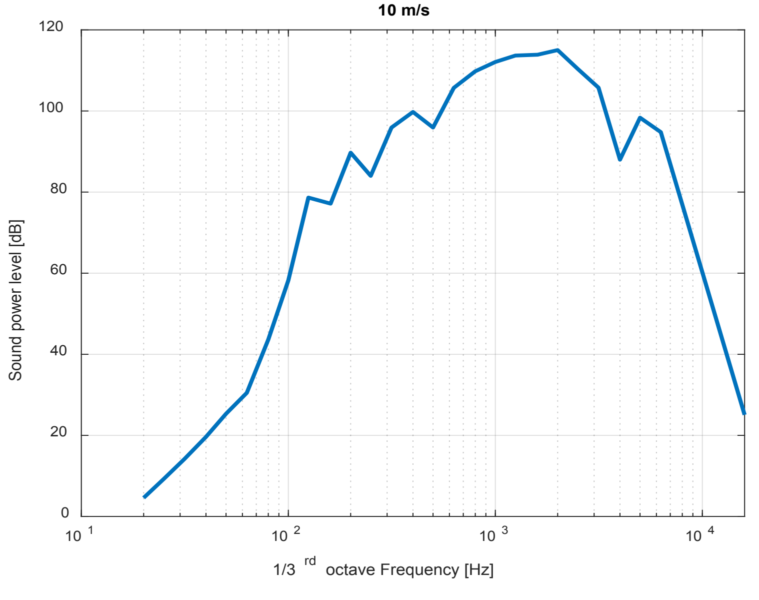


Figure 7. Computed turbulent boundary layer vortex shedding noise (TEB-VS) for a blade length of 37 m, 2 MW turbine using trailing edge thickness of 0.5 %c at two different wind speeds (a) 7 m/s (b) 10 m/s

From Fig. 7(a) and Fig 7(b) one can notice the computed turbulent boundary layer trailing edge bluntness noise using the BPM model; the figures? show peaks that shift closer to frequencies, f ~ 5 kHz and reach an amplitude values of 97 dB and 115 dB, respectively.

It must be noted that when the trailing edge thickness or heights are increased to 0.5% of the local blade chord length, a difference of 15 dB was found for wind speeds of 7 m/s while a difference of 10d dB was obtained for wind speeds of 10 m/s.

Further, from Fig 8 it is evident that the difference in the sound power levels between 7 m/s and 10 m/s continued to increase by a maximum value of 15 dB for frequencies, f < 200Hz when the trailing edge thicknesses are 0.1 % and 0.5 % of the local blade chord length, respectively. However, for frequencies, f > 200Hz, a noise reduction of 17dB was observed when the trailing edge thickness was 0.5 % of the local chord length.

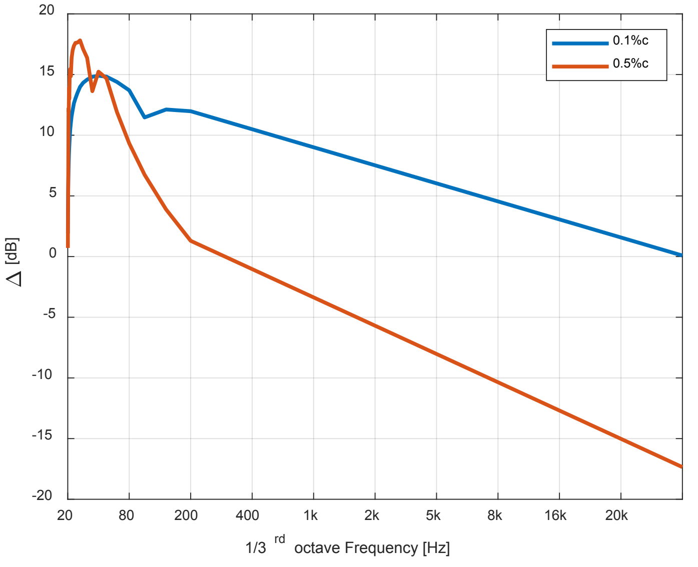


Figure 8. Computed difference, Δ dB, of the turbulent boundary layer vortex shedding noise (TEB-VS) between wind speeds 7 m/s and 10 m/s, for trailing edge thicknesses of 0.1%c and 0.5%c.

5. CONCLUSIONS

A computational analysis of the trailing edge bluntness vortex shedding noise for 2MW horizontal axis turbine was performed for trailing edge thicknesses of 0.1 % and 0.5 % of the local chord using the original BPM model. The original BPM results for trailing edge bluntness noise showed that for a trailing edge thickness of 0.1% and 0.5 % of the chord length the effect on sound power level was found to be ~83 dB, 92 dB and 95 dB and 115 dB at wind speeds of 7 m/s and 10 m/s, respectively. At 10 kHz, the region turbulent boundary layer vortex shedding noise masks all other self-noise mechanisms. Finally, the existing overall sound power level (OSPL) experimental data showed very good agreement with simulated outputs for the trailing edge bluntness noise at both wind speeds of 7 m/s and 10 m/s, respectively.

ACKNOWLEDGEMENTS

The authors would like to thank all those who provided constructive comments for the present work and helped to improve the overall quality of manuscript.

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