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Empirical Method of Determining Vortex Induced Aerodynamic Noise from Wind Turbine Blades: A Computational Approach

Vasishta Bhargava^{*1}

Delta Cons Projects Ltd,

Venkateshwara Road, Banjara Hills, Road no 3, Hyderabad, 500034

Samala Rahul²

Indian Institute of Technology, Madras,

Sardar Patel Rd, Adyar, Chennai, Tamil Nadu, India, 600036.

Maddula, Satya Prasad³

School of Aerospace Engineering, GITAM School of Technology

Patancheru, Hyderabad, India, 502329

ABSTRACT

A dominant aerodynamic noise source from lifting surfaces occurs from trailing edge section of an airfoil as found in wind turbine blades. Computational analysis of trailing edge bluntness noise mechanism is demonstrated for a three bladed 2 megawatt wind turbine using empirical method proposed by Brookes, Pope, Marcolini (BPM). The method predicts the 1/3rd octave band sound pressure level from trailing edge bluntness source using boundary layer displacement thickness on pressure and suction side of airfoil. For low Mach number flows (0.1884) and moderate Reynolds number ($4.73 \times 10^5 - 3.35 \times 10^6$) in span wise direction of blade, turbulent boundary layer on the trailing edge surface is responsible for noise production. The trailing edge thickness effect on sound power level is illustrated for wind speed regime between 8 and 20 m/s. The results showed that sound levels increase for higher values of free stream velocity but blunt trailing edge noise source becomes insignificant when the trailing edge height scales to lower values of chord length. The computed results also confirm good agreement between overall A-weighted sound power levels and experiment data available for GE 1.5sle turbine with a rotor diameter of 77m at wind speed of 8m/s and 10m/s. The extent of reduction in sound power level was analysed using the trailing edge thicknesses scaled to 0.1 %, 0.5 % and 1% chord lengths at hub height wind speed of 8m/s and 10m/s.

Keywords: Airfoil, Boundary layer, Sound power level, Noise, Blade

I-INCE Classification of Subject Number: 30

¹ Corresponding author,

¹vasishtab@gmail.com; ² rsamala2@gmail.com; ³ satyaprasad.maddula@gmail.com

1. INTRODUCTION

Wind turbine blades produce aerodynamic noise when they operate in varied terrains such as grass land, hills, or open sea surface. Aerodynamic noise produced from blades can be heard at audible frequencies which cause annoyance and sleep disturbance create health concerns such as stress to inhabitants. Different community inhabitants across the world have mixed views regarding the presence of wind turbine operation located near homes. Therefore, noise regulation standards are implemented in several countries like the UK, Germany, Denmark and Sweden where threshold noise level outside environment is 55 dB during day time and at 40 dB at night time, with a difference of 15dB for urban mixed areas [3]. In the last century the wind turbine sizes have been predominantly smaller due to limited applications, however, in past few decades the size of modern wind turbines have changed dramatically due to improvements in technology and design. The design of quieter wind turbine is highly dependent upon the tip speed of blade during operation. Longer blades usually tend to possess high tip speed which is potential design constraint. It also drives the cost of energy for a given turbine since increased tip speed of blades tend to capture higher energy from a turbine but result in higher noise emissions. Aerodynamically produced noise utilizes the principles of classical acoustics and fluid mechanics and depends on the turbulent flow field characteristics over the moving surfaces e.g. airfoil. Broadband noise from wind turbines blades is caused due to interaction of turbulent shear flows over the trailing edge of blade. From many empirical wind tunnel studies conducted on symmetric airfoils in open circuit anechoic wind tunnel, a logarithmic relationship for sound pressure level was derived [1,8, 12,16] Further these studies also revealed that sound pressure level is affected by trailing edge thickness of blade and sloping angle between the trailing edge surfaces. A regression based curve fitting relationship between the trailing edge height and turbulent boundary layer thickness was derived. This relationship describes the vortex shedding mechanism and demonstrated by several experiment studies¹ in an attempt to quantify noise radiation. The turbulent shear flow downstream of trailing edge produces vortex also known as starting vortex, formed as result of increasing boundary layer thickness and subsequent pressure gradients along the chord line of airfoil. Hence boundary layer parameters viz. Thickness, displacement thickness also plays an important role in noise radiation. It must be noted that sound pressure level as perceived by human ear vary with atmosphere conditions as well as with the distance between source and receiver in far field. An inverse square relation is often consistent approximation of sound levels in far field. This objective of this paper is to predict the far field broadband and tonal noise caused due to trailing edge thickness of the airfoil based on the method developed by Brooks Pope and Marcolini (BPM). For the present study a 2MW wind turbine blade with blade length of 37m and hub height of ~80m was considered to assess the sound power level at three trailing edge heights viz. 0.1 %c, 0.5 %c, 1 %c and 1.5%c. The effect of trailing edge thickness and bluntness parameters on the sound levels are illustrated for different free stream flow conditions. The significance of the blade geometry and flow variables are regarded as important factors in the estimation of strength of this source [1, 6, 8, 12] The flow field over the

blade is computed using boundary element momentum (BEM) method to derive the angle of attack, inflow angles and blade relative velocity and coupled to noise solver. In addition this work also aims to analyse the extent of reduction in 1/3rd octave band A-weighted sound power levels as result of change in the trailing edge thickness properties of blade.

2. METHOD

BPM Model – Trailing edge bluntness vortex shedding

The wind turbine blades experience subsonic or low Mach number flows and operate in atmospheric boundary layers where the effects of air density, wind shear on sound pressure levels are important. Noise from wind turbine blades depends upon airfoil geometry, local angle of attack for the airfoils, and rotational speed of the turbine. One of the noise mechanisms from blades is caused due to periodic vortex shedding from suction side of trailing edge surface and exhibits tones in the sound spectrum. According to this model, the vortex shedding occurs when the boundary layer displacement thickness is at least 30 % higher than characteristic dimension of source [1,8] For a given angle of attack the vortex shedding from sharp or blunt trailing edge is caused due to excessive adverse pressure gradient on suction surface of airfoil. However, as the thickness of trailing edge increases, the boundary layer instabilities occur at faster rate and lead to the flow separation. According to this method, strength of this source is approximated using the spectral functions, G₄ and G₅ which are functions of ratio of trailing edge thickness and average boundary layer displacement thickness as given by Eq. (5). Hence it is needed to compute the spectral functions G₄ and G₅ as given by Eq. (6) – Eq. (8) G₄ represents the narrowband peak in spectra and G₅ is used to determine the broadband overall shape of spectra which is dependent on Strouhal number. The spectral function $(G_5)_{\varphi=14^\circ}$ and $(G_5)_{\varphi=0^\circ}$ are solid angles determined using the symmetric NACA 0012 airfoil experiments [1,4,5,6] As mentioned before this source becomes significant in sound spectrum and appear as tonal peak near ~ 10 kHz. The scaling expressions are function of flow angle of attack for airfoil at moderate Reynolds number and dependence of Mach number power 5.5 show better approximations of sound levels¹. It must be noted that at low to moderate Reynolds number, and for subsonic Mach number flows, the chord wise Reynolds number and boundary layer, displacement thicknesses for zero and non-zero angle of attack are obtained using the equations (5) - (16) in ref [1] (Brookes et al, 1989) The 1/3rd octave sound pressure for this source is approximated using the Eq. (1). The narrowband tonal peak is given by function G₄ and expressed using Eq. (6) and Eq. (7)

$$\cdot \text{SPL}_{\text{Blunt}} = 10 \cdot \log_{10} \left[\frac{h M^{5.5} L D_h}{r_c^2} \right] + G_4 \left(\frac{h}{\delta_{\text{avg}}^*}, \varphi \right) + G_5 \left(\frac{h}{\delta_{\text{avg}}^*}, \varphi, \frac{\text{St}'''}{\text{St}_{\text{peak}}'''} \right) \quad (1)$$

$$\text{St}''' = \frac{fh}{U} \quad (2)$$

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

$$0.1 \left(\frac{h}{\delta_{\text{avg}}^*} \right) + 0.095 - 0.00243 \varphi \quad \text{for} \left(\frac{h}{\delta_{\text{avg}}^*} \right) < 0.2 \quad (4)$$

$$\delta_{avg}^* = \frac{\delta_p^* + \delta_s^*}{2} \quad (5)$$

$$\mathbf{G}_4 \left(\frac{h}{\delta_{avg}^*}, \varphi \right) = 17.5 \cdot \log \left(\frac{h}{\delta_{avg}^*} \right) + 157.5 - 1.114 \cdot \varphi \quad \text{for} \quad \left(\frac{h}{\delta_{avg}^*} \right) \leq 5$$

$$(6) \quad 169.7 - 1.114\varphi \quad \text{for} \quad \left(\frac{h}{\delta_{avg}^*} \right) > 5 \quad (7)$$

$$\mathbf{G}_5 \left(\frac{h}{\delta_{avg}^*}, \varphi, \frac{St'''_{peak}}{St'''_{peak}} \right) = (\mathbf{G}_5)_{\varphi=0^\circ} + 0.0714 \cdot \varphi [(\mathbf{G}_5)_{\varphi=14^\circ} - (\mathbf{G}_5)_{\varphi=0^\circ}] \quad (8)$$

Function \mathbf{G}_5 is calculated using ratio of trailing edge thickness to average boundary layer displacement thickness and sloping angle of 0° to 14° , φ , given by Eq. (78) & Eq. (79) found in ref [1] φ is the angle between the sloping surfaces near trailing edge of airfoil. δ_p^* , δ_s^* are the pressure and suction side boundary layer displacement thickness. h is the trailing edge height. The curve fitting equations used to determine the pressure and suction side displacement thicknesses for zero and non-zero angle of attack for symmetric airfoils are taken from ref [1, 12, 16] They are found to be dependent upon the local angle of attack and chord Reynolds number. For an airfoil it is expressed in terms of the 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 the Eq. (9)

$$\mathbf{D}_H(\theta, \phi) = \frac{2\sin^2(\frac{1}{2}\theta)\sin^2(\phi)}{(1+M\cos\theta).(1+(M-M_c)\cos\theta)^2} \quad (9)$$

Where θ, ϕ 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. The denominator term in Eq. (9) represents the Doppler effect and convective amplification of acoustic waves produced at the trailing edge of airfoil [1, 4, 8, 12] For high $1/3^{rd}$ octave centre frequencies viz. a large Strouhal number or order greater than 2, the flow is dominated by boundary layer thickness and results in small scale flow instabilities. The Strouhal number and the spectral shape functions vary with shape of airfoil, inflow velocity conditions and local angle of attack. Experiments conducted by Brookes et al [1], used a reference chord length for test airfoil which was 30.86cm and boundary tripping was done with help of 2cm wide strip or grit applied at 15% chord length. Tripping of boundary layer is found to reduce the noise levels in certain regions of sound spectrum [11, 12, 16] For the present analysis, tripping of boundary layer is not taken into consideration. The maximum trailing edge height in BPM model airfoil was 2.5mm which is $\sim 0.8\%$ of chord while for present case of 37m blade it is 3.22mm, 16.1mm, 32.2mm and 48.3mm respectively. Also for a blade length of 37m, the mean trailing edge angle of 5.6° is evident as depicted in Fig 1(a) and maximum chord length of blade is 3.22m for the turbine.

3. DISCUSSION

In the analysis of sound pressure level from wind turbine blade, boundary element method is used to compute the relative velocity field along the blade span. The total length of blade is discretized into airfoil segments typically on order of 15. Airfoil is modelled as half infinite flat plate with finite thickness [1]. The flow over airfoil is assumed 2D incompressible and quasi uniform along the blade length which means there is no dependence of span wise correlation of flow. The shape of blade is approximated using selected airfoils viz. NACA 0012, NACA 6320 and NACA 63215 and hence the boundary layer properties on suction and pressure side of airfoils along the span. The boundary layer data for individual airfoils is obtained from X-Foil computations using 2D panel method. In the prediction of sound pressure levels, each blade segment is treated as point source in near field and rotating blade as line source in far field. Sound pressure level is hence calculated by logarithmic addition of individual line sources relative to observer position. For the present simulation work, receiver height is fixed at 2m above ground level and source height at 80m. The distance of receiver location is set at 110m which is approximately the total turbine height ($HH + D/2$) and in accordance with IEC 61400-11 regulations for measurements of acoustic emissions from wind turbines. HH is the hub height of turbine, and D is rotor diameter in m. A downwind scenario is considered as worst case due to fact that sound waves bend in downward direction behind the rotor plane with respect to free stream direction, hence downwind receiver location is taken into account. Table 1 show the turbine configuration used in the computational study. Fig 1 (a) shows the chord and twist distribution for the rotor blade of 37m. Fig 1(b) represents 37m blade developed using open source software NuMAD [17]. The boundary conditions for blade are Reynolds number, angle of attack along the blade span are implemented to verify that boundary element method (BEM) computed values do not exceed predefined threshold values as given in ref [1,5] The blade pitch angle is set to 3.5° for sound pressure calculations and rotation speed for machine as 17 rpm.

Table 1: Turbine parameters of 2MW machine

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

The relative position of receiver with respect to airfoil coordinate system is shown in Fig 2(a). The development of wake behind trailing edge of airfoil describing the vortex shedding mechanism is shown in Fig 2(b). It reveals the significance of trailing edge thickness for a given set of flow conditions. For a wind turbine blade, the turbulent boundary layer that causes the vortex shedding will also depend on blades pitch angle operation. Particularly for moderate pitch angles and at low or positive angle of attack the boundary layer on pressure side of airfoil shows laminar flow structure however the

boundary layer on suction side remains mostly in turbulent state near trailing edge. Further, this noise mechanism is dominant in mid span region of blade where 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 does not contribute significantly to the sound levels [8, 12]

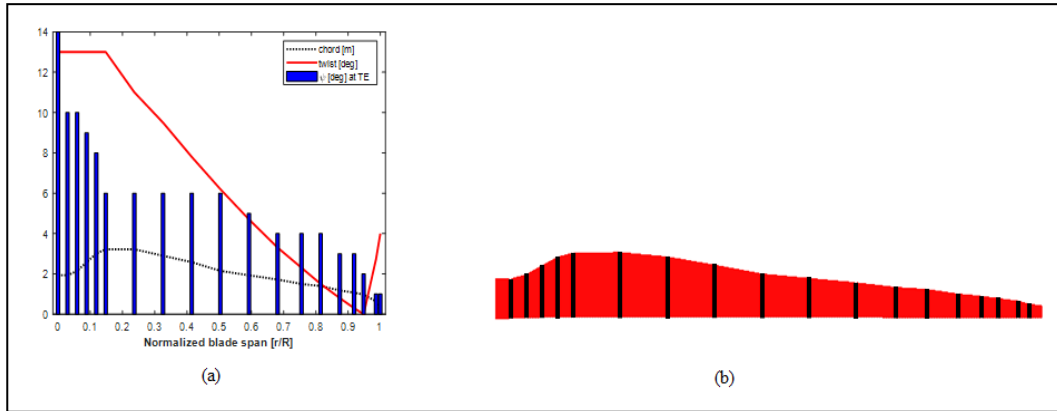


Figure 1 (a) Geometric properties of 2MW wind turbine blade (b) Top view of 37m blade developed using NuMAD¹⁷ software

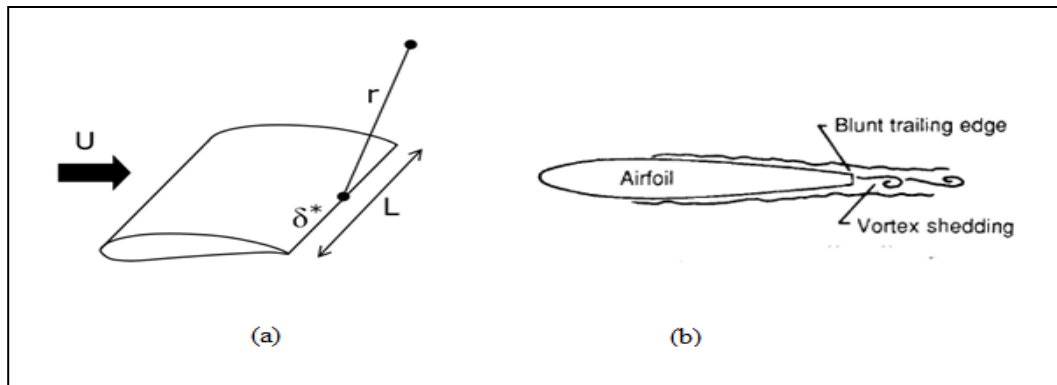


Figure 2 (a) Illustration of distance between the source and receiver [1] (b) Vortex shedding pattern at trailing edge [1]

4. RESULTS

4.1 Trailing edge thickness effect

The receiver position is placed at distance of $2.2R$ from the turbine at a ground height of $\sim 2\text{m}$. R is the blade radius, m. The type I in the matrix uses the trailing edge thickness of 0.1 % chord length and type II using the trailing edge thickness of 0.5 % chord length of airfoils. For all the test cases in the matrix, computer simulations were performed using program code developed in MATLAB 2018b software. Table 2 shows the maximum values obtained from the simulated cases and illustrated in Fig 3(b). The maximum sound power levels for type I was found to be 113dB and for type II it is 135 dB respectively. The chord Reynolds number which corresponds to the wind speeds are

1.3×10^6 , 2.6×10^6 , 4.87×10^6 The Strouhal number range 0.01 and 10 was obtained for the test cases over the entire frequency region.

Table 2 Comparison of Maximum Sound Power Level, dB

Trailing edge thickness [%c]	Wind speed [m/s]		
	8	10	15
0.1	86.84	96.18	113.12
0.5	103.86	115.01	135.26

It is evident from Fig 3(a) that by decreasing the trailing edge thickness the bluntness noise contribution will reduce and peak reduce by 5dB. A broad hump is observed for the thickness of 0.5 %, 1% and 1.5% chord length, near 1 kHz caused due to flow separation and consequent increase of boundary layer thickness from suction side of airfoil and at 2 kHz a smaller peak is also evident that's produced from pressure side of airfoil. Further from Fig 3(a) the peaks in sound spectrum for 0.1 % chord length it appears to shift near 10 kHz with lower magnitude. Therefore, at lower thickness and bluntness angle, this type of noise does not show significant variations other than the peak in the sound spectrum, i.e. $f < 5$ kHz. In addition to blade characteristics, the physics of the vortex generation from an airfoil is governed by the chord Reynolds number, angle of attack and determined by occurrence of stall on blade surface. Previous studies have also shown that active flow control over airfoils with porosity have the potential to reduce noise significantly due to control of boundary layer thickness on surface [6,7,10] These methods are used to energize the flow that can withstand adverse pressure gradient and delay the flow separation near trailing edge [14] The maximum reduction of sound power levels between the type I and type II test matrix are found to reach ~35dB observed between 2 kHz and 8 kHz.

4.2 Sound Level Change

From Fig 4 (a) it can be seen that large noise increments are observed for frequencies $f < 2$ kHz and decrease in noise levels for frequencies $f > 5$ kHz. These noise reductions are achieved for change in trailing edge thickness from 0.1%c to 0.5 %c for the blade. It must be noted that extent of tonal peak in spectrum vary with Strouhal number range. The amplitude of tone noise is affected by the thickness of trailing edge and trailing edge angle. Further at low to moderate frequencies between 100 Hz and 1100 Hz the noise level is increased with peak values found at 200Hz order of 35dB. On the contrary for high frequencies, between 4.5 kHz and 10 kHz the trailing edge bluntness noise tend to decrease sound power level, in order of 20dB. Similarly from Fig 4(b) for a change of trailing edge thickness from 0.5 %c to 1 %c the extent of increment of sound levels is found to be as high as 50dB between 100Hz and 1.5 kHz but continue to reduce in high frequency region. Also from Fig 4(a) and Fig 4(b), a negative value indicates the reduction in noise levels while positive values show increase in noise levels.

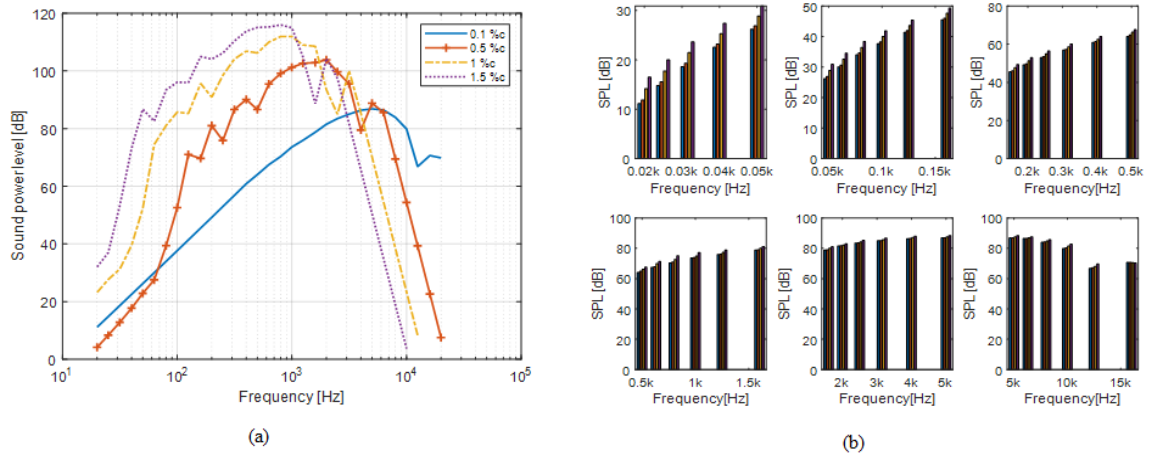


Figure 3 (a) Influence of trailing edge thickness on bluntness vortex shedding noise [dB] at hub height wind speed of 8m/s (b) Bluntness noise [dB] for thickness of 0.1 % chord at wind speeds of 8m/s, 10m/s , 15m/s and 20m/s

Hence it is evident that influence of bluntness parameters show tonal peak effect on the sound power level and contributed mainly from the mid span region of blade. At high wind speeds, $U > U_{rated}$ this effect is less pronounced than at below rated wind speeds i.e. $U < U_{rated}$ and does not exhibit the large tonal peak found in high frequency region. The boundary layer displacement thickness on the airfoil surface is found to develop slower at high Reynolds number and extend along the chord direction of blade. The trailing edge angle or slope between the trailing edge surfaces also show similar effect forming the vortex wake due to adverse pressure gradient within the turbulent boundary layer near the trailing edge of airfoil. The adverse pressure gradient is caused when the boundary layer thickness exceeds a critical value (point of inflexion) and leads to separation of flow over the surface of airfoil. The starting vortex formed downstream of trailing edge is carried further in flow direction. Presence of thick turbulent boundary layer on the trailing edge region is responsible for edge scattering and lead to subsequent noise radiation. The acoustic waves radiated near trailing edge come in contact with incoming flow field along the chord. The sound waves are also believed to travel backwards to the leading edge of airfoil through a feedback mechanism. The feedback mechanism is caused due to the formation of T-S (Tollmein-Schlichting) oscillating waves in flow field and observed in laminar boundary layer region near leading edge of airfoil. The perturbed waves of incoming flow travel again downstream along the chord direction towards trailing edge of airfoil. Studies have shown that exact reason behind this feedback mechanism is not known clearly and beyond the scope of present study²

The hump in the sound power level spectrum observed at 10 kHz is attributed to vortex shedding from trailing edge of blade. The extent of vortex shedding from the trailing edge depends on dominant frequency in sound spectrum defined by Strouhal number as well as Reynolds number. This frequency is found to vary with the magnitude of free stream velocity and the turbulent boundary layer displacement

thickness [1,5,8] The broad shape of spectrum decreases gradually and results in truncated form at high frequencies in spectrum, $f > 5$ kHz. Further, the amplitude of sound level reaches the peak between 5 kHz and 10 kHz. This peak extends to 10 kHz at which sound power level is 91dBA for wind speed of 10m/s. From the Figure 6(b), for frequencies below 10 kHz the experimental data for GE 1.5sle 77m turbine show good agreement within 1 % to the computational results obtained for the 2MW turbine. The trailing edge thickness effect on the overall sound power level (OASPL) is also seen negligible.

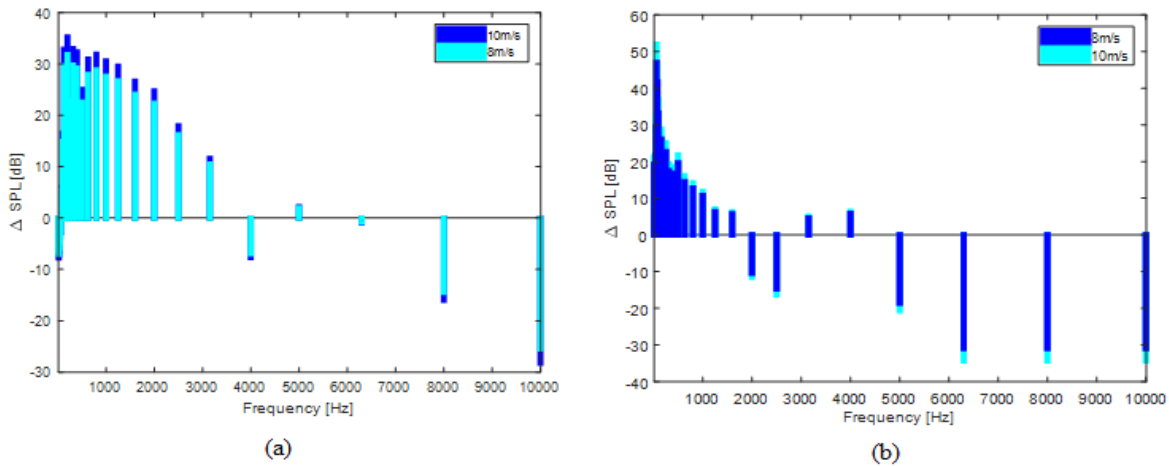


Figure 4 (a) Δ SPL (dB) for a change of 0.1% c to 0.5 % c in trailing edge thickness at wind speeds of 8m/s and 10m/s (b) for a change of 0.5 % c and 1 % c in trailing edge thickness.

Hence, this source becomes higher at frequencies near 10 kHz and contributed mainly from mid span region of blade. Therefore, it can be concluded that trailing edge bluntness source masks all other noise mechanisms at 10 kHz region. The Strouhal number variation is observed from 0.01 to 0.13 at free stream wind speeds 4m/s 8m/s 15m/s and 20 m/s for the case of 0.1% c . It can be noted that peak of sound power level is found to increase by 5dB due to the increase in wind speed near 10 kHz. Also, for high trailing edge thickness ratios the peak appears as tone and amplitude exhibits an oscillatory behaviour near low frequency region of spectrum. Further, it is also evident that tonal peak appears only near higher frequencies when the trailing edge thickness is scaled to 0.1 % of chord length. So, for low Mach number flows, given the higher bluntness ratio (h/δ^*) the tonal peak is found to shift to lower frequencies as shown in Fig 3(a). Fig 5(a) and Fig 5(b) shows the trailing edge thickness effect and influence of free stream velocities on peak Strouhal number along normalized blade span. As the trailing edge height is increased, the peak Strouhal number increases but remains almost steady along blade span for a given case. But with increase in free stream velocities, the peak Strouhal number shows a linear increase in trend along span wise direction. Towards the tip, for all velocities, the peak Strouhal number approaches nearly same value. It indicates that overall sound power level from turbine is also functionally

dependent on the angle of attack or otherwise blade pitch angle for a given flow condition

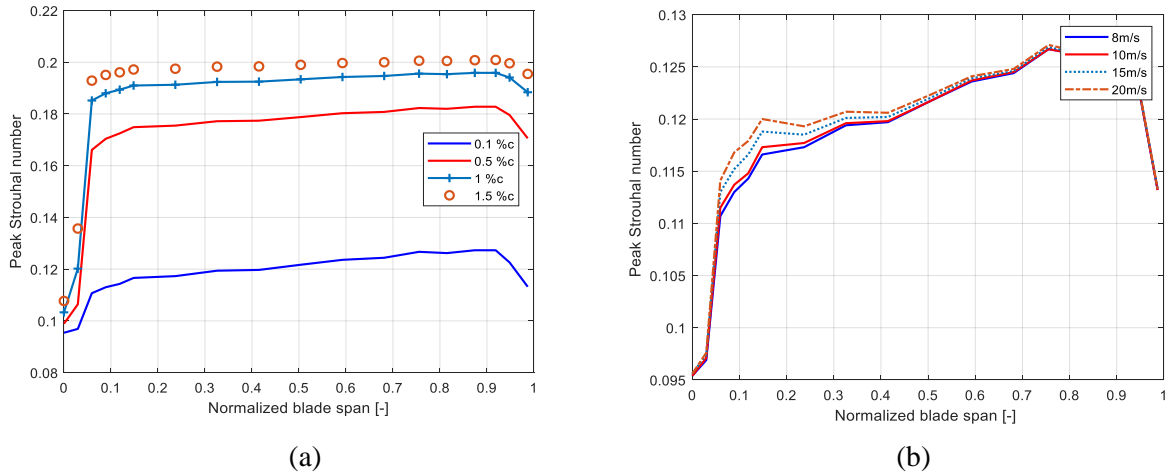


Figure 5 Peak Strouhal number, St_{peak} change along normalized blade span (a) with varying trailing edge heights, 0.1% c, 0.5% c, 1% c & 1.5% c for $U = 8m/s$ (b) with varying free stream velocities, $U = 8m/s, 10m/s, 15 m/s, 20m/s$

From Fig 6 (b) it can be seen that overall A-weighted sound power level for 2MW turbine agrees well with experiment data obtained for GE -1.5sle with 77m rotor diameter [13]. The overall sound levels also include turbulent inflow noise mechanism proposed by Lowson. It is based on Amiet’s theory [5, 12, 15] for inflow turbulence noise prediction developed for thin symmetric airfoils. It can be seen that maximum value of 95dBA and 105dBA is observed near 500 Hz region of spectrum and correlate very well with experiment data at 8m/s and 10m/s.

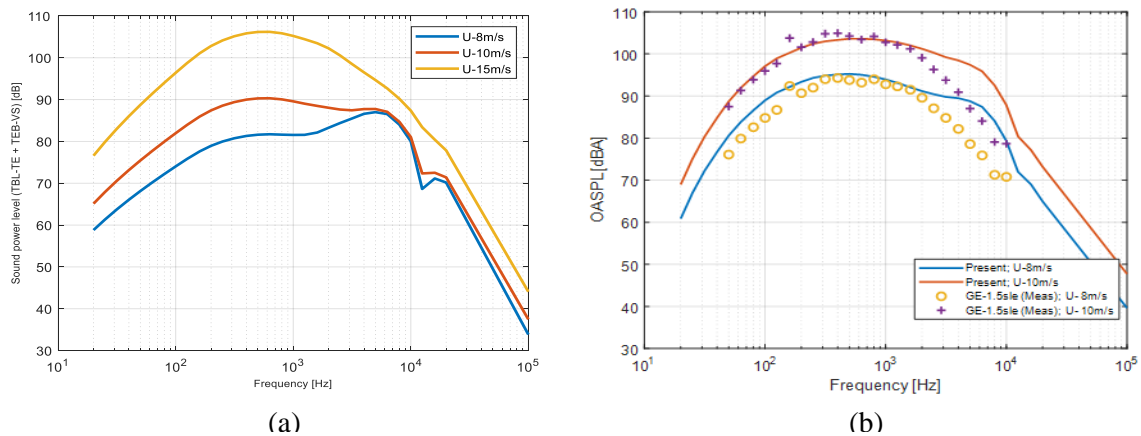


Figure 6 (a) Sound power level, dB due to combined effect from turbulent boundary layer trailing edge noise and bluntness sources at free stream wind speeds of 8m/s, 10m/s and 15 m/s using 0.1% trailing edge thickness (h/δ^*) (b) Validation of 1/3rd octave A-weighted overall sound power level for 2MW turbine of blade length 37m, with measured results of GE-1.5sle, 77m rotor diameter using 0.1% trailing edge thickness (h/δ^*)

Turbulence intensity and length scale are two important parameters in prediction of turbulent inflow noise. So, it has been evaluated for the current turbine using an integral length scale which is equivalent to maximum aerodynamic chord length of blade and for a turbulence intensity of 14 %. Turbulence intensity of 14 % according to IEC 61400-1 turbine design regulations corresponds to class B or otherwise classified as medium range. It has been found from studies that the speed of turbulent eddies in atmosphere are better correlated with aerodynamic chord length [12,16] Therefore, the length scale and intensity range are chosen which is most suitable to represent the plain grassland or country side conditions at which turbines operate. Also from Fig 6(a) for above rated wind speeds i.e. 15 m/s the trailing edge bluntness noise source becomes less significant and does not show strong tonal peak at high frequencies, ~10 kHz as found for wind speeds at 8m/s and 10m/s. It can be inferred that for pitch controlled turbines, at above rated wind speeds, the change in the maximum sound levels are found to vary negligibly as rotational speed of machine is kept constant. Therefore, the overall sound levels do not vary significantly. Fig 7 shows the contour plot of variation of peak Strouhal number with blade azimuth angle for free stream velocity of 8 m/s and also shown along the normalized blade span direction.

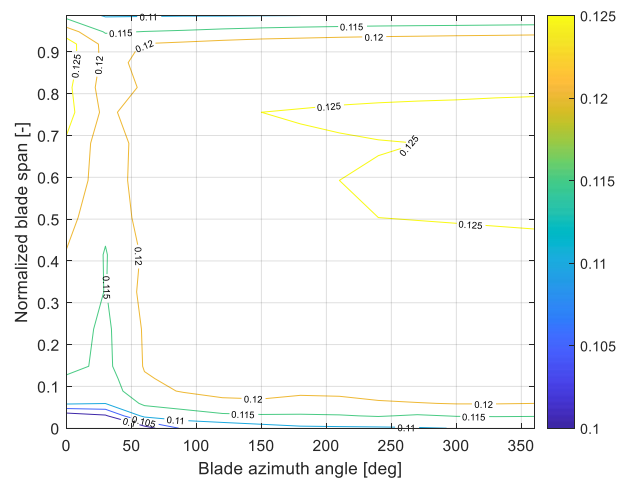


Figure 7 Peak Strouhal number, St_{peak} , variation along the normalized blade span for different blade azimuth angles for 0.1% trailing edge thickness and for $U = 8$ m/s

From Fig 6 (b), the noise spectrum is dominated by the turbulent boundary layer trailing edge noise in nominal mid band frequency range i.e. 63 Hz and the 8 kHz with approximately 95dBA at wind speed of 8 m/s. In the low frequency region however between 60 Hz and 200 Hz turbulent inflow noise dominates the other noise mechanisms. The experimental results for the GE 1.5sle machine does not show the tonal peak effect near 10 kHz as it is observed from computational prediction using BPM model. Hence it confirms that trailing edge bluntness vortex shedding noise becomes important noise source for wind turbines if characteristic dimensions of the blade i.e. trailing edge height scales to higher values of blade chord length and for below rated wind speeds of turbine operation.

5 CONCLUSIONS

A computational analysis of trailing edge bluntness vortex shedding noise mechanism for horizontal axis 2MW turbine was performed for different trailing edge thicknesses. The effect of trailing edge thickness on $1/3^{\text{rd}}$ octave overall A weighted sound level showed tonal peak near 10 kHz region and masks all other self-noise mechanisms. The experiment results showed very good agreement with simulated outputs for the overall A weighted sound power level spectrum at wind speed of 8m/s and 10m/s. The extent of reduction or increase in bluntness noise levels is 15dB and 35dB for a thickness increment from 0.1 %c to 0.5%c while for an increment of 0.5%c and 1 %c it is 35dB and 50dB. The predominant changes in sound power levels were found between 1 kHz and 10 kHz region of spectrum and illustrates that the tonal peak shift towards the low frequency region in spectrum with increasing values of trailing edge thickness.

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