The Effect of Wind on Low Frequency Noise

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ABSTRACT

The impact of wind on the measurement of low frequency noise is a topic that is worth researching into. Since the existing "Measuring Method of Environmental Low Frequency Noise" applies only to indoor measurement of low frequency noises (According to the provision of law in our country, low frequency refers to the frequency range of 20 Hz ~ 200 Hz), if a petitioner demands measuring the low frequency noise at an outdoor location, there is no method and/or control standard for outdoor measurement of low frequency noise currently available in our country. This paper aims to explore the effect of the windscreen on reducing wind noise. It is hoped that the findings of the study can serve as reference for formulating method and control standard for outdoor measurement of low frequency noise. When conducting noise measurement, if the sensor of the sound meter is affected by the effect of wind force, there is an influence of wind noise on the measurement, particularly at low frequencies (20 Hz ~ 200 Hz). This study aims to explore the effect of wind noise on outdoor noise measurement at low frequencies. Through comparing and probing into the effects of wind noise when using different types of windscreens, we have obtained some noticeable noise reducing results under different wind speeds when using different types of windscreens, which might serve as reference for selecting windscreens when conducting outdoor noise measurement at low frequencies.

Keywords: Low frequency noise, windscreen, wind noise

1. INTRODUCTION

Wind noise is mainly produced by the air agitation that is caused by air turbulence [1, 2]. To reduce wind noise, a windscreen is generally installed over the sound sensor (microphone) and the shape, size and material of the windscreen all have significant effect on the reduction of wind noise [3]. When conducting outdoor noise measurement, the performance of the sound sensor (microphone) is more or less affected by the effect of wind force. Particularly in the part of low frequency (20 Hz ~ 200 Hz), the "effect" of wind noise is even more significant. Therefore, to conduct outdoor noise measurement, we must first identify the "effect" of wind noise (instead of the level of wind noise) in order to obtain correct measuring results.

Morgan and Raspetm conducted tests in high speed turbulence in 1992, during which they made noise measurements through a sound sensor (microphone) equipped with a windscreen of various sizes or with no windscreen. The results of their tests showed that the reduction of wind noise was not significantly relevant to the dimension and opening size of the windscreen. In addition, they also explained that in high speed turbulence, wind noise is mainly produced by the air agitation caused by air turbulence [1]. In 2008, George F. Hessler, David M. Hessler, Peter Brandstätt and Karlheinz Bay conducted sound level tests using different types of windscreens under various wind speeds to identify the reduction of wind noise in relation to various windscreens through experimental research. The results showed that the sound pressure increases with the increase of wind speeds in a linear manner [4]. It is worthwhile to note that so far most studies have been conducted on windscreens of various sizes or types for comparative research. None of them was conducted on windscreens of different materials.

This study aims to explore the "effect" of wind or the performance of windscreen and its use limits in low frequency part through wind tunnel environment experiment under various parameters (wind speed, windscreen and material, etc.). It is known that the low frequency noise has a very strong penetration force on obstacles. However, in the application of windscreens, other than satisfying the

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need to reduce the "effect" of wind noise surrounding the sound sensor (microphone), it is also to ensure that the low frequency noise can penetrate the windscreen and reach the position of the sound sensor (microphone). The parameters used in the experiment include the wind speed and windscreen. While the range of wind speed is 0.5 m/s ~ 5.0 m/s (with a class interval of 0.5 m/s), the windscreens used are of different materials and sizes (WS-10, WS-03, RKK-08-66A, denim fabric, velvet fabric and woolen fabric). The experiment produced some results that are worthwhile noticing: when adopting different windscreens and measuring under different wind speeds, the noise reduction (anti-wind performance) and "effect" of wind are also varied.

2. Experimental method

2.1 Experiment venue

This study was conducted at the wind tunnel laboratory of Tamkang University of our country. The LW-3840 wind tunnel used in the study is an aspiration subsonic wind tunnel with an open loop structure. The specifications of the wind tunnel are as follows: overall dimension: 2.6 (W) m × 10 (L) m × 2.8 (H) m; operating space: 4 (W) m × 15.5 (L) m × 3.5 (H) m; test section: 1.3 (W) m × 1.3 (H) m × 2.4 (L) m; wind speed: 1 m/s ~ 25 m/s; quality of flow field: wind speed > 2 m/s, sectional area = 80% (counting from the center), flow field uniformity > 95%, and turbulence strength < 2%. During the experiment, the whole process can be monitored through a large-scale reinforced glass window (shown in Figure 1).

Figure1 – Wind Tunnel Lab owned by Department of Aerospace Engineering, Tamkang University

2.2 Equipment

1. Measuring instruments: Rion NL-32 omnidirectional microphone, that meets CNS 7129 Type 1 Sound Meter and IEC 61260 Class 1 standards, was adopted in the experiment. Before and after the measurement, the sound meter was calibrated in accordance with manufacturer's instructions. After calibration, the absolute variation between the display value and calibration value (acoustic calibrator) must not be larger than 0.7 dB and the absolute variation between two display values must not be larger than 0.3 dB. The certification interval for the sound meter is two years and the calibration interval for the sound calibrator is one year.
2. Sound Calibrator: A sound calibrator that meets the standards specified in CNS 13331 C7222 was adopted. For setting frequency points for the sound calibrator, at least one frequency point has to fall in the low frequency range (20 Hz ~ 200 Hz).
3. Recorder: A recorder that meets the standards specified in CNS 10915 C4410 was connected. When in use, the dynamic characteristics of the recorder have to be consistent with those of the sound meter. Before recording noise measurements, the calibration signal level of the sound meter has to be confirmed on the recording paper.
4. Wind speed measuring system: the pitot-static tube commonly used in flow experiment was used in the wind speed measuring system. The average wind speed was calculated through pressure variation.
5. Experimental plate: Acrylic material was used to make the experimental plate, which was set at the test section of LW-3840 wind tunnel in an elevated manner to allow the measuring position to stay in a

uniform and stable flow field and receive a uniform wind speed. The setup and configuration of the experimental plate and related instruments are shown in Figure 2.

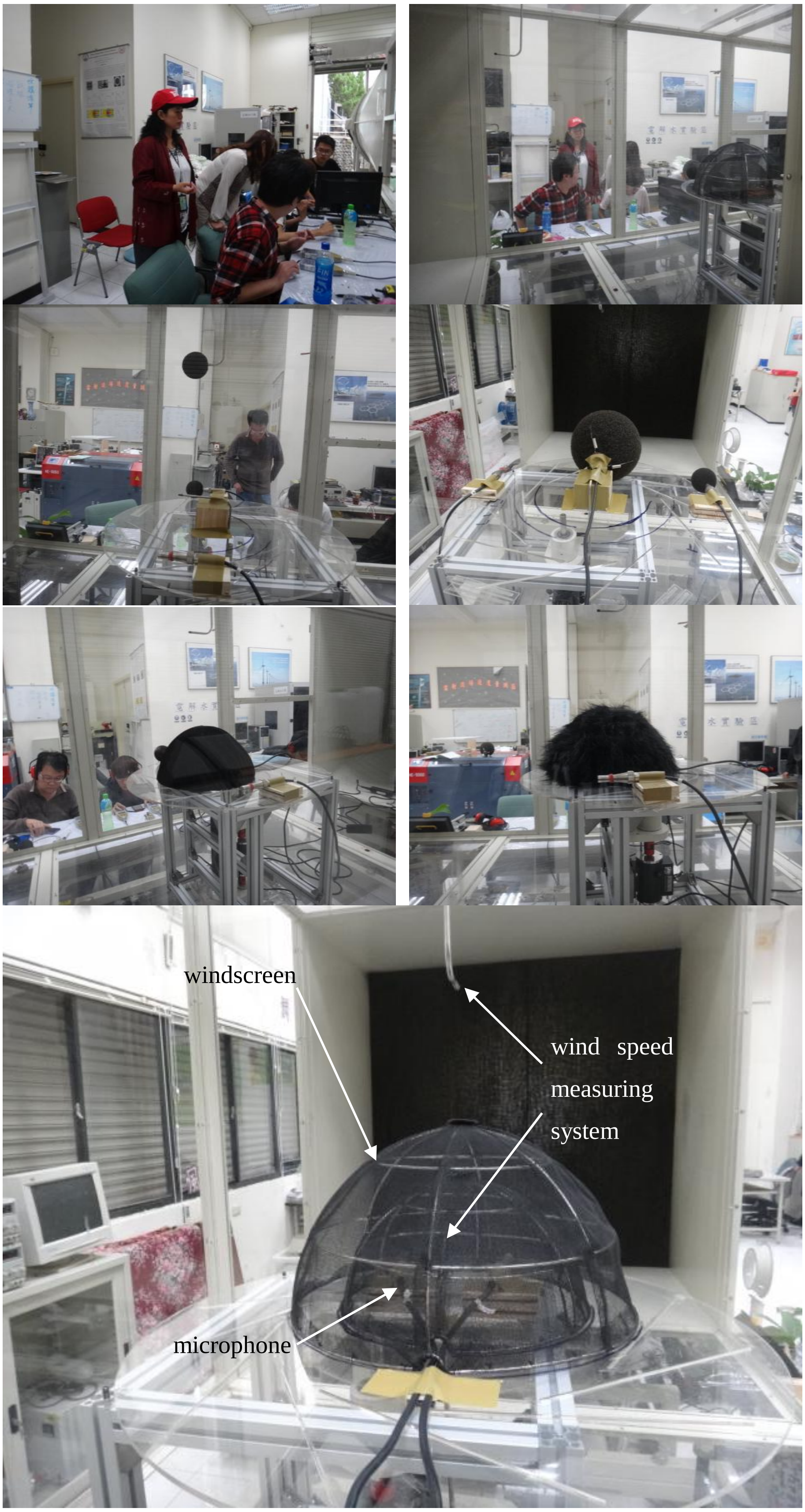

Figure 2 – Setup and configuration of experimental plates and related instruments

2.3 Parameter setting

1. Rion NL-32 omnidirectional microphone was used to measure the wind field environment and low frequency noise level in the wind tunnel under various wind speeds. While unweighted measurement was adopted for frequency-weighting, fast mode was used for time-weighting. The measuring time for each wind speed was two minutes. The measuring frequency range was 20 Hz ~ 20 kHz and 20 Hz ~ 200 Hz was adopted for numerical analysis.
2. Wind speed range was 5.0 m/s ~ 0.5 m/s with a speed decreasing class interval of 0.5 m/s.
3. The used included Rion Windscreen WS-10 (7cm diameter), Rion Windscreen WS-03 (20cm diameter), and two bowl-type mesh structure frames (30cm and 40cm diameter respectively). Covering materials included Rion RKK-08-66A, denim fabric, velvet fabric and woolen fabric.

2.4 Measuring steps

1. Before conducting measurements, turn off all noise sources in the room that are likely to make low-frequency noises (e.g. air conditioner).
2. Use two pitot-static tubes and two Rion NL-32 microphones (along with two 3.0m extension cords) to lay out two test groups (each contains a pitot-static tube and a Rion NL-32 microphone). Set the instruments of each test group on an experimental plate in an elevated manner with one microphone at the center of the windscreen and the other outside of it so as to measure the noises and wind speeds inside and outside of the windscreen simultaneously (one microphone is screened and the other unscreened).
3. During measurements, the wind speed decreases from 5.0 m/s to 0.5 m/s with a class interval of 0.5 m/s. Turn on the instruments of the two test groups simultaneously to measure the noises and wind speeds inside and outside of the windscreens continuously.
4. Analyze the results simultaneously and continuously measured from the microphones and pitot-static tubes inside and outside of the windscreen. Each wind speed (average) is measured for two minutes to produce one result.
5. Conduct the measurement process repeatedly to include all types of windscreens: WS-10, WS-03, RKK-08-66A, denim fabric, velvet fabric and woolen fabric.

3. Experimental results

In this section, the experimental results of the wind tunnel environment are explained in two parts: 3.1 analysis of noise reduction by windscreens (anti-wind performance); 3.2 the effect of wind noise.

Table 1 – Experimental parameter setting

Windscreen / Wind speed	WS-10 (7 cm diameter)		WS-03 (20 cm diameter)		RKK-08-66A (double-layer 30 cm and 40 cm diameter)		Denim fabric (40 cm diameter)		Velvet fabric (40 cm diameter)		Woolen fabric (40 cm diameter)	
	inside	outside	inside	outside	inside	outside	inside	outside	inside	outside	inside	outside
5.0 m/s~ 0.5 m/s Class interval 0.5 m/s	●	●	●	●	●	●	●	●	●	●	●	●
Rion NL-32 omnidirectional microphone was used to measure the wind field environment and low frequency noise level in the wind tunnel under various wind speeds. While unweighted measurement was adopted for frequency-weighting, fast mode was used for time-weighting. The measuring time for each wind speed was two minutes. The measuring frequency range was 20 Hz ~ 20 kHz and 20 Hz ~ 200 Hz was adopted for numerical analysis.												

3.1 Analysis of noise reduction by windscreens (anti-wind performance)

1. WS-10 (7 cm diameter) & WS-03 (20 cm diameter)

Table 2 shows the analytical comparison of noise reduction by WS-10 & WS-03 under various wind speeds. When the wind speed increases from 0.5 m/s to 5.0 m/s, the experimental results are shown as follows:

(1) The average wind speed variation between wind speeds measured inside and outside of WS-10 ranges from 0.5 m/s to 2.8 m/s. Other than when the wind speed is under 2.0 m/s, the wind speed inside WS-10 is always a non-zero value, indicating that the effect of wind noise cannot be completely and effectively blocked out. However, when the wind speed is over 2.5 m/s, the variation of low-frequency A-weighted sound level with or without WS-10 gradually appears (Figure 3).

(2) The average wind speed variation between wind speeds measured inside and outside of WS-03 ranges from 0.5 m/s to 4.0 m/s. Other than when the wind speed is under 3.0 m/s, the wind speed inside WS-03 is always a non-zero value, indicating that although the effect of wind noise cannot be completely and effectively blocked out, WS-03 is quite effective to reduce the wind noise when the wind speed is less than 5.0 m/s. When the wind speed is over 2.5 m/s, the variation of low-frequency A-weighted sound level with or without WS-03 becomes more obvious (Figure 3).

(3) The noise reduction performance of WS-03 is better than that of WS-10 and the linear variation of sound level of these two windscreens shows a similar pattern (Figure 4): the noise reduction obviously increases when the wind speed becomes over 2.5 m/s. That means when the wind speed is over 2.0 m/s, the effect of wind noise increases significantly.

Table 2 – Analytical Comparison of Noise Reduction by WS-10 & WS-03 under Various Wind Speeds

Volume unit: dB(A)

Wind speed	WS-10				WS-03			
	Inside ave. wind speed	Low-freq. A-weighted sound level, without WS-10	low-freq. A-weighted sound level, with WS-10	Noise reduction	Inside ave. wind speed	Low-freq. A-weighted sound level, without WS-03	low-freq. A-weighted sound level, with WS-03	Noise reduction
0.5 m/s	0.0	60.9	60.9	0.0	0.0	60.9	60.4	0.5
1.0 m/s	0.0	61.1	61.0	0.1	0.0	61.1	60.5	0.6
1.5 m/s	0.0	61.4	61.3	0.1	0.0	61.4	60.7	0.7
2.0 m/s	0.0	62.3	61.8	0.5	0.0	62.3	61.0	1.3
2.5 m/s	0.7	64.0	62.5	1.5	0.4	64.0	61.5	2.5
3.0 m/s	1.1	66.4	63.8	2.6	0.5	66.4	62.4	4.0
3.5 m/s	1.5	68.8	65.6	3.2	0.7	68.8	63.8	5.0
4.0 m/s	1.8	71.7	67.6	4.1	0.8	71.7	65.5	6.2
4.5 m/s	2.0	74.5	69.8	4.7	0.9	74.5	67.7	6.8
5.0 m/s	2.2	76.9	72.0	4.9	1.0	76.9	69.7	7.2

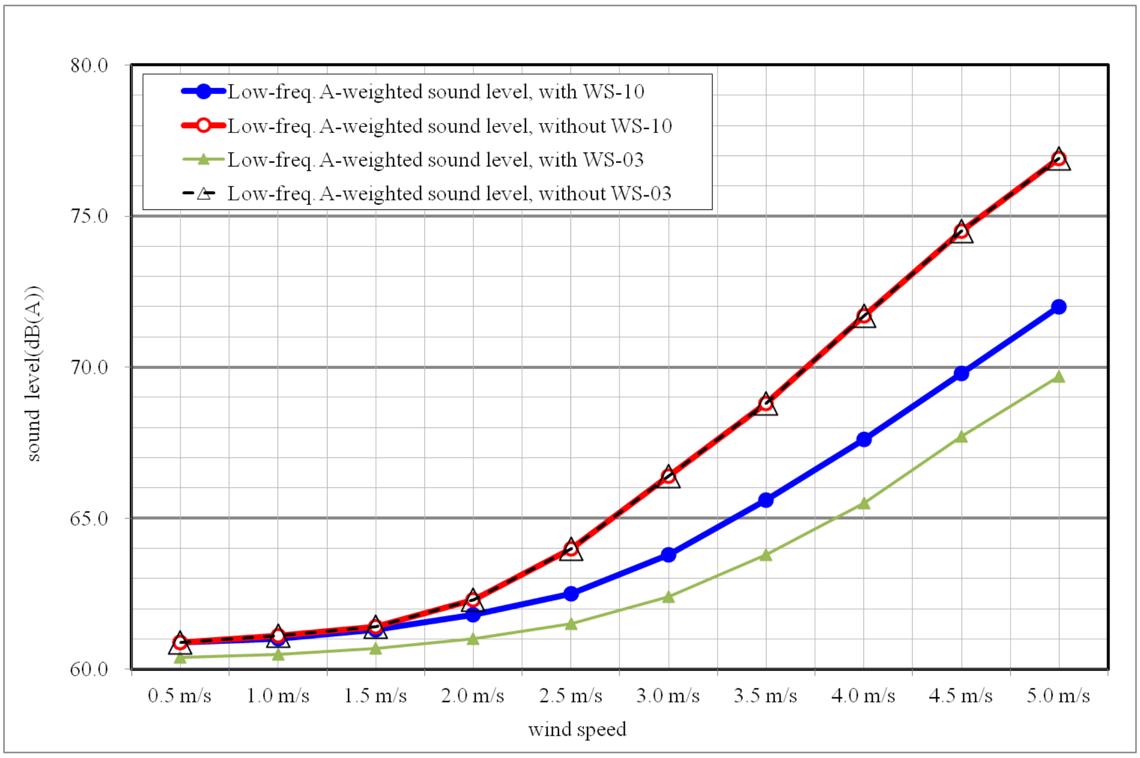

Figure 3 – Trend plot of Variation of Low-frequency A-weighted Sound Level with or without WS-10 & WS-03

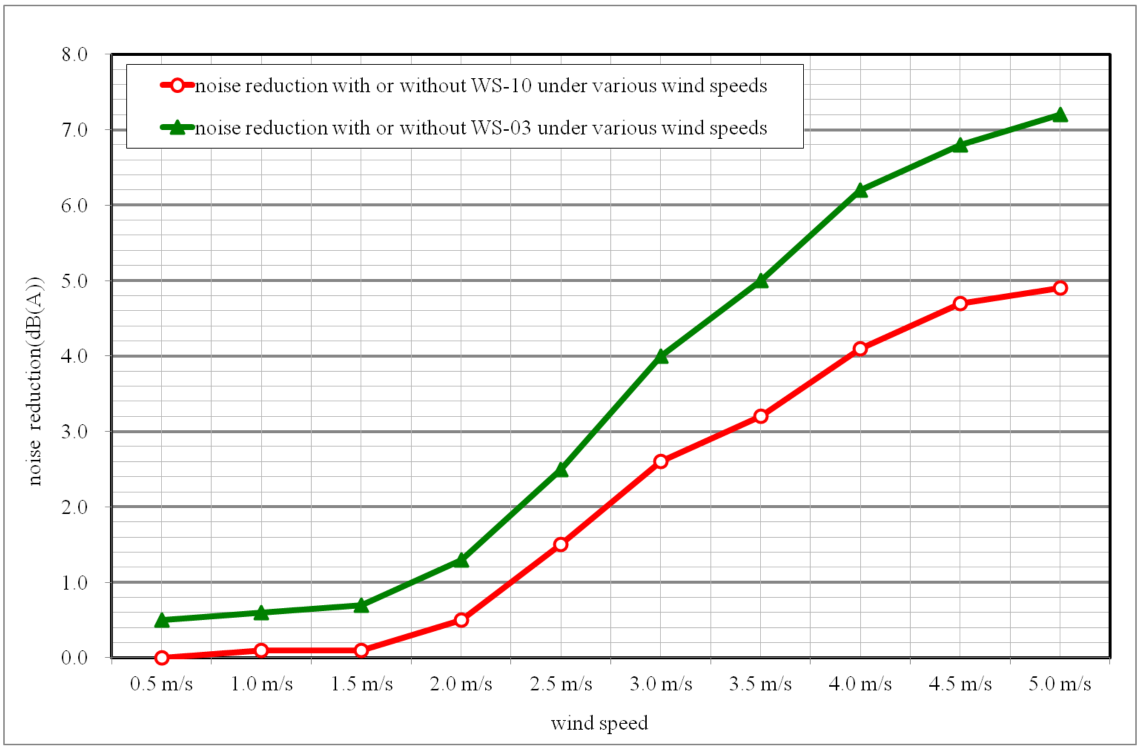

Figure 4 – Analytical Comparison Plot of Noise Reduction by WS-10 & WS-03 under Various Wind Speeds

2. Rion RKK-08-66A

Table 3 shows the analytical comparison of noise reduction by RKK-08-66A under various wind speeds. When the wind speed increases from 0.5 m/s to 5.0 m/s, the experimental results are shown as follows:

Table 3 – Analytical Comparison of Noise Reduction by RKK-08-66A under Various Wind Speeds

Volume unit: dB(A)

Wind speed	Inside ave. wind speed	Outside low-freq. A-weighted sound level	Inside low-frequency A-weighted sound level	Noise reduction
0.5 m/s	0.0	53.9	53.3	0.6
1.0 m/s	0.0	54.9	54.3	0.6
1.5 m/s	0.0	59.2	58.6	0.6
2.0 m/s	0.4	59.8	58.3	1.5
2.5 m/s	0.7	61.0	59.0	2.0
3.0 m/s	0.9	65.3	61.8	3.5
3.5 m/s	1.2	67.4	63.6	3.8
4.0 m/s	1.5	70.3	65.2	5.1
4.5 m/s	1.7	73.2	67.7	5.5
5.0 m/s	2.0	75.2	69.3	5.9

(1) The average wind speed variation between wind speeds measured inside and outside of RKK-08-66A ranges from 0.5 m/s to 3.0 m/s. Other than when the wind speed is under 2.0 m/s, the wind speed inside of the double-layer windscreen is always a non-zero value, indicating that the effect of wind noise cannot be completely and effectively blocked out. However, when the wind speed is over 3.0 m/s, the variation of sound level with or without RKK-08-66A is obvious (Figure 5).

(2) When the wind speed is over 2.0 m/s, noise reduction increases significantly, indicating that when the wind speed is over 2.0 m/s, the effect of wind noise increases obviously (Figure 6).

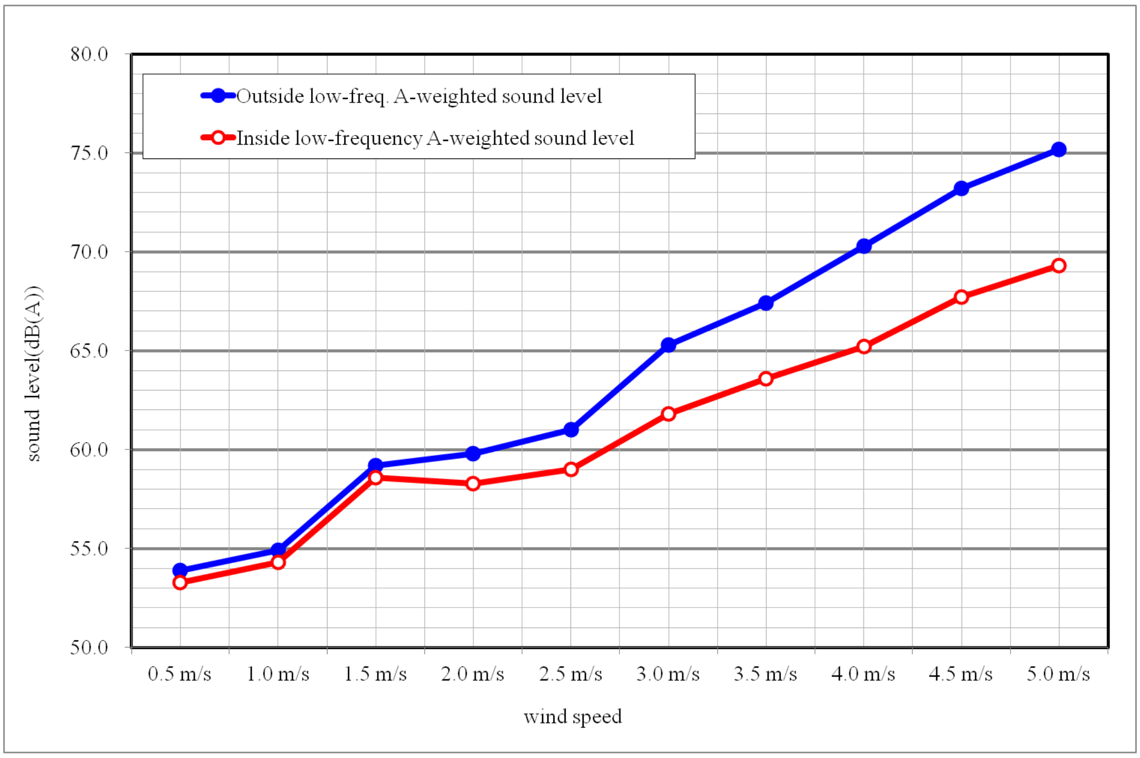

Figure 5 – Trend plot of Variation of Low-frequency A-weighted Sound Level Inside or Outside (unscreened microphone) of RKK-08-66A

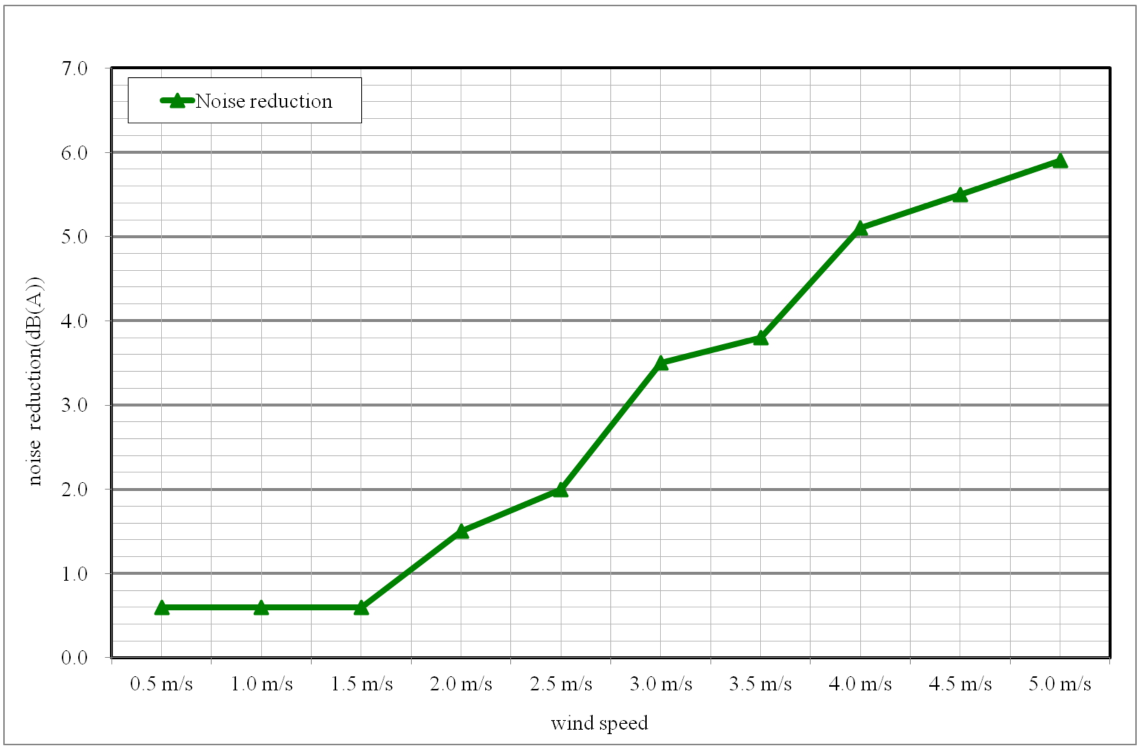

Figure 6 – Analytical Plot of Noise Reduction by RKK-08-66A under Various Wind Speeds

3. 40 cm bowl-type mesh structure frame covered with denim fabric, velvet fabric and woolen fabric (unscreened microphone)

Table 4 shows the analytical comparison of noise reduction by a 40 cm bowl-type mesh structure frame covered with denim fabric, velvet fabric and woolen fabric (unscreened microphone) under various wind speeds. When the wind speed increases from 0.5 m/s to 5.0 m/s, the experimental results are shown as follows:

(1) The average wind speed measured inside of the windscreen is always a zero value, indicating that when covered with three kinds of anti-wind fabrics, the effect of wind noise can be effectively blocked off. When the wind speed is over 2.5 m/s, the variation between sound levels measured inside and outside of the windscreen becomes obvious (Figure 7).

(2) Judging from the variation of average wind speed between inside and outside of the windscreen, when covered with fabrics, the single-layer windscreen can totally block out the effect of wind noise (as shown in Table 4 and Figure 8). In terms of low-frequency A-weighting, when the average wind speed is under 1.5 m/s, the variation of sound level ranges from 0.0 dB(A) to 1.4 dB(A). When the wind speed is 2.0 m/s ~ 5.0 m/s, the variation of sound level ranges from 2.0 dB(A) to 12.0 dB(A). Overall speaking, the variation of noise reduction among these three anti-wind fabrics is not obvious.

4. Comparison of noise reduction among windscreens

The noise reductions of various types of windscreens are shown in Table 5 and Figure 9. The bigger the diameter of the windscreen, the less the air turbulence produced on the surface of the microphone, hence the less the deviation of low-frequency noise measurements caused by air turbulence. The sequence of the noise reduction performance among windscreens is: windscreen covered with one layer of fabric > WS-03 > RKK-08-66A > WS-10.

Table 4 – Analytical Comparison of Noise Reduction by a 40 cm Bowl-type Mesh Structure Frame Covered with Denim Fabric, Velvet Fabric and Woolen Fabric under Various Wind Speeds

Volume unit: dB(A)

Wind speed	Denim fabric				Velvet fabric				Woolen fabric			
	Inside Ave. wind speed	Outside low-freq. A-weighted sound level	Inside low-freq. A-weighted sound level	Noise reduction	Inside Ave. wind speed	Outside low-freq. A-weighted sound level	Inside low-freq. A-weighted sound level	Noise reduction	Inside Ave. wind speed	Outside low-freq. A-weighted sound level	Inside low-freq. A-weighted sound level	Noise reduction
0.5 m/s	0	61.3	61.7	0	0	61.2	61	0.2	0	61.1	60.9	0.2
1.0 m/s	0	61.5	61.8	0	0	61.6	61.1	0.5	0	61.3	61	0.3
1.5 m/s	0	62.1	61.9	0.2	0	62.6	61.2	1.4	0	61.8	61	0.8
2.0 m/s	0	65.2	62.2	3	0	65.1	61.6	3.5	0	63.5	61.5	2
2.5 m/s	0	68.1	62.7	5.4	0	68.3	62	6.3	0	66.6	61.8	4.8
3.0 m/s	0	71.1	63.5	7.6	0	71.3	62.9	8.4	0	69.4	62.7	6.7
3.5 m/s	0	74.1	65	9.1	0	74.6	64.4	10.2	0	72.3	64.2	8.1
4.0 m/s	0	76.8	66.4	10.4	0	77.5	65.9	11.6	0	75.1	65.8	9.3
4.5 m/s	0	79.6	68.8	10.8	0	80.2	68.2	12	0	77.5	68.2	9.3
5.0 m/s	0	81.4	70.8	10.6	0	82.1	70.4	11.7	0	79.9	70.2	9.7

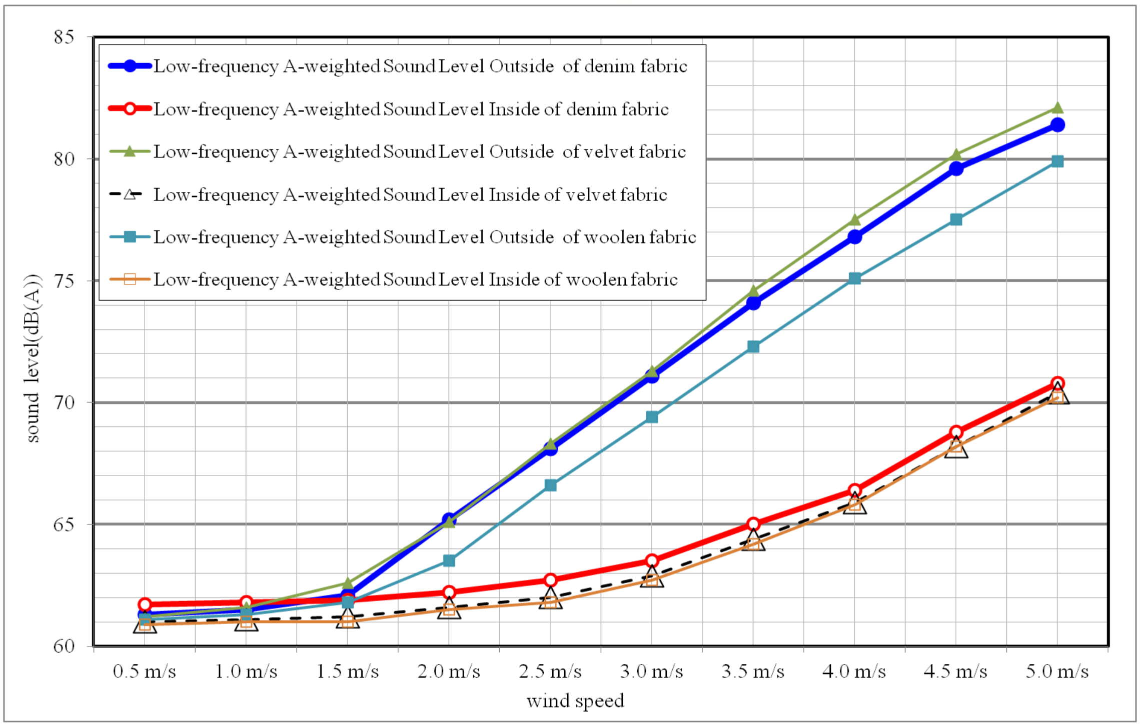

Figure 7 – Trend Plot of Variation of Low-frequency A-weighted Sound Level of a 40 cm Bowl-type Mesh Structure Frame Covered with Denim Fabric, Velvet Fabric and Woolen Fabric (unscreened microphone)

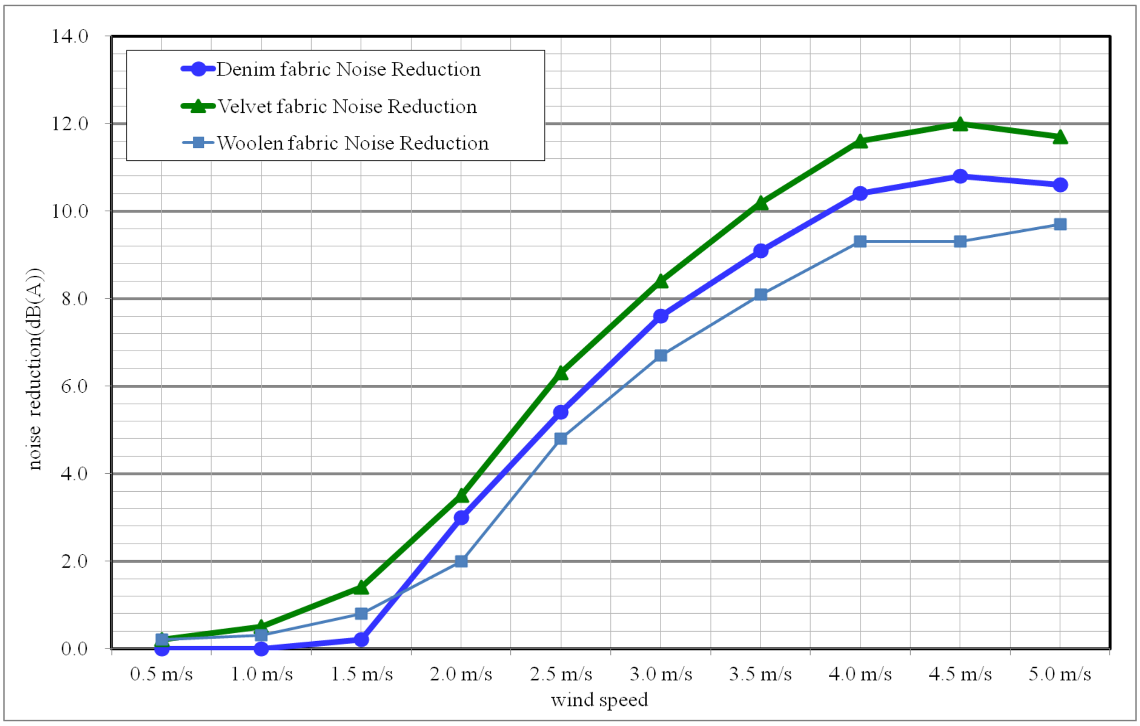

Figure 8 – Analytical Comparison Plot of Noise Reduction by a 40 cm Bowl-type Mesh Structure Frame Covered with Denim Fabric, Velvet Fabric and Woolen Fabric (unscreened microphone) under Various Wind Speeds

Table 5 – Analytical Comparison of Low-frequency Noise Reduction by Windscreens under Various Wind Speeds

Volume unit: dB(A)

Wind speed	WS-10 Noise reduction	WS-03 Noise reduction	RKK-08-66A Noise reduction	Single fabric Windscreen Noise reduction (note)
0.5 m/s	0.0	0.5	0.6	0.1
1.0 m/s	0.1	0.6	0.6	0.3
1.5 m/s	0.1	0.7	0.6	0.8
2.0 m/s	0.5	1.3	1.5	2.8
2.5 m/s	1.5	2.5	2.0	5.5
3.0 m/s	2.6	4.0	3.5	7.6
3.5 m/s	3.2	5.0	3.8	9.1
4.0 m/s	4.1	6.2	5.1	10.4
4.5 m/s	4.7	6.8	5.5	10.7
5.0 m/s	4.9	7.2	5.9	10.7

Note: Figures in this table are arithmetic averages obtained from those in Figure 4.

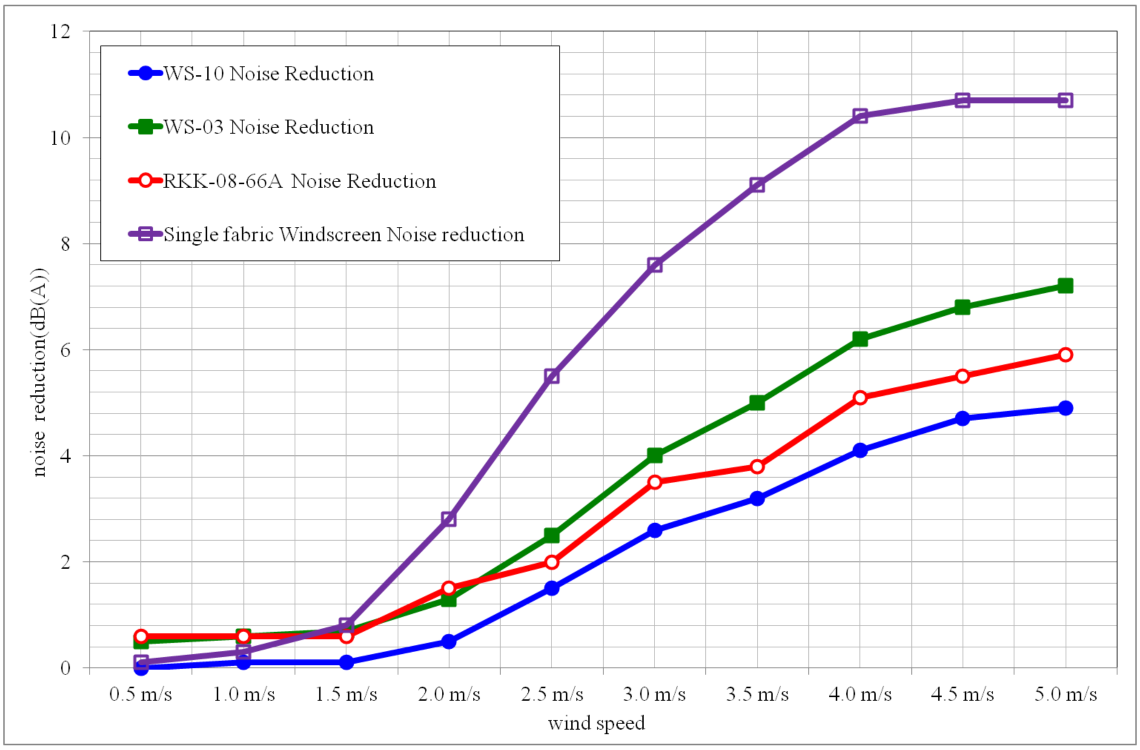

Figure 9 – Analytical Comparison Plot of Low-frequency Average Noise Reduction by Windscreens under Various Wind Speeds

3.2 Effect of wind noise

As shown in the above analysis of noise reductions by various windscreens, it is known that the effect of wind noise can only be partially improved and deviation of measurements cannot be totally excluded due to part of the wind noise left. In other words, under experimental wind speeds, when the microphone is shielded with WS-10, WS-03 or RKK-08-66A, the wind speed inside the windscreens is not always a zero value, indicating that the wind noise cannot be totally and effectively blocked out.

Table 6 shows the effect of low-frequency (20 Hz ~ 200 Hz) A-weighted wind noise under various wind speeds. When the wind speed is 0.0 m/s, there is no effect of wind noise. When the wind speed is 1.0 m/s, the effect of wind noise is around 0.3 dB (A). When the wind speed is 2.0 m/s, the effect of wind noise is around 0.7 dB (A). When the wind speed is 3.0 m/s, the effect of wind noise is around 3.8 dB (A).

Table 6 – Effect of Low-frequency A-weighted Wind Noise under Various Wind Speeds

Volume unit: dB(A)

Wind speed	Effect of low-frequency A-weighted wind noise
1.0m/s	0.3
2.0m/s	0.7
3.0m/s	3.8

4. Conclusions and recommendations

This study conducted experimental evaluation on the effect of A-weighted low-frequency wind noise on WS-10, WS-03, RKK-08-66A, and single-layer windscreen (covered with denim fabric, velvet fabric and woolen fabric) under various wind speeds, including variation of wind speeds measured inside and outside of the windscreen, change pattern of sound level, and experimental results of the noise reduction of windscreens. Conclusions can be described as follows:

1. Through relevant statistical analysis on wind noises and wind speeds, it concludes that there is a strong linear relationship between the wind noise and wind speed.
2. The results of the wind tunnel experiment show that when the wind speed is under 2.0 m/s, the effect of wind noise is less significant.
3. Generally, when the wind speed is under 1.5 m/s, the noise reduction performances of various types of windscreens, such as WS-10, WS-03, RKK-08-66A, and single-layer windscreen, are similar.
4. Generally, when the wind speed is under 2.0 m/s, the noise reduction performances of various types of windscreens are similar, except for the single-layer windscreen.
5. When the wind speed is over 2.0 m/s, the noise reduction performance of the single-layer windscreen is obviously better than other windscreens.
6. When the wind speed is under 2.5 m/s, the noise reduction performances of WS-03 and RKK-08-66A are similar. However, when the wind speed is over 2.5 m/s, the noise reduction performance of WS-03 is better than that of RKK-08-66A.
7. Overall, when the wind speed is over 2.5 m/s, the increase of noise reduction by the windscreen is obvious. Therefore, when the wind speed is over 2.0 m/s, the effect of wind noise on the measurements of low-frequency noise will increase.
8. When the wind speed is 1.0 m/s ~ 2.0 m/s, the effect of wind noise on the microphone is equivalent to the noise reduction of WS-10. When the wind speed is 3.0 m/s, the effect of wind noise on the microphone is equivalent to the noise reduction of WS-03. These facts may serve as reference for selecting the windscreen to avoid wind interference when conducting low-frequency noise measurement outdoor.

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