

Effects of splitting a ground board on wind turbine noise measurements

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1. Introduction

As developments in wind energy progress, acoustic noise from wind farms has become an issue of concern in many countries. The IEC Technical Committee 88 (Wind turbine generator systems) set up Working Group 5 in 1992 to create a draft international standard of acoustic noise measurement techniques for wind turbines, which was published as IEC 61400-11 [1] in 1998. This standard defines procedures for characterizing the noise emissions of a wind turbine. The locations of acoustic measurements, requirements for acoustic acquisitions, meteorological conditions, and associated wind turbine operational data are described in the document. In 1999, TC88 set up Maintenance Team 11 (MT11) to revise the standard, whose revision is to be issued in the near future.

For acoustic measurements, the standard requires that a microphone be mounted on a one-piece board placed on the ground. The purpose of using this ground board is to minimize the influence of differing ground types on the measurements and to reduce wind-induced noise at the microphones. The board can be either circular or rectangular with a minimum diameter or width of 1.0 m. At one meeting of IEC/TC88/MT11, the use of a split board was suggested. While the use of a larger board would be expected to improve the accuracy of the measurements, it is inconvenient to transport and handle. If a split board could be used, the board could be larger.

Since no data were available about how a split in the board might affect acoustic measurements, experiments to investigate the possible effects of a split upon the measurements were carried out by using a setup that simulated wind turbine noise measurements. The experimental results indicated the proper location of the split and the allowable gap size that could be used without degrading the accuracy of the acoustic measurements when compared with those obtained with a one-piece board. This letter reports the experimental methods used and discusses the results.

2. Test methods and test sites

2.1. Test methods

A diagram of the experimental setup is shown in Fig. 1 [2]. A loudspeaker raised 12.0 m above the ground surface and driven by a white noise signal was used as the sound source. Two microphones, M1 and M2, were used; M1 was located 1.15 m from the speaker to serve as the reference, and M2 was

placed on the board surface and scanned to obtain sound levels on the board. The center of the board was located at a horizontal distance of 18.3 m from the speaker. This arrangement provided an angle of inclination between the speaker and the board surface of about 34° , which simulated the angle usually encountered in actual noise measurements of a wind turbine, according to the standard [1].

Two circular boards (a one-piece board and a split board), both made of 21-mm-thick plywood and with diameters of 1.0 m, were prepared for the tests. The split board was divided by a straight cut 10 cm from the center, and the two pieces thus divided were connected by means of three iron plates and bolts to form a flat circular board with a split. This connecting structure allowed the gap of the split to be set optionally as large as 4 mm. The board was simply placed on sod-covered ground for the acoustic tests.

Figure 2 shows the three split locations that were tested together with an x - y coordinate system that was superimposed on the board surface. Sound levels on the x and y axes were measured by scanning the M2 microphone while keeping the axis of the microphone parallel to the x -axis.

2.2. Test sites and measurement conditions

The experiments were carried out at two selected sites (sites A and B) at AIST Tsukuba Northern Office, which is located in a quiet rural area and surrounded mainly by farmland or woods, and partly by private residences. Site A, used only to determine the reference response as mentioned later, was a 200 m by 130 m flat space whose surface was covered by a 31-cm-thick structure composed of asphalt and concrete. This site can be regarded as a half free field with a hard reflecting boundary. Site B was a nearly flat but slightly undulating space covered by cut sod. There were no sound-reflecting structures or obstacles influencing the measurements at either site.

The reference response of $L(M2) - L(M1)$, designated by $(M2/M1)_0$, was first determined as the reference to obtain the relative response defined in the following, where $L(Mi)$ is the level of the response of the microphone Mi ($i = 1$ or 2), and the M2 microphone was placed directly at the origin of the x - y coordinates on the site A surface. Then the responses of $L(M2) - L(M1)$, designated by $M2/M1$, where the M2 microphone was mounted on the board placed upon the site B surface, was measured to determine the relative response of $M2/M1 - (M2/M1)_0$.

The frequency range of measurements required by the standard [1] is 50 Hz to 5 kHz using one-third octave band

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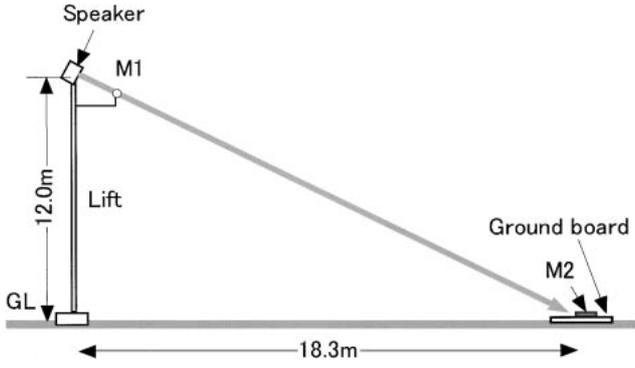


Fig. 1 Diagram of the experimental setup.

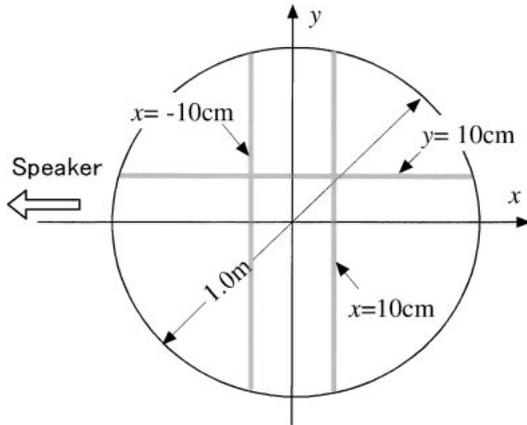


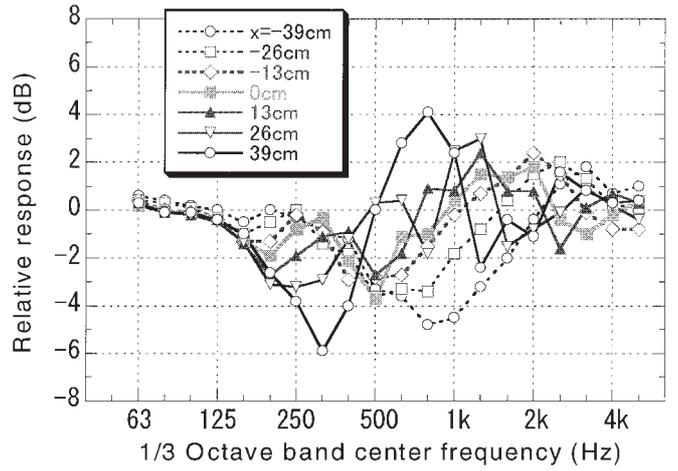
Fig. 2 Split locations and x-y coordinate system of the test ground board.

center frequencies. However, results of the tests are presented only for frequencies higher than 63 Hz due to background noise at 50 Hz.

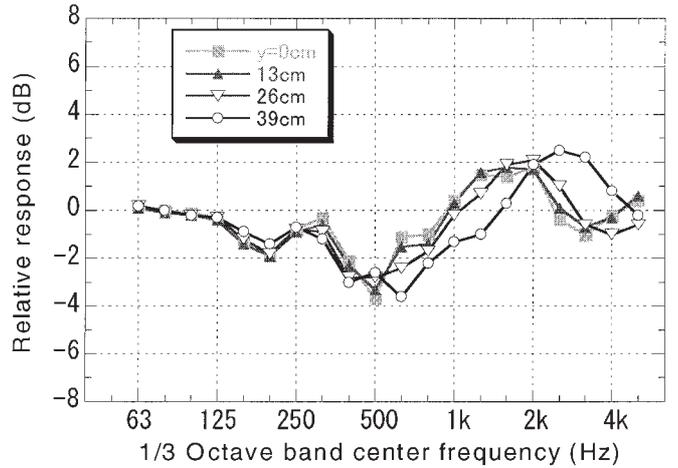
3. Results and discussion

The relative responses along the x- and y-axes for the one-third octave band frequencies obtained by using the one-piece board on the sod-covered ground are shown in Fig. 3(a) and (b), respectively. Note that the responses along the x-axis differed depending on the microphone position, and the largest response fluctuations occurred when the microphone was near the rear edge of the board ($x = 39$ cm) (Fig. 3(a)). Except for the response at $y = 39$ cm, the responses along the y-axis almost coincided with one another (Fig. 3(b)). These differences in the sound level fluctuations must have occurred due to a scattering or diffraction of the sound waves incident on the board and its influence on the measurements was stronger in the x direction than in the y direction [2].

We introduce here the difference level $\Delta L = L_D - L_C$ to evaluate the effect of the split on the measurements, where L_D is the level of the relative response with the split board and L_C is that with the one-piece board. Both L_D and L_C were measured with the microphone at the center of the boards, and L_C is shown on Fig. 3(a) as $x = 0$ cm. The center of the board was selected for this test following the latest draft international standard of 88/141/CDV [3], which requires that the



(a)



(b)

Fig. 3 Relative responses along the x- and y-axes of the board. Microphone positions ranged from -39 to 39 cm along the x-axis and from 0 cm to 39 cm along the y-axis. (a) x-axis response; (b) y-axis response.

microphone be mounted at the center of the board.

The effect of a split with a 2 mm gap on the measurements was as large as 1 dB, and the magnitude of ΔL depended on the location of the split (Fig. 4). If we compare the energy summed level of each response (63 Hz to 5 kHz) among these three responses, the largest was found with the split at $x = 10$ cm and the smallest at $y = 10$ cm, although the difference was small. If we take the difference between the maximum and minimum levels of ΔL , that difference was also found to be smallest for $y = 10$ cm. The frequency range with the largest irregularity in ΔL at $x = 10$ cm roughly coincided with that when the microphone position was at $x = 39$ cm (Fig. 3(a)). A possible cause for the smaller response with the split at $y = 10$ cm is a characteristic of scattering or diffraction of the sound waves incident on the board (Fig. 3(b)); the effect of the scattering or diffraction was found to be weak in the y-axis direction compared with that in the x-axis direction.

The gap $s = 0$ mm was obtained by fixing the two pieces tightly together. Figure 5 shows that the wider the gap, the

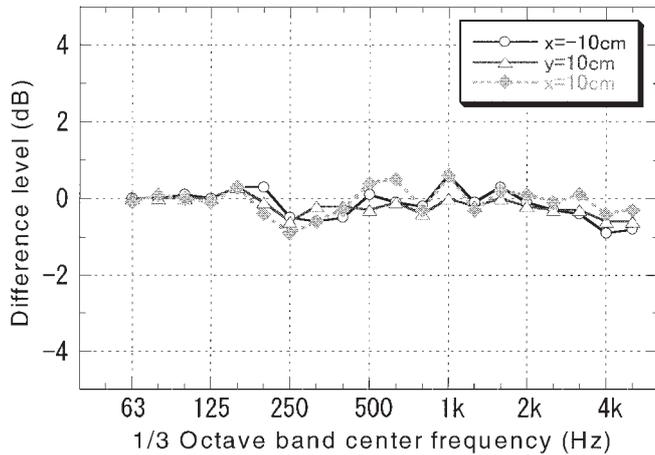


Fig. 4 Effect of split location on the difference level ΔL with a gap of 2 mm located at $x = -10$ cm, $y = 10$ cm, or $x = 10$ cm.

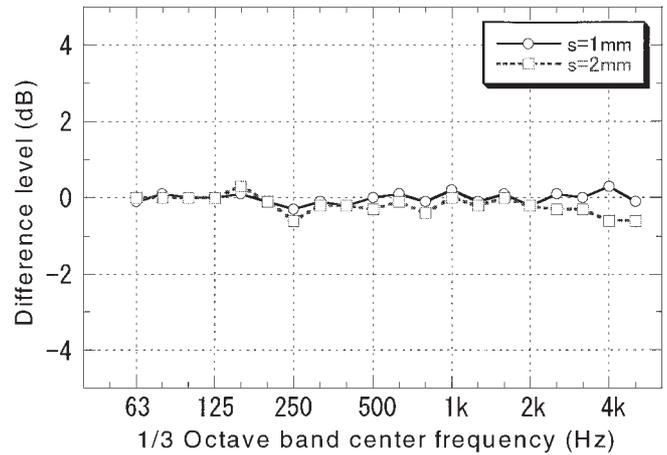


Fig. 6 Effect of gap size on the difference level ΔL with the split located at $y = 10$ cm.

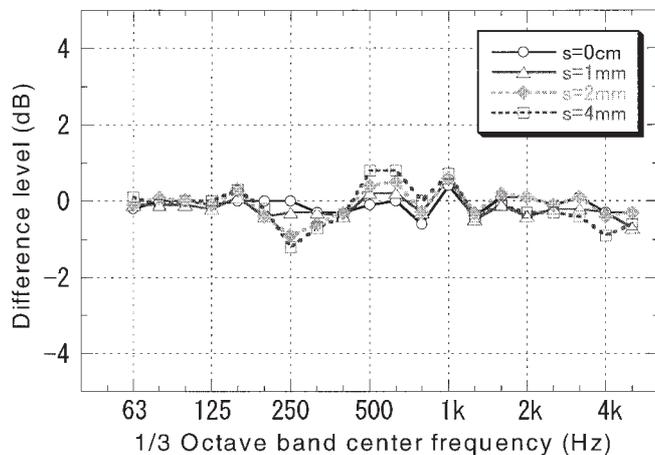


Fig. 5 Effect of gap size (0 to 4 mm) on the difference level ΔL with the split located at $x = 10$ cm.

larger the difference level; the difference of maximum and minimum levels of each response increase from 1.0 dB to 2.0 dB as the gap s increases from 0 mm to 4 mm. It should be noted, however, that even for $s = 0$, the sound level deviated from that measured on the one-piece board.

The difference levels with gaps $s = 1$ mm and $s = 2$ mm with the split located at $y = 10$ cm were compared, and the response with $s = 1$ mm was found to coincide over the full frequency span with that obtained by using the one-piece board (Fig. 6).

4. Conclusions

The effects of a split on the accuracy of measurements taken at the center of a board were investigated by using a

setup to simulate wind turbine noise measurements based partly on the standard IEC 61400-11. The split of the tested board was 10 cm from the center of a board 1 m in diameter, and the effects on measurements performed at the center of the board were evaluated. The following results were obtained from experiments carried out on flat sod-covered ground:

- 1) Measurements at the center of the board were affected both by the location of the split and the size of the gap, and the effects were smallest when the split was parallel to the sound propagation direction.
- 2) For a split set parallel to the sound propagation direction, the measurements obtained with split with a 1 mm gap were the same as those obtained with a one-piece board over the full frequency span.

Acknowledgments

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References

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