Wind turbine noise reduction by means of serrated trailing edges

Seunghoon Lee[a)]
Soogab Lee[b)]
AeroAcoustics and Noise Control Laboratory
School of Mechanical and Aerospace Engineering, College of Engineering
Seoul National University, Seoul, 151-744, Korea

In order to reduce aerodynamic noise generated from a 10kW wind turbine, we applied serrated trailing edges to the wind turbine blades. Two types of serrated plates and a rectangular plate was attached to the blades. Noise measurements were carried out according to IEC 61400-11 standard. Inflow wind speed, power output and the rotational speed of the wind turbine was also recorded with the noise signal. Significant noise reduction of up to 5dBA was achieved, but it is expected that the noise reduction obtained was partly due to the reduction of the trailing edge noise, and partly because of the reduction of the trailing edge bluntness noise.

1 INTRODUCTION

Trailing edge serration is known to reduce turbulent-boundary-layer trailing edge noise, such as generated from wind turbine blades. To date, several analytical, numerical and experimental studies have been conducted regarding the trailing edge serration[1-4]. However, in practice only a few studies[4-6] applied the trailing edge serration to an operating wind turbine, which can be influenced by atmospheric conditions such as atmospheric turbulence. In this study, we attached serrated trailing edges to a 10kW wind turbine, and evaluated the effect of the trailing edge serrations on the wind turbine noise reduction.

2 EXPERIMENT

2.1 Wind Turbine Model

The wind turbine used in this experiment is a 10kW small wind turbine. It is a variable speed type, and the rated rotational speed is 180RPM at a wind speed of 10m/s. The rotor radius and the hub height of the turbine are 4m and 18m, respectively.

[a)] email: kami00@snu.ac.kr
[b)] email: solee@snu.ac.kr

2.2 Serrated Trailing Edges

A total of four cases are examined: the baseline blade, two types of serrated trailing edges, and a rectangular plate trailing edge. Figure 1 shows the three trailing edge plates. The ratios of the width to the amplitude of the serration were 0.5 and 1.0, and they remained the same along the blade span. The serrated trailing edges were applied from 75% to the tip of the rotor blades. The height of the serration was set to be 15% of the local chord length. The trailing edge plates were attached on the pressure side of the wind turbine blades, as shown in Fig. 2.

2.3 Noise Measurements

Noise measurements were carried out according to IEC 61400-11 standard[7]. During the measurement, one-minute average inflow wind speed, power output, and the rotational speed of the wind turbine were also recorded synchronously with the noise signal.

3 RESULTS AND DISCUSSION

Figure 3 shows the one-minute average A-weighted sound pressure level in terms of the rotational speed for the four trailing edge cases. The results indicated that the A-weighted sound pressure level was reduced by up to about 5dB due to the use of the serrated trailing edges. However, the noise from the rectangular trailing edge blade was also reduced from that of the baseline blade.

To investigate these results in more detail, 1/3 octave band spectra were calculated as shown in Fig. 4. Low frequency noise, which was dominant in the range of 100~200Hz when the rotational speed is high, was the mechanical noise from the generator. It was shown that the mechanical noise level was consistent regardless of the blade trailing edge. However, broadband noise spectra were different depending on the trailing edge shape. The noise spectra of the serrated blades had the lowest level, and the noise spectra of the rectangular trailing edge blade were slightly higher than that of the serrated blades.

The difference between the noise spectra of the baseline blade and the rectangular trailing edge blade may be explained by the noise reduction due to the decrease of trailing edge bluntness noise. The trailing edge of the baseline blade had a round shape and a radius of about 4mm, while the trailing edge plates had a blunt edge and their thicknesses were 1mm. The trailing edge bluntness noise can be generated if the height of the trailing edge is larger than about one-fifth of the boundary layer displacement thickness[8]. From a simple calculation using an empirical formula[9], we found that the boundary layer displacement thickness of the outboard region of the blade is of the order of 1mm. A previous study showed that for a large wind turbine the dominant noise source of the wind turbine noise is trailing edge noise, and trailing edge bluntness noise is unimportant[8]. However, the results of this study imply that for a small wind turbine the trailing edge bluntness noise may occur depending on the operation conditions, because the boundary layer displacement thickness has the same order of magnitude as the height of the trailing edge.

On the other hand, the differences between the noise spectra of the rectangular trailing edge blade and the serrated blades are expected to be due to the reduction of the trailing edge noise, which results from the trailing edge serrations. It was found that the noise reduction increases with decreasing λ/h, which is consistent with previous studies[1].

4 CONCLUSIONS

The aerodynamic noise from a 10kW wind turbine is reduced by applying trailing edge serrations to the wind turbine blades. Significant noise reduction of up to 5dBA is achieved, but it is expected that the noise reduction obtained in this experiment is partly due to the reduction of the trailing edge noise, and partly because of the reduction of the trailing edge bluntness noise.

5 ACKNOWLEDGEMENTS

This work was supported by the New and Renewable Energy of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government Ministry of Knowledge Economy (No. 20104010100490).

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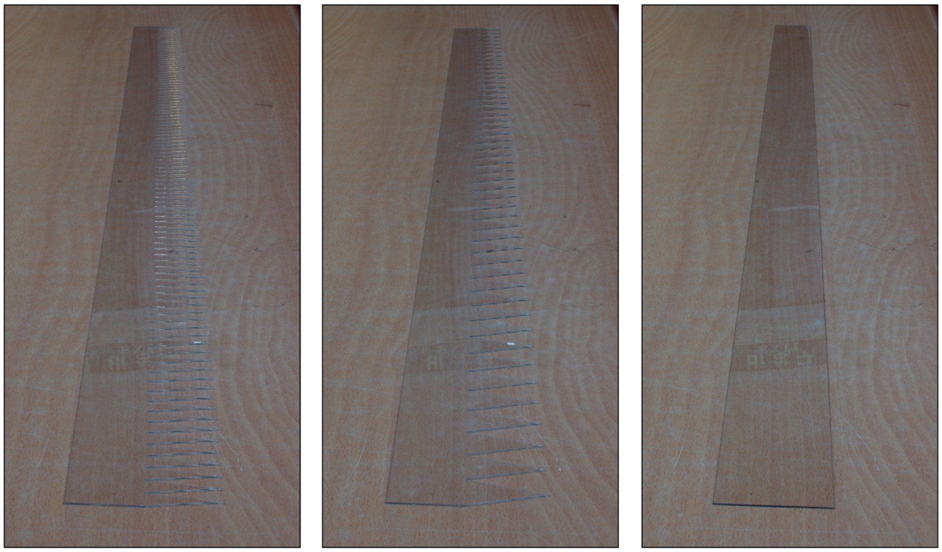

(a) (b) (c)

Fig. 1 – Serrated trailing edge plate: (a) $\lambda/h = 0.5$, (b) $\lambda/h = 1.0$, and (c) rectangular trailing edge plate

(a) (b)

Fig. 2 – Photos of (a) the 10kW wind turbine and (b) attached trailing edge serration

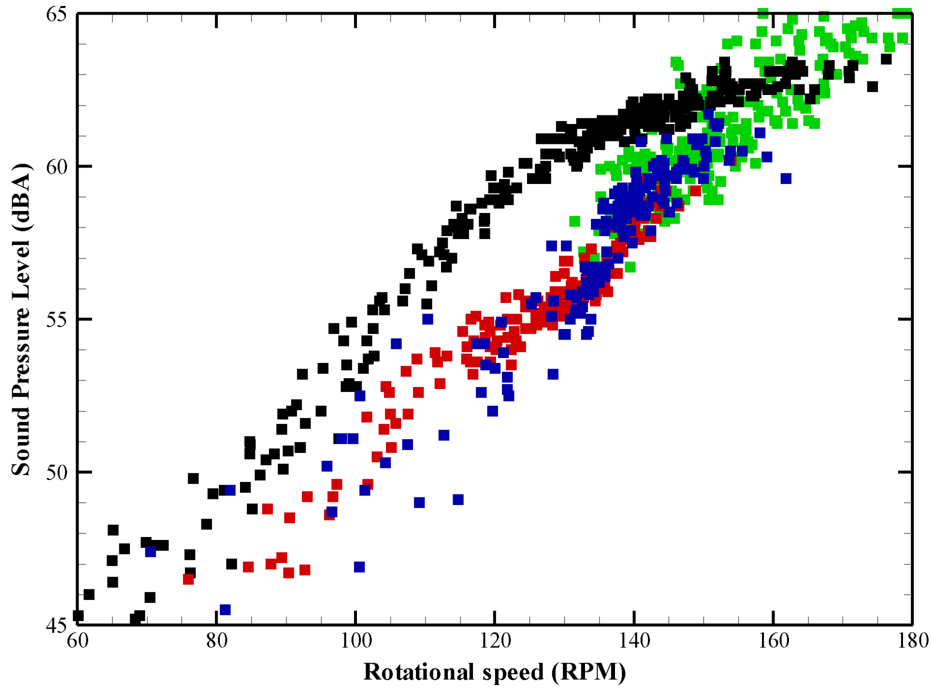

Fig. 3 – A-weighted overall sound pressure level for the baseline blade (black), the serrated blades of $\lambda/h = 0.5$ *(blue),* $\lambda/h = 1.0$ *(red), and the rectangular trailing edge blade (green)*

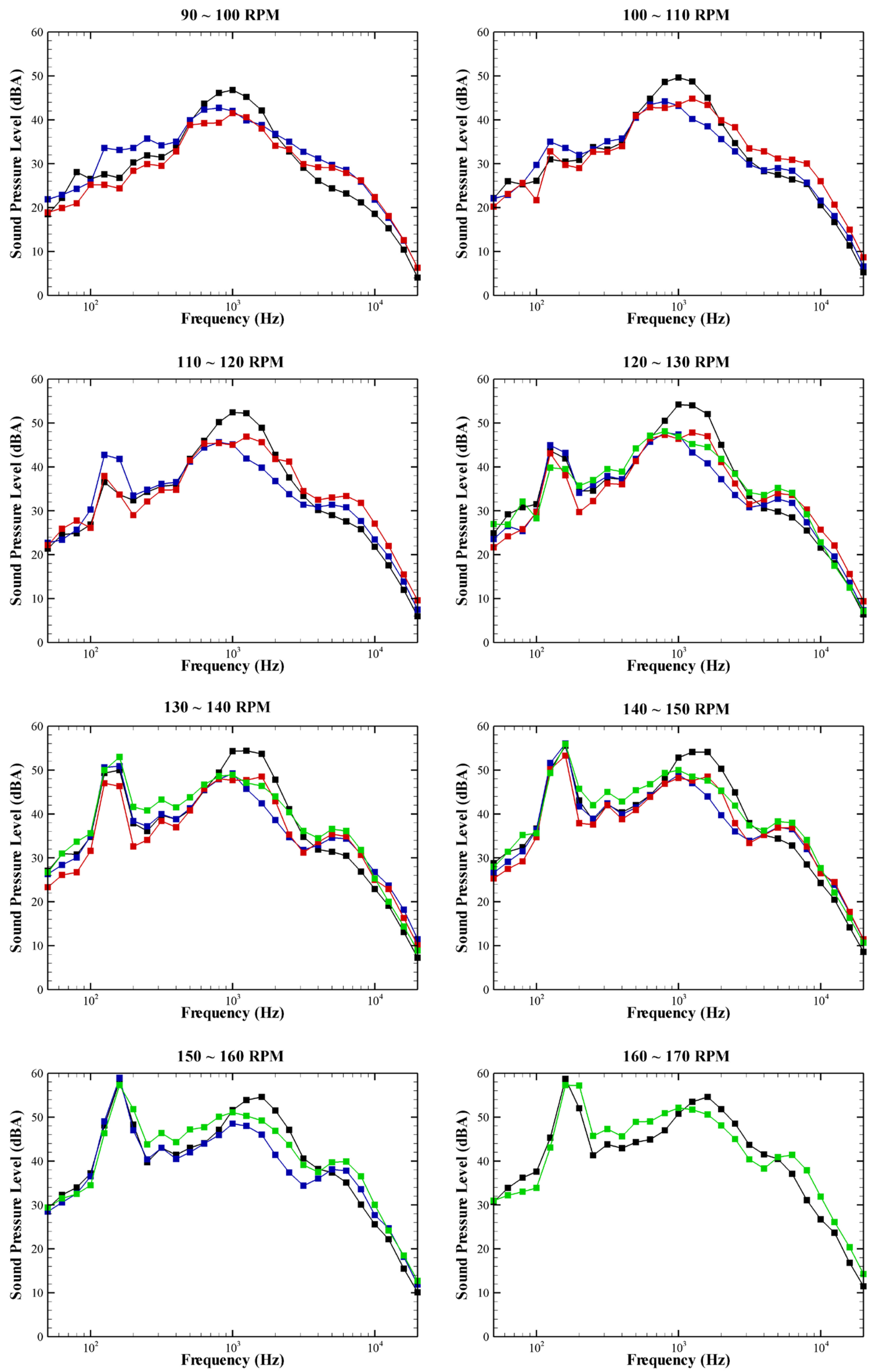

Fig. 4 – 1/3 octave band spectra with respect to wind turbine rotational speed: the baseline blade (black), the serrated blades of $\lambda/h = 0.5$ *(blue),* $\lambda/h = 1.0$ *(red), and the rectangular trailing edge blade (green)*