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USING AN ACTIVE CONTROL SYSTEM TO INCREASE THE INSERTION LOSS OF A BLAST FENCE FOR RUN-UP NOISE AT VANCOUVER AIRPORT

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ABSTRACT

Night-time aircraft run-up noise has been a problem that causes annoyance to adjacent communities at the Vancouver International Airport. It was found that the main contribution to the noise is the propeller aircraft that generate blade-passing low-frequency noise, which makes it feasible to apply the active noise control (ANC) to mitigate this noise. An existing blast fence at the run-up site was found to have a noise insertion loss of 4-15 dB over the frequency range 20-2000 Hz. In the work reported here, a multi-channel ANC system was applied to the blast fence, in the hope of increasing the insertion loss of the fence. Numerical simulations indicated that the system could create an extra noise attenuation of 10 dB or more in a large area behind the fence. The controllability of the run-up noise with the multi-channel ANC system was examined through experiments.

1 - INTRODUCTION

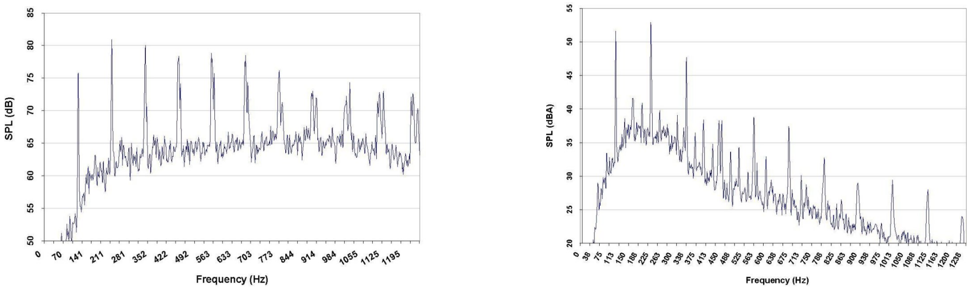
Aircraft run-up is one of the major steps of normal maintenance, consisting of revving up the engine, sometimes to full power. Aircraft run-ups at Vancouver International Airport (YVR) often occur between late evening and early morning, creating noise pollution problems in the neighbouring communities to the north and south of the airport [1]. To solve this noise-pollution problem, the Airport Authority is investigating feasible control technologies, such as a ground run-up enclosure, noise barriers, a hush-house, and active noise control.

Propeller aircraft are found to be the source of most complaints. They represent over 80% of the nighttime run-ups. Our measurements demonstrate that the run-up noise generated by the propellers has the tonal nature, which is dominated by the low-frequency harmonics in the neighbouring resident area. This makes the propeller aircraft run-up noise a potentially good candidate for applying ANC, and its feasibility was previously investigated by the authors [2].

There is a huge blast fence installed at one of the run-up sites. The major objective of building this fence was not, of course, to reduce the noise. However, it does block the propagation of the noise, and reduces the noise behind the fence. It has been found that an active noise control system can increase the insertion loss of a noise barrier [3, 4, 5]. The main idea of this paper is to apply an active noise control system to the existing blast fence to increase its insertion loss, especially for the first several low-frequency tones. An optimally arranged multi-channel active noise control system developed by the authors was examined to work with the blast fence. The controllability of the run-up noise with a multi-channel control system was also tested with experiments.

2 - RUN-UP NOISE

The run-up noise of a typical propeller aircraft, Beech-1900D, was measured in both the near and far fields, at 75 m and 3 km from the aircraft, respectively. The near-field measurement revealed that the



(a): Near field. **(b):** Resident area.

Figure 1: Noise spectra of Beech-1900D aircraft.

run-up noise has a fundamental frequency of 111.7 Hz, as well as several harmonics at equally high levels as the fundamental, as shown in Fig. 1 (a).

The noise spectrum recorded in the residential area at 3 km was significantly different, as shown in Fig. 1(b). Although the structure of the spectrum was much the same as near the aircraft – with the fundamental and harmonics – the run-up noise in the far field was dominated by the low-frequency components. This is due to the larger propagation loss for high-frequency components. It demonstrates that the run-up noise in the neighbouring residential area can be significantly reduced by controlling only the fundamental and the first two harmonics. The control of run-up noise can therefore be focused on low-frequency attenuation.

3 - BLAST FENCE

The existing blast fence is shown in Fig. 2. Its dimensions are 5 meters in height and 294 meters in length. The fence is made of steel plates. It can be seen that there are air gaps in both the upper and bottom parts of the fence. Aircraft run-up normally occurs in the area of 20−50 m in front of the fence.

Figure 2: Existing blast fence at Vancouver International Airport.

The insertion loss of the blast fence was measured when the Beech-1900D was 26 m in front of the fence. A receiver position was located 47 m behind of the fence in a parking lot, at a height of 2.0 m. It was found that the insertion loss of the fence varies with the heading of the aircraft. Figure 3 shows the insertion losses of the blast fence for three headings. The theoretical insertion loss of an infinitely-long barrier is also shown for comparison [6].

The significant fluctuation at low frequency is most likely due to reflections from the ground on the

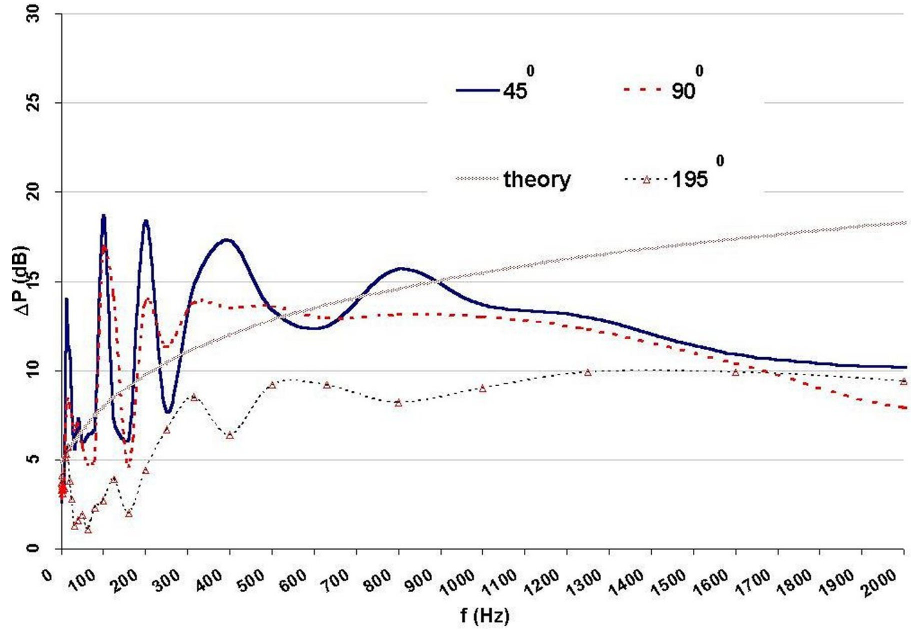


Figure 3: Insertion loss of the blast fence.

run-up site. The decrease of the insertion loss at high frequency, on the other hand, is likely due to sound leakage through the air gaps.

4 - ACTIVE BLAST FENCE

The proposed arrangement of the active noise control fence is shown in Fig. 4. The multi-channel control sources and error microphones are in two parallel lines, with the control source array in front of the barrier and the error microphone array on the top of the fence. The objective of this configuration is to cancel the noise at the top of the fence with the control sources. This is to attenuate the noise diffraction over the fence and is equivalent to increasing the height of the fence. It has been found that the optimal configuration of the multi-channel control system – i.e. the spacing of the adjacent control sources and error microphones – is dependent on the frequency of interest, and on the distances between the control source and the error microphones [7, 8]. The control system examined in this study was strictly arranged within the optimal range for the configuration.

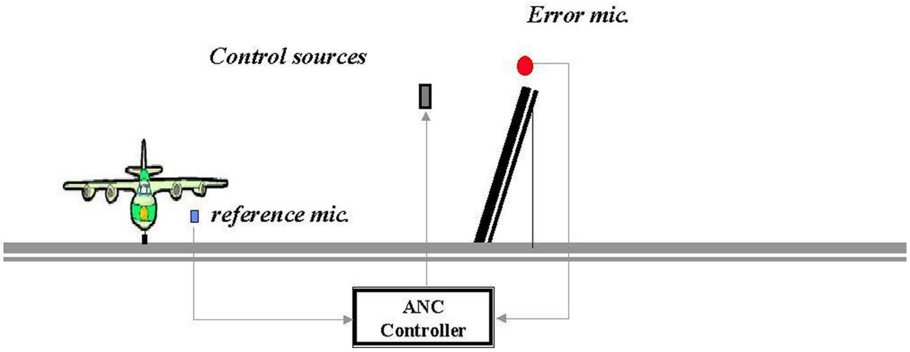


Figure 4: Configuration of the ANC fence.

The extra insertion loss of the blast fence with the ANC system was calculated using computer simulation [5]. The results demonstrated a very large quiet area behind the fence when the multi-channel control system is optimally arranged. Figure 5 is a demonstration of the extra insertion loss of an ANC system. The run-up noise source was 30 m in front of the fence at height of 2 m, the 21 control sources are positioned 2 m in front of the blast fence at a height of 4.5 m, and the 21 error microphones are placed on the top of the fence. In this simulation, the propeller noise of the aircraft was treated as a point source. The frequency of the noise for this simulation was 111.7 Hz. The optimal spacing of the control sources and error microphones was calculated to be 0.532 λ [7], equal to 1.64 m. The ground in front of the blast fence was regarded as rigid, while the ground behind was treated as absorptive.

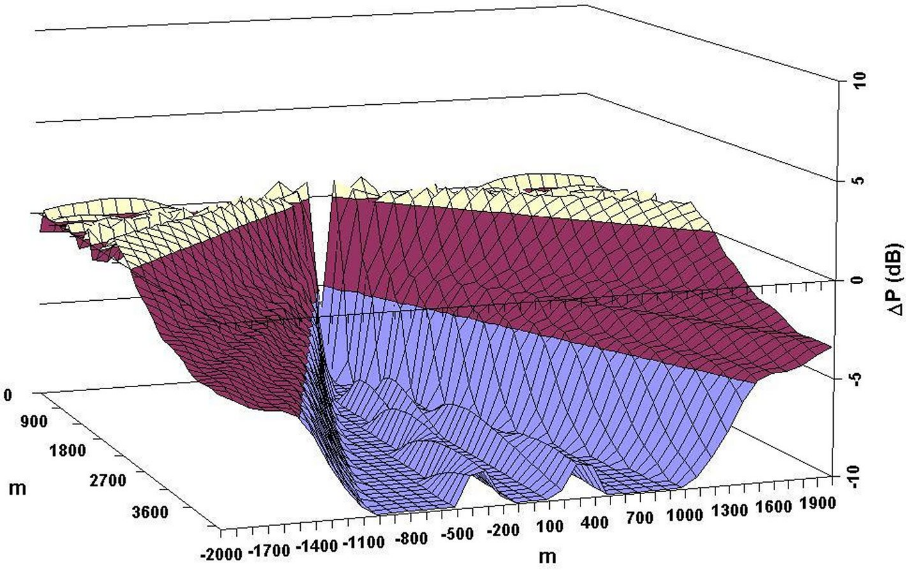


Figure 5: Extra insertion loss of the blast fence with ANC system.

It is very clear that an additional insertion loss of 10 dB was attained at the fundamental frequency of 111.7 Hz over a large area behind the blast fence. This increased the overall insertion loss of the blast fence to 14-20 dB. The more control channels used, the larger is the quiet area that can be obtained.

5 - EXPERIMENTS

The controllability of the run-up noise by a multi-channel ANC system was examined in the experiments in an anechoic chamber, as shown in Fig. 6. The run-up noise recorded in the field was replayed by a loudspeaker as the primary source. Three loudspeakers and the same number of microphones were arranged in two parallel lines as the control sources and error microphones. The separation of the control channels was optimized for the fundamental and the first harmonic of the run-up noise. An adaptive multi-channel controller, EZ-ANC, was used in the experiments. The noise attenuation was measured in the area behind the control system.

Figure 6: Experimental setup.

It can be seen from Fig. 7 that the fundamental and the first harmonic of the run-up noise were significantly reduced in the area behind the ANC system. The attenuation was over 15 dB for the fundamental and over 10 dB for the first harmonic. It can also be seen in Fig. 7 that, since the system was optimally arranged for frequencies lower than the first harmonic, it increased the noise at frequencies higher than the first harmonic. A low-pass filter in the control channels might be needed to avoid this problem.

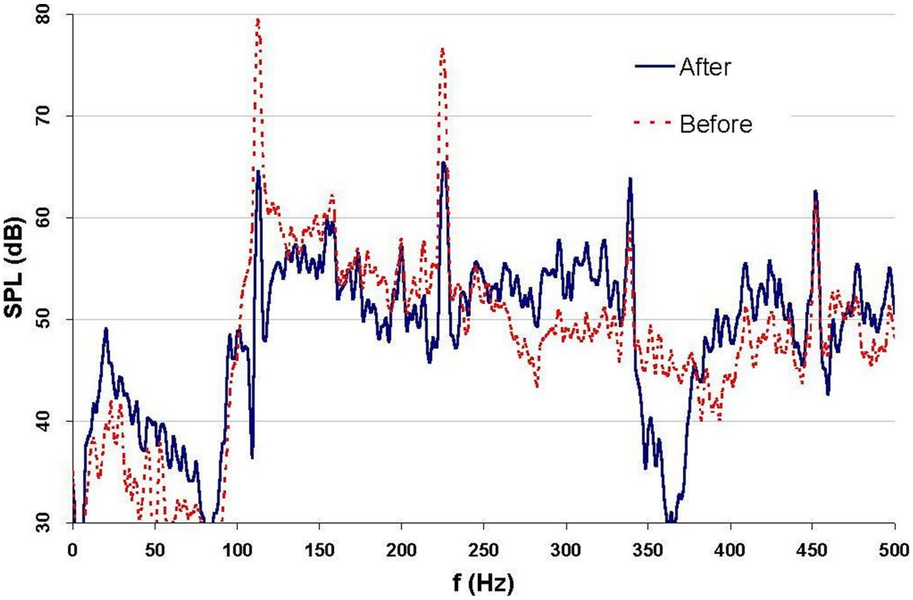


Figure 7: Attenuation in the area of quiet.

The experiments also indicated that, although the run-up noise varied during the experiments, the control system was able to adapt to the changes.

6 - DISCUSSION AND CONCLUSION

Run-up noise pollution can be reduced by ANC technology, due to its tonal and low-frequency characteristics. A multi-channel active noise control system has the potential to improve the noise-control performance of the blast fence by increasing the insertion loss for low-frequency components. This would reduce the run-up noise pollution in neighbouring residential areas.

The next step in this study is to implement the multi-channel active noise control system on the blast fence at the run-up site of the Vancouver International Airport, and to refine our computer simulation and experimental results. At that stage, more complicated factors will need to be studied, such as the power output of the control sources and meteorological influences.

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