Government of Western Australia
Department of Commerce
WorkSafe

Case study

Active control of fan noise

Introduction

On the ground floor of the Civil and Mechanical Engineering Building at the University of Western Australia is a small computer room that houses the mainframe computer network. An exhaust fan mounted inside the room runs continuously to discharge the hot air into the corridor, in order to cool down the equipment inside the computer room. The fan generated low-frequency tonal noise into the corridor, which caused noise levels in a very large area of the corridor to be over 55 dB(A) and annoyed a very large number of staff and students.

Low-frequency noise is very penetrating, travels very long distances and is difficult to attenuate using traditional passive control measures. Passive noise control technology, which usually involves using absorptive materials or noise partitions, can be bulky, ineffective and rather expensive at low frequencies. Active Noise Control (ANC), on the other hand, can be very efficient and relatively cheaper in reducing low-frequency noise.

This case study demonstrates a successful application of ANC – a new technology of noise control for low-frequency noise – to a noise problem in an educational building.

New noise control technology

Active Noise Control is a technology using noise to reduce noise. It is based on the principle of superposition of sound waves. As demonstrated in Fig.1, a sound wave is travelling in space. If another sound wave having the same amplitude but opposite phase to the first sound wave can be created, the first wave can be totally cancelled. The second sound wave is named “antinoise”. Although the idea of ANC is not new, its practical application had to wait for the recent development of sufficiently fast electronic control technology.

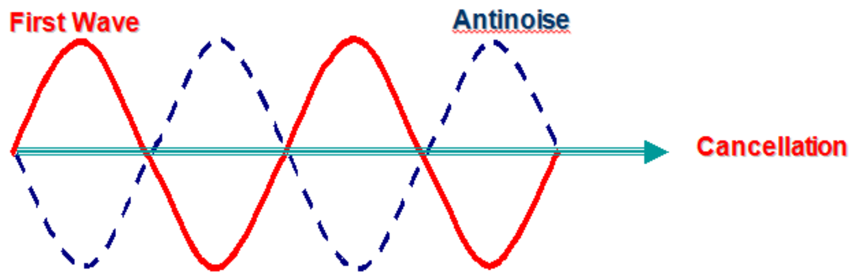

Figure 1. The mechanism of active noise control.

A basic feed-forward active noise control consists of a reference sensor, an electronic controller, a loudspeaker and an error sensor, as shown in Fig. 2. It works as follows: the reference microphone picks up the information of the primary noise field and sends it to the electronic controller; the controller then drives the control loudspeaker to radiate the antinoise; the error microphone examines the control performance and modulates the controller to the best result.

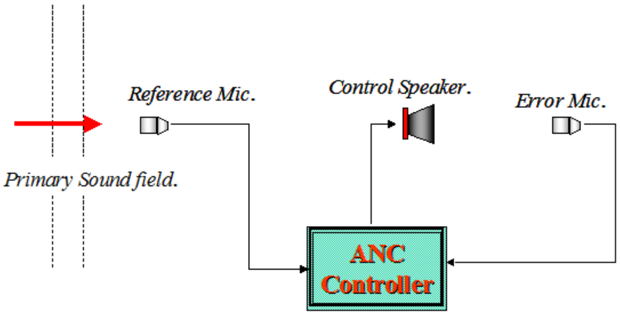

Figure 2. Basic structure of a feedforward active noise control system

Electric fan noise

The cooling fan is mounted on the wall of the corridor, as shown in Photo 1. The discharge fan is a 5 back-swept bladed, 6-pole, 300 mm diameter axial flow fan delivering an air flow of 0.35 m3/s at a rotational frequency of about 16 Hz. Power spectral measurements of the fan noise show that it contains low level broadband noise and high level discrete tonal noise. These high level discrete tones at 85 Hz, 170 Hz, 255 Hz and 340 Hz correspond to the blade passing frequency (BPF), and the second, third and fourth harmonic of the fan, respectively.

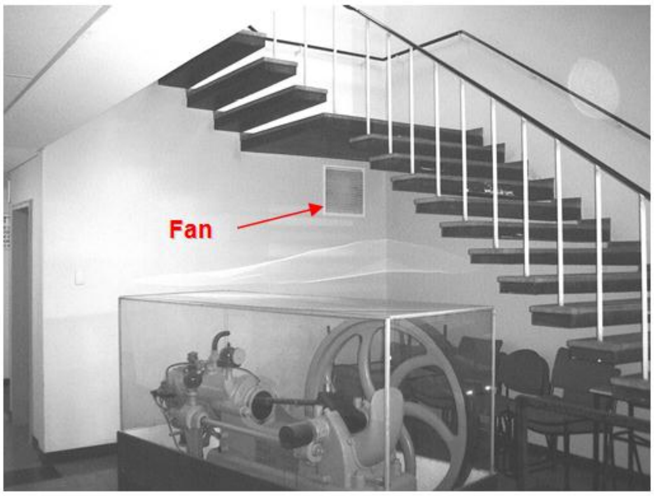

Photo 1. Cooling fan mounted on the wall.

These first few tonal components are a source of annoyance to the occupants of the building and can be heard from anywhere along the corridor as well as on the first floor. Sound pressure level measurements at various locations along the corridor indicate that the noise levels due to the fan were above the recommended noise level for an educational building. A noise control solution was therefore required.

Due to the low-frequency characteristics of the fan noise, it is very difficult to control it by traditional noise control technology. The adopted solution was a hybrid of passive and active noise controls. While the passive measure was to attenuate and filter the broadband noise, the active control system was to reduce the discrete low-frequency components.

Active noise control system installation

The Industrial Noise Control Group of the University of Western Australia, supported by the Ventilation Committee and Office of Facilities Management of the University of Western Australia, tested and installed an active noise control system to reduce this fan noise. The structure of the control system is illustrated as follows.

A short square duct made of 2 mm thick galvanised panel with dimension 0.45 m ×0.45 m × 0.9 m is installed over the outlet side of the fan, as shown in Fig. 3. The inside walls of the duct are lined with 1.5 cm thick wool blanket. There are two functions of the duct: (1) to achieve sound attenuation for broadband noise and (2) to provide a platform on which to place the control loudspeaker.

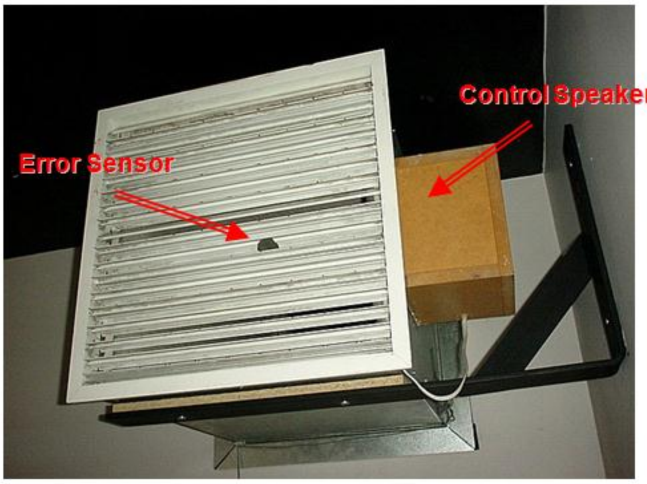

Photo 2. Error microphone and loudspeaker mounted in duct.

The reference sensor of the control system is an infra-red (IR) sensor, which is fixed at the inlet side of the fan. The IR sensor picks up the blade rotating speed as the reference signal. The advantage of choosing the IR sensor is that it avoids the noise contamination from the control end.

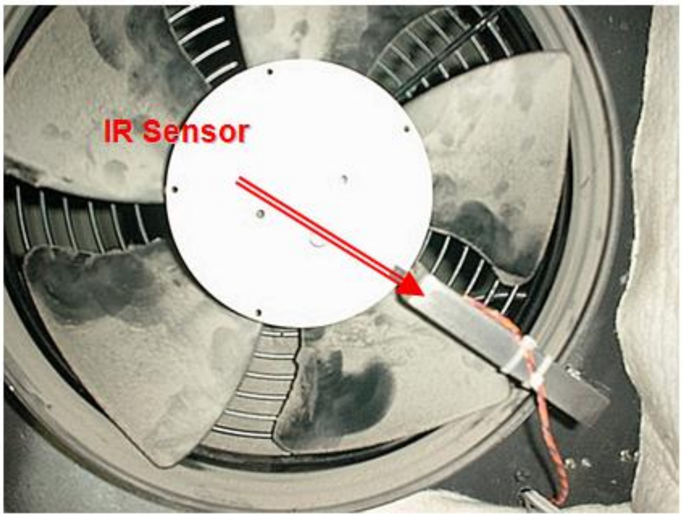

Photo 3. Optimal switch reference sensor fitted to fan.

The core part of the adaptive feedforward control system is a DSP-based controller, which is fixed in a box and placed inside the computer room, as shown in Photo 4.

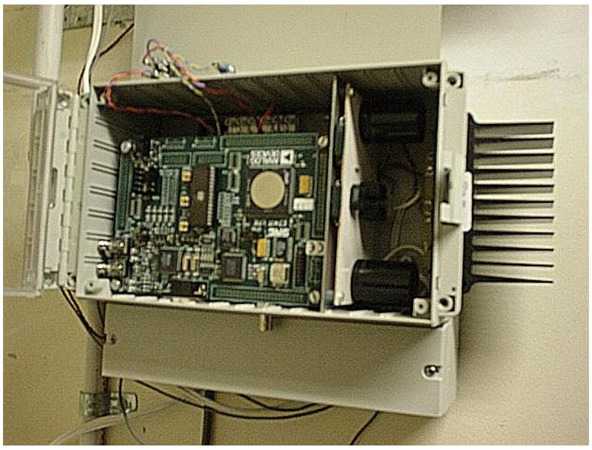

Photo 4. Controller box located inside the computer room.

Noise reduction

The result at the error microphone with the ANC switched 'ON' shows that the tonal noise cancellation is significant, as shown in Fig. 3. Reductions of more than 30 dB at 82 Hz, 25 dB at 164 Hz, 15 dB at 246 Hz and 15 dB at 328 Hz can be achieved. Such results would be practically very difficult and expensive to achieve from passive noise control methods.

Figure 3. Spectra of fan noise before and after active noise control.

The A-weighted noise levels at seven locations in the corridor were also measured, as indicated in Fig. 4, where #5 and #6 are on the stairs, and #7 is on the first floor directly above #1. The results demonstrate very significant noise reduction at all locations, as listed in Table 1. The noise reduction ranges from 4.1 ~5.6 dB(A), which makes the noise levels in the corridor well below 55 dB(A).

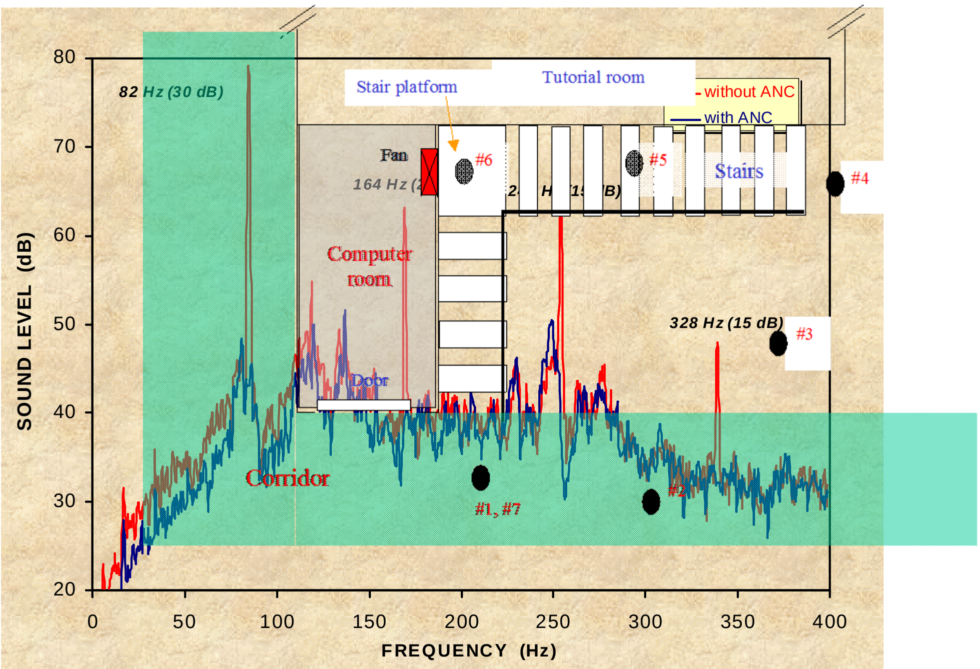

Figure 4. Locations of noise reduction measurements.

Table 1: Overall A-weighted sound pressure level (dB(A)) at measurement locations.

	#1	#2	#3	#4	#5	#6	#7
ANC off	54.9	55.3	54.1	54.2	55.1	54.9	53.9
ANC on	**50.6**	**50.2**	**49.7**	**50.1**	**49.5**	**49.6**	**49.1**
Reduction	**4.3**	**5.1**	**4.4**	**4.1**	**5.6**	**5.3**	**4.8**

In addition to the total A-weighted noise level reduction, the acoustic quality in the corridor is also significantly improved, as the annoying low-frequency humming noise is gone.

The control system is very robust and durable, and has been kept running since it was installed in 2002. It has been used as a demonstration of successful ANC application to students and visitors. Further details can be found in the technical paper “Active Control of Fan Noise,” Proceedings of Active 2002, ISVR, Southampton, 2002, which was awarded the Best Paper in the conference.

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