ACTIVE SILENCING OF ENVIRONMENTAL NOISE FROM A 0.5 MW CENTRIFUGAL FAN

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INTRODUCTION

Active noise control has been investigated in University laboratories for many years now; indeed for so long that people who have to apply noise control techniques have sometimes suspected that that is where the technique would stay. In this paper I intend to dispel such doubts, by describing a serious industrial noise problem which has been, and is being, solved using active control. I will not dwell on the theory of the technique, except where it sheds light on design constraints which determine whether or not active control can be used. Instead, I will focus on practical considerations which must be addressed on industrial installations.

THE PROBLEM

A newly commissioned cement plant was having problems with environmental noise. Although the plant had been designed to required noise limits, local residents nevertheless complained about two pure tone noises, which could sometimes be heard at night. One of these was a 270 Hz tone from the coal mill fan, which was broadcast from an exhaust stack.

THE ACTIVE SOLUTION

Since the sound to be silenced was related to the blade passing of the coal mill exhaust fan, a periodic type of active controller was seen to provide the best solution. Shown in figure 1 is a schematic diagram of the controller used, showing the various elements; the controller, loudspeakers, microphones, a tachometer and power amplifiers.

I will describe briefly each of these components in turn, before discussing the performance of the system.

Controller & Amplifiers

An important consideration in designing an active silencer is the complexity of controller which must be used. Whilst for a small pipe a single channel of control, with one microphone and one loudspeaker would be sufficient, this was not the case in this problem. Up to five acoustic wave modes could propagate in the duct where the active system was installed, between the fan and the exhaust stack. Accordingly, we used a system with six loudspeakers and seven microphones, located as shown in figure 2. Since we used a periodic controller the microphones are downstream of the loudspeakers.

It is relatively easy to visualise the control process for a single channel case. The controller has to estimate the signature due to the periodic source at the microphone, and to know the effect that the loudspeaker can have on the microphone. It is possible to imagine adjusting the amplitude and phase of the loudspeaker drive signal by hand, though of course it is easier to use a computer to adapt the 'anti-source' to minimise the microphone signal. The 'anti-source' drive signal has to be adapted if the noise signature or the transfer function between the loudspeaker and microphone changes for whatever reason. This may be due to changing fan speed, air temperature, or deterioration in the loudspeaker or microphone performance. Although the theory is much the same for a multichannel control system as for the single channel case the controller needed is much more complex. As well as needing to know the signature at the seven microphones, it is necessary to know the transfer functions between each of the loudspeakers and each of the microphones. Additionally, considerably more complicated calculations are required to determine the optimal loudspeaker driver signals to minimise the microphone sound levels. In order to calculate the required 'anti-sources' we have in this application used a controller based around the Motorola 68008 microprocessor. This is the same chip as used, for instance, on Sinclair's QL computer.

The power amplifiers used are standard models, although the cooling fans have been upgraded to cope with continuous running.

Speed Sensor

An important component in a periodic active control system is the speed sensor, which allows the computer to track precisely the signature from the fan. For this application we have used an induction probe, which responds to magnetised tape on the fan motor shaft. The controller is able to convert a wide variety of tachometer signals into the required format; in this case there are $45\frac{1}{2}$ pulses generated per motor revolution.

Microphones

Since the absolute calibration of sound level in the duct is irrelevant to the control process, it was possible to use relatively cheap dynamic microphones to monitor the sound to be controlled. To protect them from the 60°C temperatures and high humidity in the duct, they were mounted in stub tubes set out of the duct.

Loudspeakers

In addition to the heat and humidity in the duct, the loudspeakers used had to cope with high amplitude 1 - 2 Hz pressure surges which occured during the fan start up procedure. An initial design of loudspeaker was unable to stand up to these conditions. However, modifications have resulted in a design which is able to withstand the adverse environment. The loudspeakers used are rated at 600 W each, and in order to obtain the sound pressure levels of 135 - 140 dB necessary, the loudspeaker cabinets are designed with a quarter wavelength resonator pipe on the front. As well as improving the efficiency, this design has the added benefit of keeping the loudspeaker drive unit away from the adverse environment. Shown in figure 3 is a typical transfer function from a loudspeaker installed in the duct to a microphone. Superposed on the organ pipe resonance at about 270 Hz are duct cavity resonances.

Although the coal mill fan runs at a constant speed, it is interesting to note that it is also possible to use a resonant loudspeaker for variable speed fans. This is because the sound produced by a fan in a duct varies with the 4th to 6th power of fan speed. Thus if the organ pipe resonance is tuned to just below the maximum fan speed, it should still be able to provide sufficient power for the lower speed operating conditions.

PERFORMANCE

In this application we controlled only the fundamental frequency of the fan, at 270 Hz, since higher harmonics were not a nuisance. Figure 4 shows the performance achieved, as measured by a microphone in the acoustic far-field. It can be seen that the pure tone noise has been reduced by about 13 dB.

CONCLUSIONS

Although we had initial problems with the active system installed on the coal mill, these have now been largely overcome. With the confidence and experience gained on this system, we were asked to install a second system on the second major noise source in the plant, which was a 2 MW fan. In conjunction with a conventional absorptive silencer, this second source was also cured. The second active system required thirty minutes of downtime whilst the speed sensor was installed on the motor shaft and achieved 23 dB of reduction at the pure tone.

Whilst my example of an industrial active control installation does not, perhaps, break any new theoretical ground, nor convey the numerous problems which could possibly be solved with active control, it does, I hope, show that the technology is no longer a research topic, but a tool for industry to use.

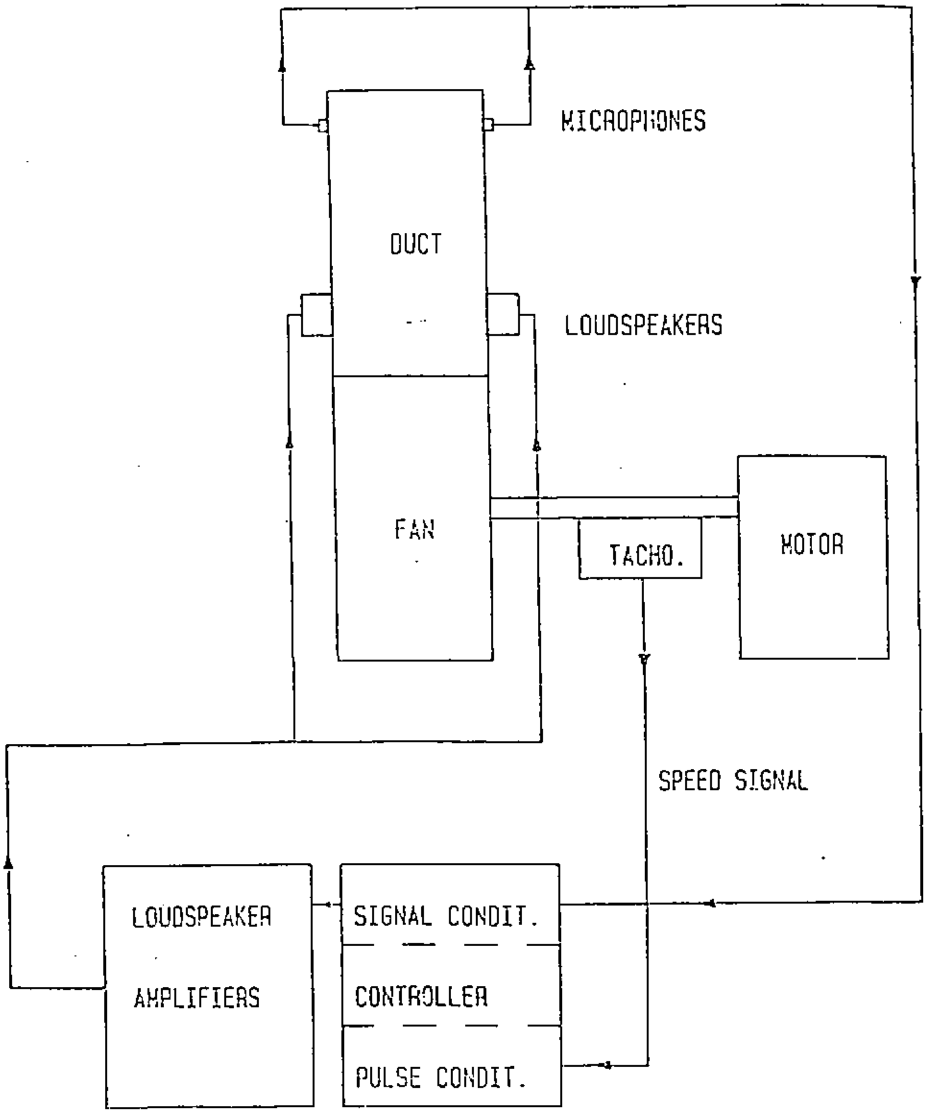


FIGURE 1

Schematic diagram of the active noise controller

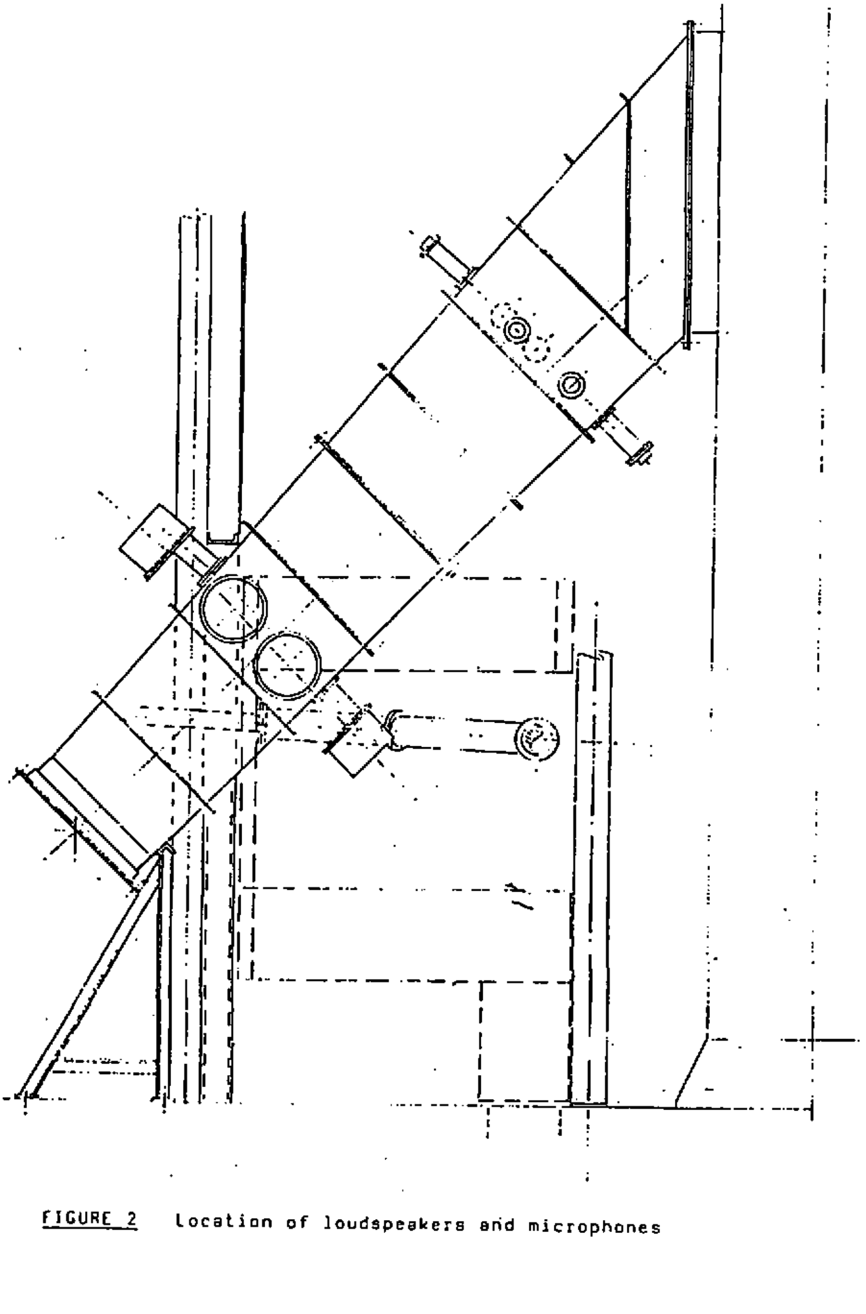
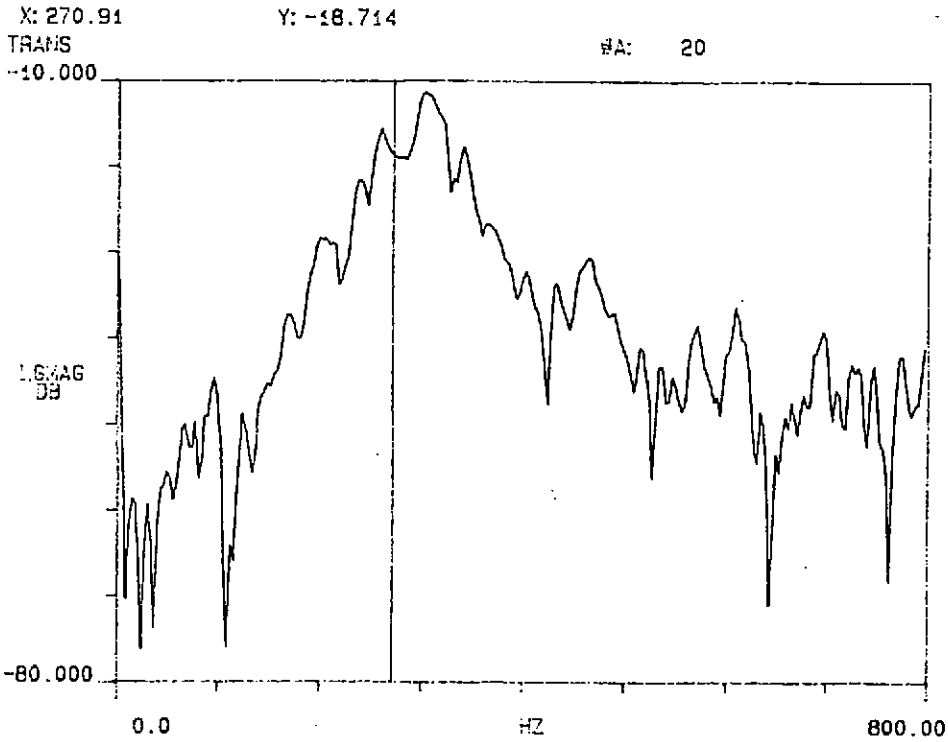


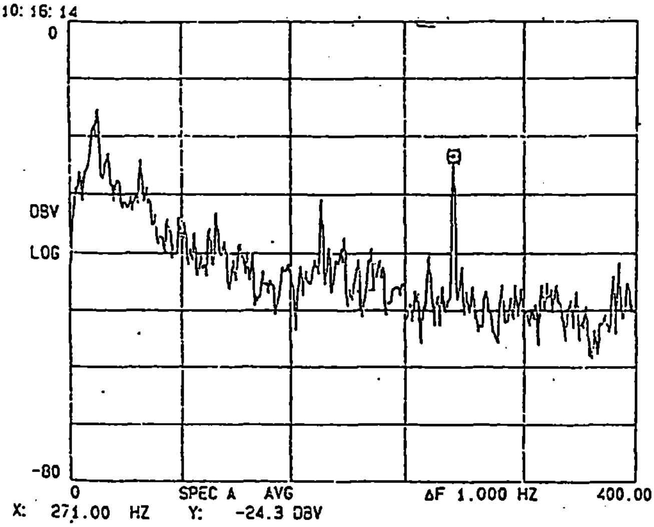
FIGURE 2 Location of loudspeakers and microphones

FIGURE 3 Typical transfer function between loudspeaker and microphone



ACTIVE FAN SILENCING

FIGURE 4 Performance of the anti-sound system installed at the cement works



i) without active control

ii) with active control