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The sound of silence

As active noise control systems begin to penetrate the marketplace, are the days of the passive attenuator numbered? *Andrew Brister* looks at the likely future for anti-noise.

Sixty years after pioneering scientist Paul Leug first patented the concept of anti-noise, designers are at last in a position to choose between so-called active and passive means of noise control.

It has taken a long time for technology to catch up with Leug's theories, but why should specifiers look beyond the traditional methods of sound insulation anyway? Hasn't good old mineral wool served the industry well for time in memoriam?

These passive means are effective, and work on the simple principle that mass is capable of blocking out noise. The sound absorbing material provides resistance to sound waves, transferring their kinetic energy into heat through friction.

All well and good. However, the Achilles' heel of mineral wool baffles lies in their low frequency performance; the lower the sound frequency, the more voluminous and expensive they become.

Hence researchers have long sought an alternative. Anti-noise or active noise control is perhaps the most promising option, but what is it?

Sound is made up of a series of air pressure variations which cause the ear drum to vibrate, enabling us to perceive it as noise.

If we can create equal and opposite pressure variations at the same frequency, the two pressure patterns cancel each other out and result in silence.

Although simple in principle, it is only today that the necessary degree of complexity has been available in digital signal processing techniques. The latest microprocessors are now fast enough to implement the control algorithms used in active noise control systems.

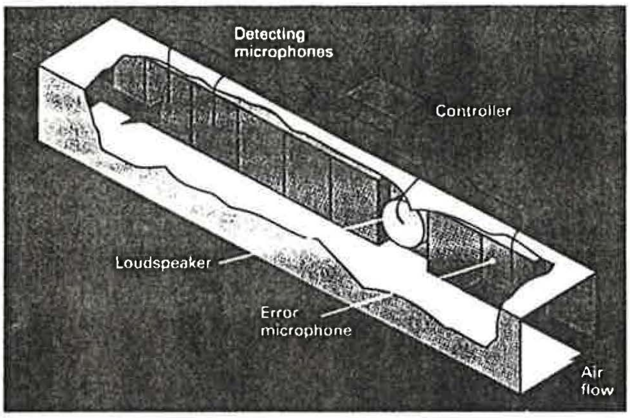

Figure 1: Layout of a simple active noise control system in a ventilation duct.

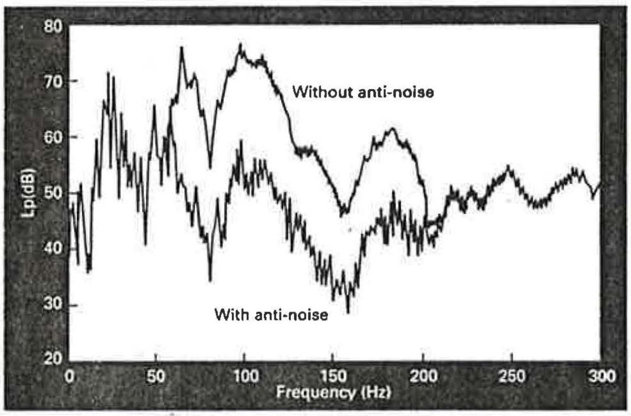

Figure 2: Results of active noise control from experiments carried out at the TNO Institute in the Netherlands.

Ductwork

In the services industry the obvious application for such techniques is ventilation ductwork. Figure 1 shows a very simplistic arrangement of an active noise control system which could be rigged up in the ducting.

Detecting microphones pick up the noise to be cancelled. A digital filter modifies the amplitude and phase of the detected signal and feeds an anti-noise signal to the loudspeaker.

If all is well the result is silence. To monitor performance, an error microphone is located downstream of the loudspeaker. This information is fed back to the controller, where the algorithm modifies the digital filter characteristics if any non-ideal performance is signalled.

This adaptive algorithm calculates separately the amplitude and phase required for every frequency component of the digital filter.

Unfortunately, the sound wave from the cancelling loudspeaker not only travels down the duct to cancel the primary sound but also travels upstream where it can be picked up by the detecting microphone. Hence, special directional microphones have to be used which only pick up sound waves that are travelling downstream.

Performance

Enough of the theory, what about some results? One organisation busy in the testing of such systems is the Active Noise Control Department of the TNO Institute of Applied Physics in the Netherlands.

Figure 2 gives the results of tests carried out at TNO on a 0·6 m by 0·6 m duct. The distance between the detecting microphones and the anti-noise loudspeaker was 4 m and a general purpose controller was built around two digital signal processors, dedicated for this type of application.

Anti-noise was generated between 60-200 Hz. Figure 2 shows that the total noise reduction between these frequencies was found to be approximately 18 Hz – ie very good low frequency performance.

However, it appears that manufacturers of passive attenuators are not about to lose their market share overnight. While low frequency performance is the weak spot of passive attenuators, active noise systems do not perform well at higher frequencies. For simple single loudspeaker systems to be effective, noise travelling down the duct must only consist of simple plane waves.

Sound propagates down a rectangular duct as a plane wave only if the wavelength of the sound is at least twice as long as the largest cross-sectional dimension of the duct.

The frequency at which this occurs is known as the limiting frequency; noise problems which occur at higher frequencies than this can be difficult to control with active systems.

Figure 3 gives the limiting frequency for a variety of duct widths; the larger the duct, the lower the limiting frequency. For a 0·6m square duct, this works out at approximately 300 Hz.

Andrew Bullmore, head of the acoustic division of consulting engineer Hoare Lea and Partners, has over ten years of experience in active noise control.

According to Bullmore, research work is underway to actively control the non-uniform sound waves which are set-up once the limiting frequency is exceeded. This would of course extend the range over which active noise is effective.

"Much work still needs to be done to establish this as a practical technique. The work has already demonstrated that the complexity of the active noise cancellation system required to attenuate higher order duct modes becomes greater and greater with increasing frequency," claims Bullmore.

Teun van den Dool of the TNO Institute says that systems are being developed with more loudspeakers, claiming that anti-noise can be generated up to 340 Hz in a 1 m by 1 m duct by using a system of four loudspeakers.

High level tones

It is the control of high level, low frequency tones where the active attenuator scores over its passive cousin. Andrew Bullmore points out that the rotation of the fan in ventilation ducting produces these tones, which can be many decibels higher than the general broad-band fan noise.

"An active controller seeks to minimise the correlation between the noise measured at the detecting microphone and that measured at the error microphone. In doing this, high level tones will be selectively attenuated to a greater degree than the general broad-band noise," says Bullmore.

He estimates that a control system providing 15 dB broad-band attenuation over the 125 Hz octave frequency band may be attenuating individual tones by more than 30 dB within the same frequency band.

"This feature can prove useful as tonal components in noise can lead to a greater level of annoyance, and it is not a feature offered by conventional passive attenuators."

Applications

For the moment at least, active noise control is likely to find its widest application as a means of enhancing the low frequency performance of passive attenuators.

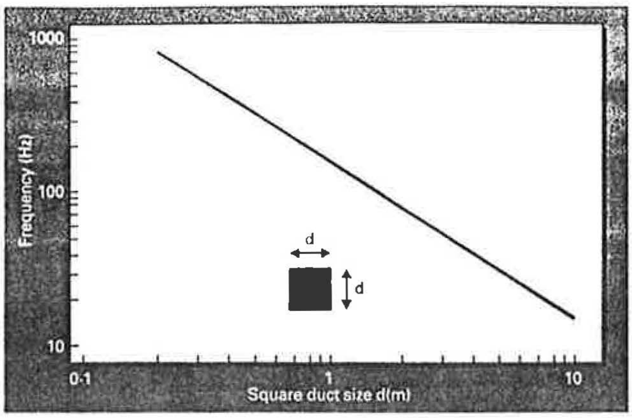

Figure 3: The maximum frequency at which anti-noise can be generated depends on the ventilation duct size.

TNO has developed a combined active/passive system in conjunction with ventilation equipment manufacturer Trox. This is similar to the apparatus shown in figure 1 except that passive baffles are positioned in the distance between the detecting microphones and the anti-noise loudspeaker.

The team used a directional microphone, sensitive only to downstream travelling sound waves, consisting of two omni-directional microphones, and a simple electronic circuit inside the controller.

TNO claims that this configuration is more directive and works out cheaper than those commercially-available microphones which claim to solve the problem.

Such a system avoids the bulky, passive silencers which would have been necessary to achieve a similar low frequency performance and, of course, obtains optimal noise reduction over a wide frequency range that is not possible with either passive or active-only systems.

Such combined systems are beginning to appear on the market, but prices are far from cheap. As a guide, Andrew Bullmore estimates that a combined active/passive system for a 2·4m long, 0·6 m sided duct would cost appproximately £2000, perhaps twice the cost of the passive-only solution.

Furthermore, the high frequency performance of the combined system may require enhancing, depending on the requirements. However, it is worth remembering before you dismiss the technology out of hand that prices will tumble as the cost of microprocessors continues to drop. Mass production due to increased demand would also force prices down.

Nevertheless Alan Fry, technical director of the Salex Group – manufacturer of sound attenuation equipment – is doubtful whether such mass production is likely. "Tin boxes and mineral wool are cheap, and so it's difficult for active systems to compete," says Fry. "If you get your calculations right first time and design out low frequency problems, passive systems will always be the cheapest solution."

However, Fry acknowledges that there is a place for active systems. "It is an excellent technique for remedial work in areas with low frequency noise problems. But it tends to be one-off work where we are hired as a specialist consultant with installation ability. From a mass production point of view it's a non-starter."

There are many companies able to offer this type of service, with US companies Digisonix, Active Noise and Vibration Technologies and Noise Cancellation Technologies competing with Salex and Trox.

It remains to be seen whether Paul Leug's theories stay years ahead of their time, or at last become part and parcel of working practices for today's designers.

Case study

A US manufacturer of resins and foams has a plant located in an established residential community. The manufacturing process requires ventilation for dust control, and a total of 42 induced-draught fans are installed for this purpose.

These radial-blade centrifugal fans make noise in the form of pure tones. Two dominant tones at approximately 60 Hz and 120 Hz exist. These tones lie some 20 dB and 35 dB above the general broad-band noise level respectively.

The application of conventional passive attenuators was considered and rejected for the following reasons:

- ☐ to perform adequately at low frequencies, passive attenuators would need to be large and heavy. This would mean reinforcing the stacks;
- ☐ passive attenuators would provide an unacceptably high pressure loss on the air flow;
- ☐ passive silencers reduce overall noise, but cannot specifically reduce annoying tones. This effect often makes the tone more irritating.

In preference to a passive system, a Digisonix active noise control system was installed. The system provides significant tonal noise reductions of all prominent tones, with the 60 Hz and 120 Hz tones being reduced by 25 dB and 35 dB respectively.

The system thus reduces these tones to the same level as the broad band noise, removing their tonal annoyance factor.