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THE PROSPECTS FOR ACTIVE ATTENUATION IN H&V NOISE CONTROL

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INTRODUCTION

Active noise attenuation has challenged many researchers worldwide ever since the pioneering effort by Lueg over 50 years ago. Since then a number of attenuator systems have been established and demonstrated successfully the basic principle of active noise control, in which an unwanted noise is cancelled with an addition of an antiphase sound. It is now time to concentrate effort in applying practical active attentuators to control H&V noise, enabling active noise attenuation to become a fully engineered form of noise control.

The practical development of active noise attenuation in H&V noise control is so far limited. The reasons why it is very much confined to the laboratory, rather than widely accepted in the H&V industry include:

- Lack of effort to investigate the technical limitations of the attenuation systems whilst working in a real H&V environment
- Insufficient work in analysing and reducing the complexity and cost of the attenuation systems
- Lack of evidence to convince engineers of the potential benefits and flexibilities that active noise attenuation can bring to their H&V design
- Lack of evidence to convince M&E contractors and hardware suppliers of the possible cost savings and the reliability of the attenuation systems
- Secretive approach to the practical realization of active noise control systems because of commercial reasons

Nevertheless, potential commercial growth has been indicated for the application of active noise attenuation in the following areas:-

- Fan noise control in air-conditioning ducts
- Control of plant exhaust noise to exterior
- Active control to reduce noise in plant rooms and enclosures

FAN NOISE CONTROL IN AIR-CONDITIONING DUCTS

This has caught the attention of many researchers and is attractive both from the academic and commercial points of view. Basically, duct noise requires a simple mathematical model to describe the one dimensional propagation of low frequency noise. The dedicated systems developed to tackle duct noise include Jessel, Swinbanks, Chelsea, Essex, etc [1] (Fig. 1). The sound field in a duct is well defined and much simpler than a sould field created by e.g. a transformer in the presence of surrounding buildings, or a reverberant sound field generated by machinery in a factory. By simply placing the detecting microphone upstream of the cancelling loudspeaker, an important time lead is obtained for the compensation of time delays produced by signal processing and filtering. This microphone-loudspeaker separation also enables the microphone to operate outside the sound mixing zone in the vicinity of the loudspeaker, which is a requirement for acoustically isolating the microphone in an absorptive system. In this, sound energy is absorbed from the in-duct sound by injecting a directional antiphase sound downstream.

A multi-million pound silencer market in the UK, and an even greater world market, is available to be tapped by commercially competitive active duct attenuators. A mammoth task, but not insurmountable, has to be undertaken in order to achieve this. The difficulties to be overcome include minimising of capital and maintenance costs and recovering the development costs. These problems are in addition to perfecting the performance of the attenuation system itself, e.g. overcoming the in-duct environmental influences such as flow turbulence.

Besides the favourable point that an active attenuator can perform better at low frequencies than the bulkier and less efficient dissipative silencer, a potential saving in operating cost may not have been fully recognised. It appears feasible[2] that an active and dissipative silencer combination, designed to satisfy a specified silencing requirement, but with a lower pressure drop then a longer silencer, can result in a long-term saving from a reduced operating cost for the fan and motor system.

Recent developments in active attenuation in air-conditioning ducts favour the use of the monopole system[1,3,4] (Fig. 1). This is in line with the cost saving aspect in realizing a commercially viable system in which the loudspeaker is an expensive element. The control electronics required range from an inverting amplifier in the Tight-Coupled Monopole[3] to digital signal processing in more complex systems[4,5]. All these monopole systems are susceptible to the effects of cross-modes that are present in actual ducts. Suggested methods to minimise the cross-mode effects are placing absorptive material on the duct wall opposite the loudspeaker and partitioning or dividing a bigger duct into smaller modules, for example, each module may have dimensions of 600mm wide and 500mm high. The performance of the monopole systems[4-6] is about 10-15dB at low frequencies when the in-duct flow velocities are in the range of 5-7m/s. Various requirements, which are crucial to the practical realization of a viable system have received little attention, such as suppression of flow noise generated by the microphone, minimisation of changes associated with internal pressure and flow velocity to the system, including the loudspeaker and the cost and reliability analyses of the active attenuator.

Knowledge of the blade passage frequency of the fan noise has not been made use of by the above mentioned monopole systems. This could possibly be utilized[7] to generate an anti-phase version for cancelling a prominent noise peak centred at the blade passage frequency. In an experimental arrangement[7] a signal, synchronised to this frequency, was generated by a photo-cell and a light source fitted inside the fan casing on opposite sides of the fan blades. By using a variable time delay (Fig. 2), the signal is suitably delayed before feeding back to the duct by a cancelling source loudspeaker, achieving a 13 dB suppression of the fan noise peak, with an in-duct flow velocity of 6.7m/s (Fig. 3). The application of this synchronised active noise system may be limited by its narrow signal bandwidth, which makes the system only effective for cancelling fan noise with a prominent peak at the fan passage frequency.

The future role of active attenuators in air ducts will be determined by the development of low cost adaptive controls and, to a lesser extent, by the development of electronic hardware. This is looking promising, with the advent of the microchip and the better digital processing techniques.

CONTROL OF PLANT EXHAUST NOISE TO EXTERIOR

Active attenuation has successfully demonstrated its ability to control low-frequency rumble in an extremely specialised noise treatment applied to the exhaust stack of a gas turbine[8]. The noise source is a 12 megawatt turbine at the British Gas Corporation Station at Duxford near Cambridge. The power turbine was driven by an Avon engine, which produced a high volume of turbulent exhaust gases discharged through a 3 metre diameter stack. The generated sound power was about 135dB in the 20-50 Hz range at the discharge end of the 12 metre high stack. The stack had been fitted with a passive silencer which was insufficient to attenuate the low frequency rumble. Rather than constructing a massive and expensive stack extension to reduce the rumble by conventional methods, British Gas resorted to active noise attenuation. The cost for the development and installation work amounted to around £300,000, shared jointly by British Gas and the National Research Development Corporation.

The active attenuator employed was developed by Swinbanks and his colleagues[8]. The microphones, protected from the hot gas flow, detect the primary noise as it travels upwards in the exhaust gas. The microphone signal is processed by a digital control device, which produces a mirror image of the noise waveform. The cancelling sound emitted by a ring of loudspeakers placed round the stack exit, causes destructive interference as the primary noise emerges from the exhaust stack (Fig. 4). A useful 10dB reduction is achieved at the turbine's rumbling peak across the lowest octave.

A feasibility study of applying active noise attenuation to control noise from an even larger 20 megawatt installation has recently been carried out.

Results from the preliminary investigation are promising [9].

It is hoped that it will be possible to reproduce this type of control system at a lower cost and with only minor modifications to suit an individual application. There exist numerous potential areas of applications for the active control of plant exhaust noise to exterior, such as gas turbines, aircraft engine test beds, diesel generators, boilers, etc. It is likely that general air-conditioning noise control will benefit from the spin-off of the new technology achieved in tackling hot and fast flowing gases in large diameter exhaust stacks.

PLANT ROOM NOISE CONTROL

Active attenuation of noise in an enclosure or a small room presents a more demanding task than the control of duct noise. The three dimensional field within an enclosure with scattering objects requires a highly involved mathematical model once the more realistic physical conditions have been taken into account. There are practical difficulties, such as the optimum position for placing the detecting microphone whilst the microphone-loudspeaker separation may not give sufficient lead time for carrying out the necessary signal processing and filtering, which can easily be obtained by placing the sensing microphone upstream in the case of duct noise control.

Recent developments in active control of noise in enclosures concentrate on placing the cancelling loudspeaker close to the noise source [10-12]. Warnaka et al [10] demonstrated that a 10-20dB attenuation over frequency range 20-400Hz could be achieved in a 400 cubic metre reverberation room using two large loudspeakers. One was fed with a source signal and the second a cancellation signal. The cancellation signal was derived from the unwanted noise by adaptive electronic control means. The source and cancelling loudspeakers were placed adjacent to each other, forming a dipole, which is an inefficient radiator of sound along the centreline of the two sources to the far field inside the room.

Short [11] also verified that global active attenuation could be obtained by the introduction of a closely located monopole to create a dipole situation. The attenuator loudspeaker was placed 100mm from the opening of a 300mm wide and 450mm high ventilation duct and the detecting microphone was positioned halfway between the duct and the loudspeaker. The room reverberant noise was reduced by a maximum of 15dB at 50Hz, with attenuation between 30Hz and 200Hz. Other noise sources including a small air compressor were used and some global wide band attenuations were reported.

The noise sources described so far have all been located inside the room and the technique employed was to treat the noise at source. Another area of active noise application is to combat noise within small enclosures in noisy environments, such as plant rooms, heavy industry, textile works, food processing factories. An active attenuation model has been proposed for the prediction of attenuation in an audiometric enclosure [13]. The system used a monopole with a signal processing device which was programmed to achieve maximum attenuation at the microphone. Predicted results are promising, such as an attenuation of more than 10dB at 248Hz over a horizontal plane corresponding to the subject's head position inside the enclosure.

Current work on the control of aircraft cabin noise should have a spin-off for plant room noise control. The next generation of prop fan engines (Fig. 5) employing large multi-blade propellors, are fuel-efficient but generate high levels of harmonic low frequency noise with a fundamental frequency of about 80Hz. Attenuation of this noise by conventional means will involve severe payload penalties and active attenuation is presently under investigation as a solution to this problem [14].

A practical active attenuator system for use in enclosures will bring immense benefit to many areas of H&V and industrial noise control and this must be the ultimate aim of active attenuation development.

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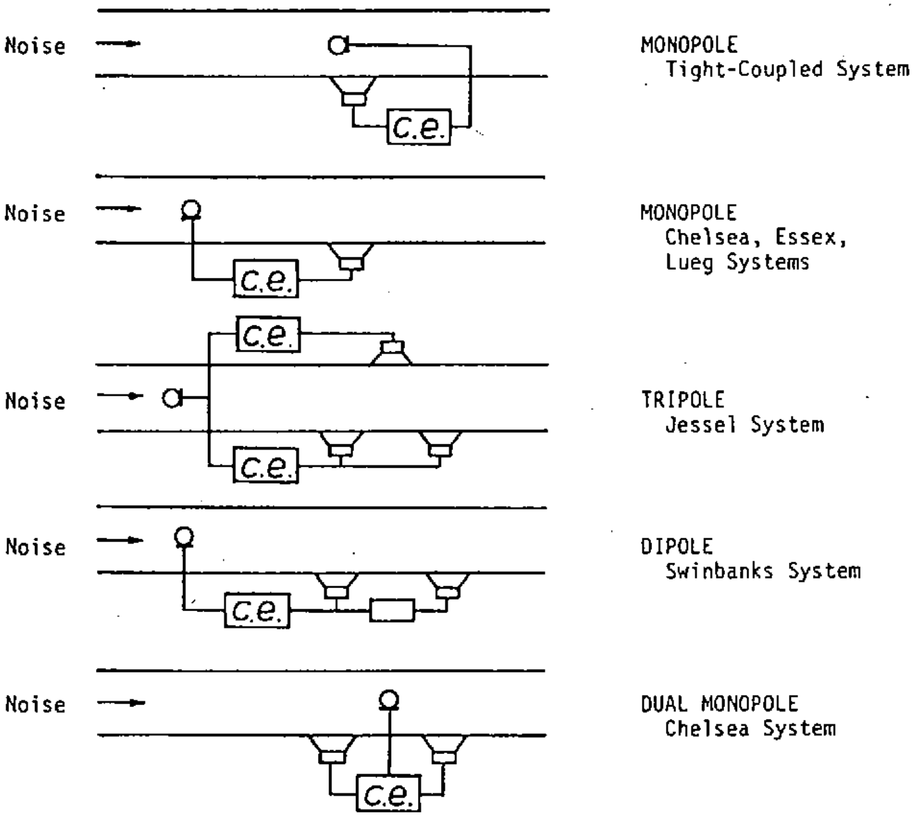

Figure 1 Active attenuation systems for ducts (C.e. = Control Electronics)

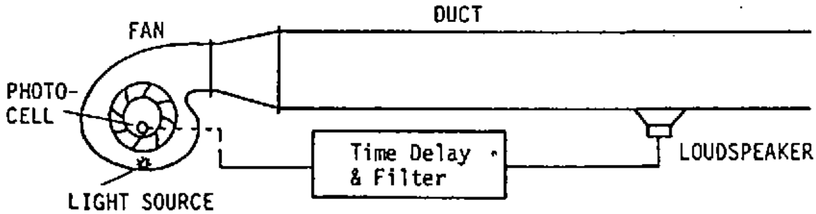

Figure 2 Active attenuation system to cancel fan noise at blade passage frequency

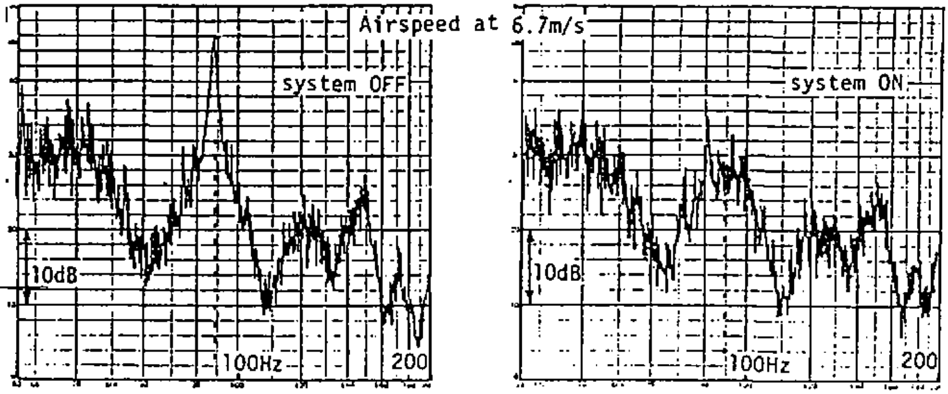

Figure 3 Active noise attenuation at fan blade - passage frequency

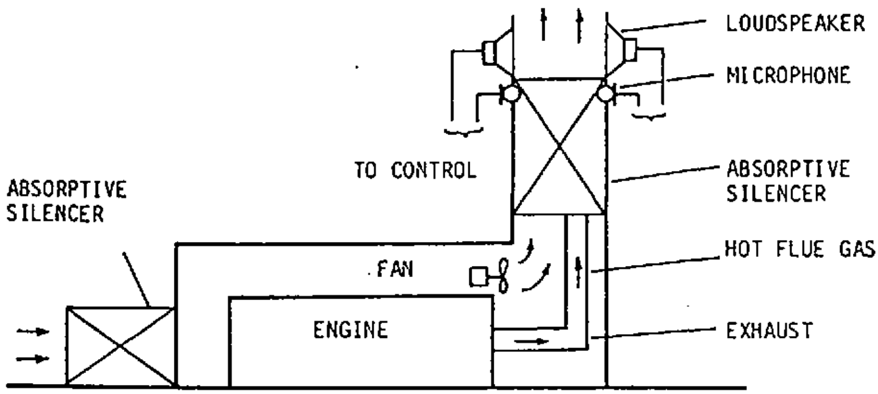

Figure 4 Exhaust active attenuator

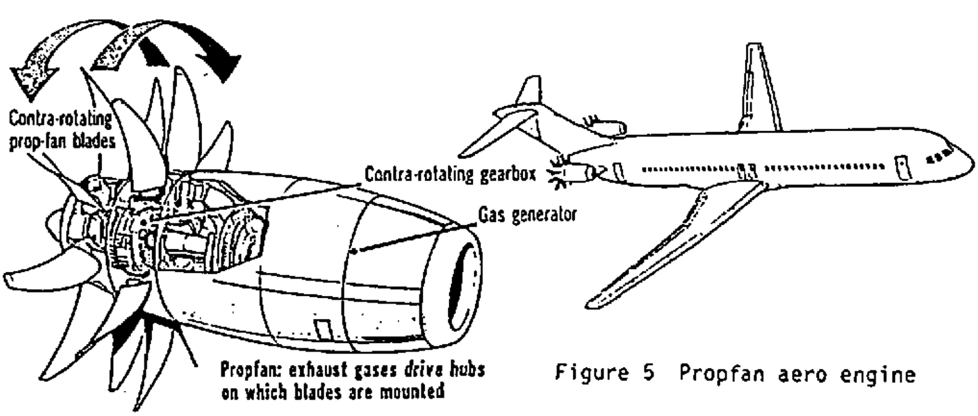

Figure 5 Propfan aero engine