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ACTIVE CONTROL OF REPETITIVE NOISE AND VIBRATION

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INTRODUCTION

Noise and vibration which is of a repetitive nature - such as noise produced by a diesel engine exhaust, and vibration transmitted through its mounting pads - can be cancelled without the need to sense it, process it, or use linear transducers or actuators.

This is accomplished by the use of a self-adaptive system, which also reduces installation and commissioning costs, and applications are limited only by the power rating of available actuators. Even using currently available loudspeakers, the exhaust noise of engines of several thousand horsepower can be cancelled.

THE RANDOM SYSTEM

Figure 1 shows the basic method for cancelling random noise in a duct, and is included to enable the novel features of the repetitive systems to be more readily appreciated. The duct hardware consists of a sensing microphone, a single cancellation loudspeaker, and a "residual" microphone which, by measuring noise power, enables the microprocessor to adjust the filters for minimum residual noise. No prior information on the duct or loudspeaker characteristics is needed.

THE REPETITIVE SYSTEM

Figure 2 shows a loudspeaker injecting a cancellation sound pressure waveform at the outlet of a diesel exhaust. A "residual" microphone is again employed to instruct the microprocessor to reduce the nett noise pressure to a minimum, but note the absence of sensing microphone or filter. The microprocessor simply constructs the required waveform for application to the loud-speaker terminals by, for example, trial and error. The response of the loudspeaker is unimportant, provided it can supply sufficient power. Synchronisation pulses lock the microprocessor to engine speed.

Figure 3(a-c) shows a "slow" adaption algorithm, for relatively constant speed engines, in which a single "time element" of the cancelling waveform is adjusted each firing cycle. Thus, for 32 elements, 32 firing cycles are needed to complete one pass through the waveform, and full adaption is activated after about 30 secs.

Figure 3(d) shows the cancellation waveform being synthesized by a faster algorithm, in which all 32 elements are adjusted by a single amplitude increment every firing cycle. This algorithm reduces the adaption time to about 8 secs, and also greatly increases the immunity to external noise. Both systems produce an attenuation of about 20dBs from 20Hz to 250Hz on a 3HP laboratory engine, and similarly on a 100HP, 74KVA, standby generator in a local factory. A system is being currently installed on the exhaust of a diesel engined container ship. A substantial reduction in adaption time can be achieved by making use of amplitude information in the residual waveform.

Engine related noise can also be cancelled in a region remote from its source, such as at the driver's position in a cab.

REPETITIVE VIBRATION

Figure 4 shows the same repetitive system applied to the cancellation of vibration arriving at an engine bed plate through one of the engine mounts. An inertial vibrator is applied to the bed plate underneath the mount. The loudspeaker and residual microphone of Figure 2, become the inertial vibrator and residual accelerometer of Figure 4. The vibrator opposes the vibration from the engine, and produces a displacement null at the accelerometer. Attenuations of up to 40dBs, in the frequency range 15 to 500Hz are achieved in the present test rig. The system is highly immune to random ambient vibration such as might be produced by other machinery installed in the same structure or vehicle.

Alternatively, a vibrator can replace the engine mount, and operate so as to produce a force null at a residual force transducer in series with it. The active mount is therefore highly compliant, but can be tailored electronically to support the static force or react to transient shocks.

SOLVING INTRACTABLE PROBLEMS

The electronic system, being self-adaptive, can be applied to complex problems, such as vibration in helicopters, which might have hitherto defied analysis, and will automatically find a solution, if one exists.

On the other hand, there are some situations, such as a major resonance in a ship, where the problem can be analysed, but passive solutions based on masses and springs may be too cumbersome or dangerous. In such a situation, an adaptively driven active actuator could be much more compact and effective.

Furthermore, without the constraint of linearity, one is free to consider unorthodox, but more effective, transducers and actuators for repetitive noise or vibration. For example, this freedom might enable a simple actuator to be designed which could cancel engine exhaust noise at the manifold itself, rather than at the exhaust outlet.

CONCLUSIONS

Self-adaptive methods complement, rather than compete with, passive methods.

By taking advantage of the special features of repetitive noise and vibration, self-adaptive systems can be built which combine simplicity with stability, are very tolerant of defects in transducers and actuators, and are capable of solving problems hitherto considered intractable.

Thus the most useful applications of these systems may well lie in areas not yet foreseen.

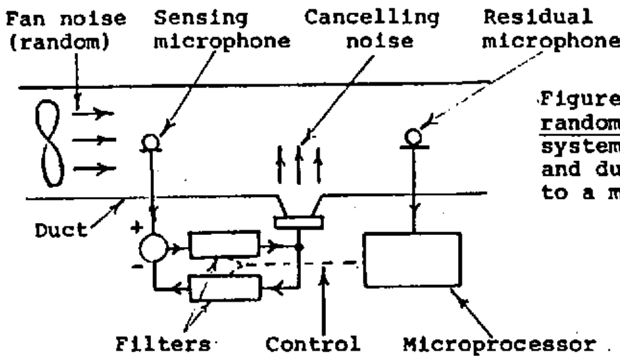

Figure 1. Cancellation of random noise in duct. The system is self-adaptive, and duct hardware is kept to a minimum.

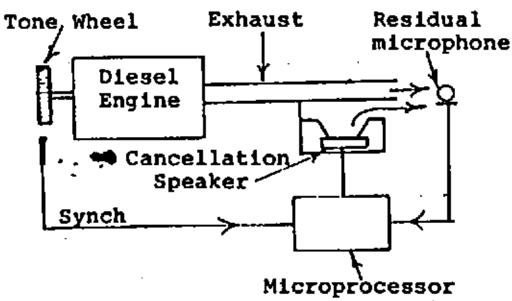

Figure 2. Cancellation of repetitive noise. Note the absence of sensing microphone or filters. Cancellation is not affected by non-linearity in the loudspeaker.

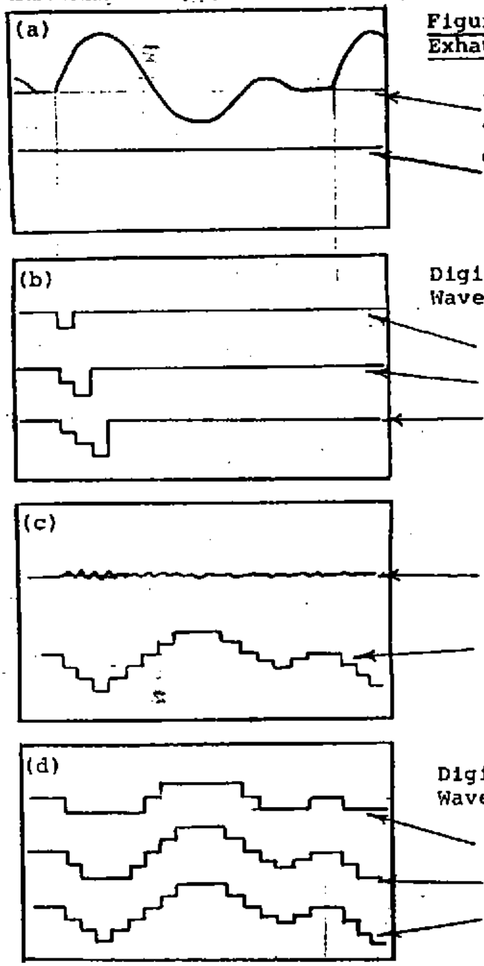

Figure 3. Oscillograms of Diesel Exhaust Noise during Adaption

Digitally Generated Cancelling Waveforms for "Slow Adaption"

Digitally Generated Cancelling Waveforms for "Faster Adaption"

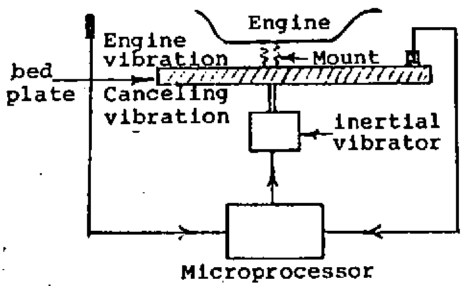

Figure 4. Cancellation of repetitive vibration. The vibrator adaptively opposes vibration transmitted through the mount.