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THE IMPLICATIONS OF SYNCHRONISED CANCELLATION FOR VIBRATION

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INTRODUCTION

The success of the synchronous adaptive waveform cancellation technique (Ref 1) for removing high levels of low-frequency noise leads naturally to the adoption of the technique for vibration cancellation. Many engine-related noises begin as vibrations within the engine body, and only become significant as noise following their transmission through the engine mounts, into the supporting structure.

A Basic Property of Repetitive Cancellation Systems.

Synchronised cancellation notches out the harmonic series of very narrow spectral lines associated with the particular machine to which it is linked. As a result, vibration from any other (even another repetitive, but unsynchronised) source is ignored by the system: This selective feature confers a directional effect on the system, in that only vibration going from the machine to the outside world is blocked. Vibration entering the machine from below, and emanating from other sources, is unaffected. If this latter vibration were to be cancelled, the cancellation would not be taking place "at source", and so active reinforcement would occur in other parts of the structure. This property of the synchronous system allows it to succeed where random-vibration sensing systems might fail, through failing to distinguish one vibration source from another.

Mounting Configuration

No matter how complex the vibrational modes operating at each engine (or raft) mounting point, they can always be resolved into three orthogonal directions - and so cancelled by three orthogonal actuators.

The minimum number of mounting points for an engine is three, although many small engines have four, and larger engines have up to eight (or more in special cases). Thus, on this basis the number of actuators required would vary from nine to twenty four, depending on engine size.

Conventional Actuator Configuration

Earlier workers in vibration isolation used inertial vibrators (shakers), largely on the basis that no modification to the existing passive mounting system would be needed, and and that existing electro-dynamic actuators are not able to sustain high static loads. The schematic configuration is shown in Fig 1a.

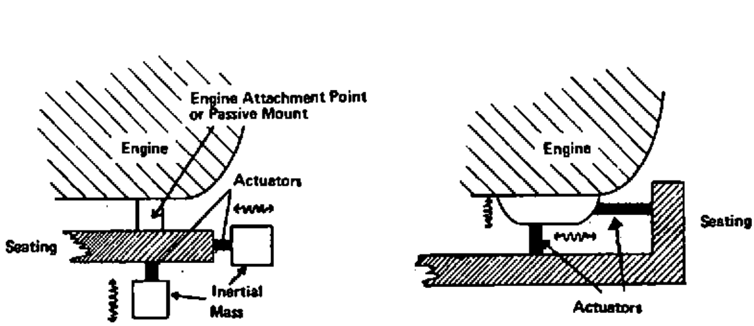

Figure 1:a - Orthogonal "inertial" actuators operating on the engine seating; b - Orthogonal "free-fall" actuators connecting the engine to its seating. [Only two of the three actuators are shown in each case]

Note that, if the engine is bolted solidly to the seating, the actuators must keep the engine attachment points stationary by opposing the full dynamic forces. These dynamic forces consist mainly of out-of-balance forces in rotating or reciprocating components, and torsional forces at cylinder firing rate, (or pole passage rate). A typical medium speed diesel engine of 2000 HP, supported on six mounts, would produce vibrational forces of several hundred pounds per mount. The cancelling actuators would need to match these dynamic forces, and would need relatively large freely suspended masses against which to react.

An Alternative Actuator Configuration

An alternative approach is to allow the engine to vibrate freely, as if in free fall. The vibration amplitude at the mount of a passively mounted engine results from the above dynamic forces acting on the relevant mass or moment of inertia of the engine, the mass/compliance relationship of the engine and mount, and the vibrating modes induced into the seating which, in turn, can react back through the mount. Measurements of this amplitude can therefore be misleading, and need correction to arrive at the free-fall value. Such measurements, taken at one of the six mounting points of a Paxman 3000 HP 12 cylinder Valenta diesel engine, and corrected for the above factors by a firm of diesel consultants, indicated that the free-fall vibrational amplitude would be only a few tens of micrometres.

The actuator configuration for supporting an engine under "free-fall" conditions is shown in Fig 1b, and it can be seen that the actuators must be capable of providing the full static, and, in a vehicle or ship, motional, forces.

However, their dynamic motion is very small, and their dynamic force is zero. This latter feature follows from the fact that the actuators do not impede the vibrating motion of the engine, and so keep the total force constant.

Shear Isolation

The system has been demonstrated by an experimental rig consisting of a raft about 4 feet square, supporting a compressor, and mounted onto a realistic seating of 6 inch U-section steel beams. This arrangment is similar to that found on a frigate's diesel generator. Four vertical "free-fall" mounts were used, but it was not possible to measure the degree of vertical cancellation, because shear modes could be transmitted through each actuator, and excited vertical modes in the seating. A passive shear isolator was therefore fabricated from a "slinky" spring, sealed with silicone rubber, filled with water, and connected in series with the mount.

Each actuator was driven by a separate waveform synthesizer module, and, in spite of severe resonances in the seating, the system adapted, to an average cancellation of 40 dB, as shown in the spectra of Fig 2.

The shear isolator serves the additional purpose of protecting the actuators from shear forces, and hence potential damage.

With this system it is not necessary to have three orthogonal actuators at each engine mounting point. For example, a total of eight actuators could be deployed.

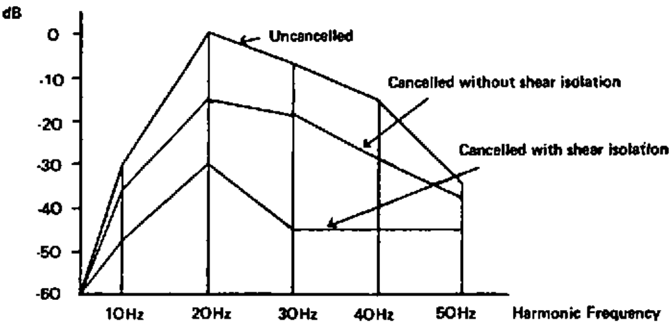

Figure 2 Vibration cancellation in an experimental rig.

Properties of the Two Systems

Both inertial and "free-fall" actuator configurations, when driven by the Essex synchronous system, are extremely stiff to static and motional forces, but do not transmit any significant engine related vibration.

The main difference between the configurations is that the first requires inconvenient, and possibly dangerous, inertial masses, and the second requires actuators capable of supporting static and motional forces.

Inclusion of Passive Mounts

Passive mounts may be placed (a) in series with the inertial actuators, to reduce the dynamic force needed - but at the expense of static stiffness; or (b) in parallel with the shear-isolated mounts to reduce the static force needed - but at the expense of shear isolation, and hence the amount of cancellation achievable.

This latter degradation in cancellation can be quite serious, since shear vibration can propagate through the passive mount, and excite all modes of vibration in the seating.

REFERENCE

[1] Chaplin, G.B.B., & Smith, R.A. 'Waveform Synthesis - The Essex Solution to Repetitive Noise and Vibration, Inter-Noise Proceedings 1983.