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Controllers for hybrid isolation of structure borne sound in a demonstrator set-up

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Abstract

The joint research program in cooperation with TNO-TPD called "Hybrid Isolation of Structure Borne Noise" studies the possibilities of reducing the sound radiation at certain locations in a structure, due to the presence of a vibration source. A ship engine is such an example of a vibration source, which causes noise annoyance due to the vibration transmission through its carrier structure.

The existing passive isolation methods (e.g. rubber mounts) are insufficient to achieve the desired sound reduction. A promising approach for this type of applications is the use of so called hybrid isolation techniques, being a combination of passive (spring, damper) and active (controlled actuator) isolation methods. Important issues are optimal performance and integration in the existing construction.

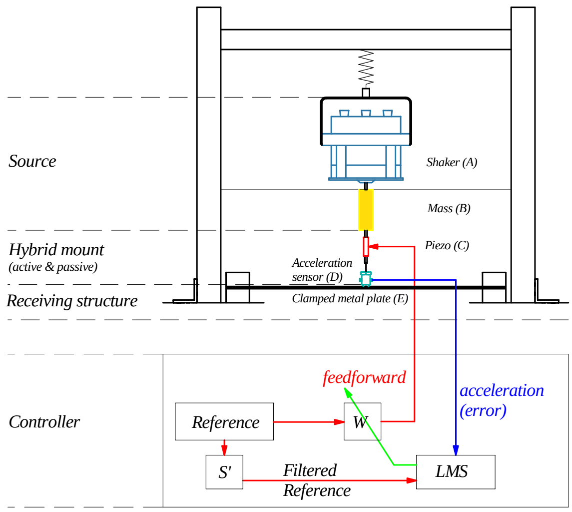

Figure 1: Schematic of 1-DOF demonstrator set-up

The experiments are performed with an experimental set-up for a one degree of freedom (1-DOF) system (see fig. 1). An electrodynamic shaker(A) serving as a vibration source excites a mass(B) with an unknown (harmonic) disturbance. The mass is mounted on a clamped metal plate(E) by a piezoelectric actuator(C) which operates as a hybrid isolation mount. Setting the frequency of the disturbance close to the 1^{st} or 3^{rd} eigenfrequency of the receiver construction results in significant sound radiation from the metal plate. Remark that the mount is designed to transfer only forces perpendicular to the plate. This means that the mount can completely isolate the source from the receiver by ensuring that the external force in the mount-plate interconnection point equals zero. Effectively the hybrid mount needs to generate an internal force to counteract the force induced by the mount stiffness and the displacement of the vibration source. As a consequence the source vibration remains unchanged while the receiver remains silent.

An adaptive feedforward LMS controller is used for online calculation of the optimal piezo force which minimizes the signal measured with the acceleration sensor(D). The two filter coefficients in the vector $\bar{w}$ are updated according to the LMS weight update equation[1,2]

$$\bar{w}(n+1) = \bar{w}(n) + \mu \bar{x} a \qquad (1)$$

in which n is the current sample number, μ the convergence step size, $\bar{x}$ the filtered reference signal and a the measured acceleration (error signal). The reference signal needs to be filtered by an estimation of the transfer function from the piezo force to the measured acceleration in order to compensate for the mechanical delays in this transfer path. Without this, the controller may exhibit slow convergence or may even show divergent behavior, even for appropriate selection of the step size μ. In general, a smaller μ results in lower convergence speed but diminishes the residual error and therefore the radiated sound levels.

For the presented configuration the source is almost completely isolated for the frequency of the harmonic disturbance.

References

[1] C.R. Fuller, S.J. Elliott, P.A. Nelson, "Active Control of Vibration", 1996.

[2] S.M. Kuo, D.R. Morgan, "Active Noise Control Systems, Algorithms and DSP Implementations", 1996