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Self-tuning Feedforward Control for Active Vibration Isolators

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1 Introduction

Active vibration isolators are applied to isolate precision machines from floor vibrations. A simplified model for such a vibration isolator is shown in Figure 1. Self-tuning feedforward control is applied, using measured floor accelerations \(a_0\) as controller input. Feedback control by measuring machine acceleration \(a_1\) is used to add skyhook damping to the suspension mode of the system. This abstract is a summary of our work in [1].

![Figure 1: Model of an active vibration isolator.](image1)

2 Controller design

The controller scheme is shown in Figure 2. The machine motion \(a_1\) is formed by two signal components: a component \(d_e\) that is caused by the disturbance signal from the primary path \(P\), i.e. the passive system, and a component \(y_e\) that is caused by the control action from the secondary path \(S\). The actuator force \(F_a\) is the sum of the outputs computed by the controllers \(K\) (feedback) and \(W\) (feedforward). From Figure 2 it follows that perfect cancellation of floor vibrations is obtained using the feedforward control law:

\[
W_{opt}(s) = -S^{-1}(s)P(s) = -\frac{1}{s} \left( d_1 + \frac{k_1}{s} \right).
\]

![Figure 2: Combined feedforward/feedback control scheme.](image2)

Note that the controller does not need any information about the internal mode. The low-frequency control action must be limited to prevent sensor noise and drift problems:

\[
W_{opt}(s) = -\frac{1}{s} \left( \frac{1 - L_0(s)}{s} \right)^2 w_2. \quad (2)
\]

in which \(L_0\) may be any arbitrary \(n\)th-order low-pass filter with unity gain. A higher \(n\) results in more performance, but comes at the cost of a higher static controller gain. From (2), we define the IIR filters \(F_1(s), F_2(s)\), and the self-tuning weights \(w_1, w_2\) containing estimations for \(d_1, k_1\). Values for \(w_1, w_2\) are determined by minimizing a quadratic cost function using the Filtered-x LMS algorithm [2].

3 Results and Conclusions

The feedforward controller is implemented on an experimental setup of a vibration isolator, using different orders \(n\). Measurements (Figure 3) show a broadband vibration isolation up to 40 dB. Future research will focus on reduction of model uncertainties to further increase the performance.

![Figure 3: Measurements of the transmissibility \(a_1/a_0\).](image3)

References

[1] M.A. Beijen et al. (2014), Self-tuning Feedforward Control for Active Vibration Isolation of Precision Machines. Submitted to The 19th IFAC World Congress (2014).

[2] G.W. Van der Poel (2010), An exploration of active hard mount vibration isolation for precision equipment, University of Twente, The Netherlands