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Design of a smart mount for vibration isolation in high-precision machinery[1]

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1 Introduction

In high-precision machines, e.g. wafer scanners or scanning electron microscopes, the achievable accuracy and repeatability is limited by (amongst others) the presence of poorly damped structural modes. These modes can be excited by floor/base vibrations and disturbances acting directly on the machine (e.g. cables, background noise or internal acceleration forces). Therefore, most precision machines are mounted on vibration isolation systems, which provide isolation from floor/base vibrations above the first resonance frequency, called the suspension mode frequency. This frequency is typically 1 Hz in these so-called soft mounted machines. Unfortunately, in that case, the mount stiffness is small, which means the machine is very compliant to direct disturbances.

The goal of this research project is to develop a vibration isolation system which offers efficient vibration isolation from both direct disturbances and floor vibrations.

2 Hybrid hard mount concept

In this research, the use of hard mounts for vibration isolation is investigated. Hard mounts provide a compliance to direct disturbances which is at least an order of magnitude smaller compared to soft mounts. On the other hand, floor vibrations are only attenuated above the suspension mode resonance frequency, which now becomes typically 15-30 Hz. Therefore, an active control system is necessary to compensate for floor vibrations in the lower frequency range.

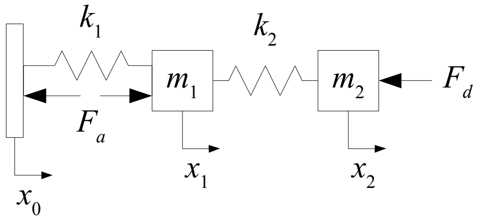

Figure 1: 1-dimensional model of a machine (m_1, k_2, m_2) supported by a hybrid mount (k_1, F_a), subject to floor vibrations x_0 and a direct disturbance force F_d

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The hard mount concept is illustrated in figure 2, which is based on the system shown in figure 1. Figure 2 shows the transmissibility of floor vibrations ($X_1(s)/X_0(s)$) for a reference active soft mount system (dash-dotted), a passive hard mount system (dashed) and the target hybrid hard mount system (solid).

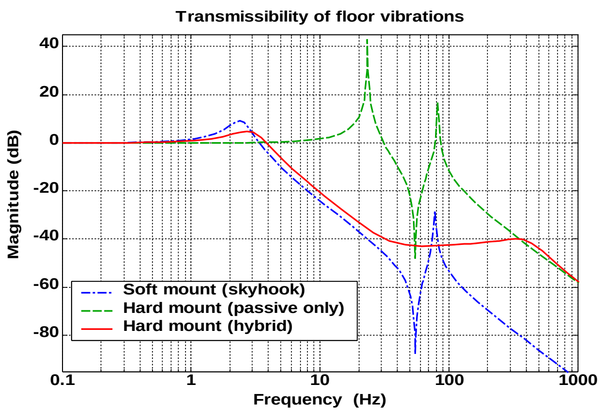

Figure 2: Transmissibility of floor vibrations for an active soft mount system (applying skyhook damping), a passive hard mount system and a hybrid hard mount system

3 Control strategies

A one-dimensional laboratory setup has been developed to analyse the performance of fixed gain and adaptive feedback as well as adaptive feedforward control strategies. The adaptive control strategies are based on the Filtered-X Least Mean Squares (FxLMS) algorithm, which is widely used in Active Noise Control (ANC) (see e.g. [1], [2]). The most promising experimental results have been obtained by using a combination of (fixed gain) feedback control and adaptive feedforward control. These results indicate that the hybrid hard mount concept is feasible.

References

[1] S.J. Elliott, "Signal processing for active control", Academic Press, 2001.

[2] S.M. Kuo, and D.R. Morgan, "Active noise control systems: algorithms and DSP implementations", John Wiley & Sons, 1996.