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Disturbance feedforward control for active vibration isolation systems with internal isolator dynamics

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Abstract

This paper presents a disturbance feedforward control strategy for active vibration isolation systems that have internal isolator dynamics. The structure of the feedforward controller follows from modeling, but to achieve robust performance the tuning of the controller parameters will be based on measurement data. More specifically, the controller poles, which correspond to internal isolator dynamics, are obtained offline from system identification experiments, while the controller zeros are obtained from online self-tuning using measured sampled-data systems. Self-tuning is used to reduce parameter uncertainty when having too limited identification possibilities, and to account automatically for the effect of noise amplification. Measurement results obtained from an industrial vibration isolation system show that residual vibrations are largely reduced up to the level of output noise limitations.

Keywords: active vibration isolation, vibration control, air mounts, high-precision mechatronics.

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1. Introduction

Vibration isolation systems are widely used in high-precision machines to achieve the often extreme demands on accuracy [1, 2, 3, 4]. The basic idea is to create a low suspension stiffness between an isolated payload and a corresponding vibrating base. As a result, passive vibration isolation is provided beyond the low suspension frequency. However, systems with low suspension frequencies generally have internal isolator dynamics at relatively low frequencies that may compromise isolation performance. An example is given by an air mount system [5, 6, 7], which achieves a low stiffness using large air tank volumes. This generally leads to low internal resonance frequencies within the air tank as a result of air acoustics [8]. Another example is found in isolators using metal springs such as coil springs [9] or leaf springs [10]. For such springs, the internal resonance frequency corresponding to the first structural eigenmode is generally proportional to the suspension frequency [11, 12].

Several methods have been proposed to improve performance of vibration isolators with internal isolator dynamics. In [13], dynamic vibration absorbers (DVAs) are proposed to counteract internal resonances, but these absorbers require hardware modifications to the isolator. Alternatively, feedback control strategies for active vibration isolation are found in [14, 15]. Feedback control, however, may associate with a poor signal-to-noise ratio (SNR), because the sensor is placed on the payload which by itself is passively isolated. Moreover, a high bandwidth is required to control internal isolator dynamics which can result in stability problems. A feasible solution is then given by disturbance feedforward control that uses measured base vibrations as controller input instead. This renders the controller inherently stable and with a much better input SNR. However, to provide an effective feedforward control force an accurate model of the vibration

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