DSTA 2021 dys-ta.com
16th INTERNATIONAL CONFERENCE
Dynamical Systems – Theory and Applications
December 6-9, 2021, On-line

Hybrid vibration absorber for self-induced vibration mitigation

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Abstract: Various active and passive methods for vibration mitigation exist, each presenting its own advantages and drawbacks. The objective of this study is to compare the performance of a hybrid active-passive dynamic vibration absorber and of a purely passive one, with respect to their ability in suppressing self-excited oscillations. The host system considered is a simple linear oscillator with a negative damping, while the actuator of the hybrid absorber generates a force proportional to the acceleration of the system's lumped masses. The presence of a time delay in the feedback loop is also considered. Results illustrate that the two systems have practically identical performance.

Keywords: vibration absorber, time-delayed system, self-induced vibrations

1. Introduction

Self-induced vibrations (SIVs) are vibrations generated by the system's inherent instability, and not by an external forcing. Real life examples of this phenomenon are the friction-induced vibrations, shimmy, and the regenerative chatter [1]. SIVs are generally detrimental in the engineering practice; therefore, several methods for their suppression were developed, encompassing active and passive vibration mitigation tools.

In this study, a hybrid vibration absorber (HVA) [2] is implemented for SIV suppression. The HVA is composed of an active and a passive part. The passive part is essentially a dynamic vibration absorber (DVA), i.e. a secondary mass-spring-damper system attached to the host system. The active part, which consists of an actuator connecting the primary system and the DVA, is controlled through a feedback loop, reading in input the acceleration of the system. The cases of time delay and no time delay in the feedback loop are considered. The main advantage of HVAs compared to DVAs is that they are capable of attenuating vibrations occurring at different frequencies [2]. Our research focuses on investigating the HVA's ability to improve the system's stability, in comparison with a simple, passive, uncontrolled DVA.

2. Methods

The host system considered in this study consists of a linear single degree-of-freedom oscillator possessing a negative damping, which models the system's instability. A HVA is attached to it through a spring, a damper, and an actuator, as illustrated in Fig. 1. After partially nondimensionalizing the equations of motion by transitioning to dimensionless time and introducing further dimensionless parameters, we carried out the stability analysis. For the case without time delay, the Routh-Hurwitz criterion was adopted. Further analytical proof is presented in the paper regarding the evolution of the stable region as the parameter used to represent the

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unstable feature of the system (ψ) approaches its critical value (ψ_{cr}), above which the passive DVA is unable to stabilize the system, as it is discussed in [3].

The stability boundaries corresponding to the delayed acceleration feedback control have been determined by implementing the D-subdivision method. In order to decide which regions correspond to a stable behaviour, numerical methods have been applied. We used numerical tools to investigate the HVA's effect on the rate by which, in stable conditions, oscillations decay. The results were validated through numerical simulations.

3. Results

The stability analyses have shown that the stable region shrinks and eventually disappears as ψ approaches ψ_{cr}, regardless of the presence of time delay (Fig. 2). On the other hand, we have found that it is possible to choose the control law parameters so that the implementation of a HVA results in faster settling.

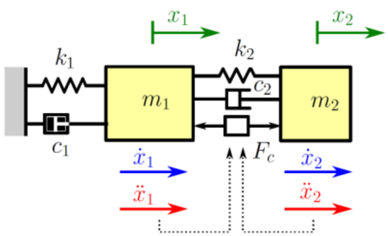

Fig. 1. The mechanical model

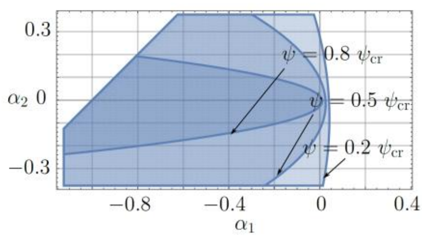

Fig. 2. Evolution of the stable region (without delay)

4. Concluding Remarks

A comparison of the performance of a passive DVA and of a HVA illustrated that the additional active controller, present in the HVA, does not improve stability properties of the system. The introduction of time delay in the feedback loop, often used for enhancing the effectiveness of acceleration based active controllers [4], was also ineffective with respect to improving the system's stability. On the other hand, the HVA, if correctly tuned, provides a faster convergence than a passive DVA.

Acknowledgement: This research was financially supported by the Hungarian National Science Foundation under grant number OTKA 134496.

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