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Experimental Prototype of a KDamper Vibration Absorber for Small Vertical Loads Utilizing Compliant Joints

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Abstract: An experimental prototype of a vibration absorption base, designed based on the KDamper concept, is evaluated. The KDamper is a passive vibration absorption and damping concept, based essentially on the optimal combination of appropriate stiffness elements, including a negative stiffness element (NSE). Compared to the traditional Tuned Mass Damper (TMD), it has significantly higher modal damping and achieves greater attenuation in a wider frequency band while utilizing significantly lower additional mass. The inclusion of the NSE facilitates excellent damping properties even at low frequencies without sacrificing the static load bearing capacity of the base as the overall static stiffness of the KDamper is maintained. The design, geared towards machine anti-vibration mounts, concerns a 20 kg seismic mass at frequencies around 3.5 Hz. The NSE is implemented utilizing compliant translational joints to overcome the limitations of conventional helical springs in this context. Finally, transmissibility measurements of the prototype have been performed, which show good agreement with the analytic predictions.

Keywords: KDamper, negative stiffness, vibration control, compliant joints, experimental

1. Introduction

Vibration isolation of systems subjected to periodic excitation with conventional elastic mounting, requires the reduction of the resonant frequency by adjusting its stiffness. At low excitation frequencies, the required stiffness reduction leads to large deflections and/or compromises the structural integrity of the system. Concepts like the Tuned Mass Damper (TMD), quasi-zero stiffness oscillators, inerters etc., have been proposed and implemented to overcome these challenges. The presented design is based on the KDamper concept [1]. A base/mounting mechanism is designed for the absorption of vertical vibrations of machines, is considered in this work. The targeted seismic mass is 20 kg for rotational speeds around 200 RPM.

The KDamper incorporates a negative stiffness element (NSE), the elastic force of which supplements the inertial forces of the added mass. Most significant comparative advantages of the KDamper, especially in the low frequency range, are the superior damping characteristics without the need of heavy additional masses or sacrificing the static loading capacity of the structure by using soft elastic mounting. The NSE of the KDamper can be realized in various ways such as pre-stressed disc springs [2] or helical springs [1] and post-buckled beams [3] among others. However, in cases where high negative stiffness along with large dynamic amplitude of the internal degree of freedom are required, most implementations are proven inadequate, mostly due to high stress development of the structural elements. Configurations of mechanisms utilizing conventional helical compression or extension springs have been investigated, demonstrating drawbacks such as buckling deformation, insufficient

stroke and manufacturing inaccuracies. Here, a configuration consisting in a mechanism with pre-stressed springs is used for the NSE. However, instead of conventional helical springs, appropriate large-displacement compliant joints [4] were utilized to overcome these drawbacks.
The fundamentals of the KDamper and compliant joints design procedure are presented, along with the numerical evaluation including the response of the system in the time and frequency domains. Finally, based on this design, a prototype was built for the conduction of experimental measurements.

2. Results and Discussion

The various manufactured stiffness elements including the compliant joints showed certain deviation relative to the design values which were partly considered during the design process. Nevertheless, the provision for modularity of certain geometrical parameters of the NSE facilitated the required adjustments for optimal operation of the system and furthermore, the testing of two cases for different seismic mass. The transmissibility of the system resulting from the processing of the various cases of experimental measurements, demonstrated very good agreement with the predictions of the numerical models. The comparisons along with relevant signal processing parameters validate the theoretical framework and analytic investigation. Even though at this stage no damping elements were incorporated in the prototype, aside of the structural damping of the various stiffness elements, the excellent damping performance of the KDamper was prevalent at frequencies as low as 2 Hz.

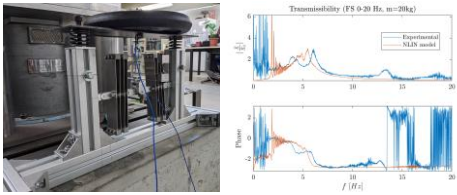

Fig. 1. Experimental prototype of the KDamper base and indicative transmissibility comparisons.

3. Concluding Remarks

An experimental prototype of a KDamper vibration absorption mounting mechanism for small masses and low excitation frequencies was built, utilizing large-displacement compliant joints for the NSE implementation. Conducted experimental measurements compare very well with the analytic predictions and the prototype showcased excellent absorption performance in the intended frequency range.

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