Nonlinear vibration isolators with spring and inerter configured in linkage

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Abstract. This study proposes various nonlinear vibration isolator designs exploiting a hybrid use of the inerter device and diamond-shaped linkage mechanisms. The combined use of the inerter and linkage mechanism is considered to fully exploit inertial properties of the former and the geometric nonlinearity of the latter for performance enhancement of vibration suppression. The steady state responses of the proposed isolators subjected to harmonic force excitations are obtained using analytical harmonic balance (HB) method, alternating frequency time HB and direct numerical integrations, with the results cross-checked and validated. The isolation effectiveness of the proposed isolators is evaluated using the time-averaged vibration energy transmission and force transmissibility as performance indices. Beneficial performance of using inerter and linkage mechanism in the nonlinear isolators is demonstrated, showing great potential for superior vibration attenuation.

Introduction

The inerter is a passive mechanical device with the property that a dynamic force across the two terminals is proportional to their relative accelerations [1]. Such device can be physically realized through a variety of designs using, for example, a ball-screw or a rack-pinion mechanism. Recent developments suggest that semi-active and fluid based inerters can offer a range of benefits and studies have demonstrated benefits of using such devices in automobile shock absorbers, in civil buildings and in aircraft landing gears. Many studies, however, have only considered the use of inerters in linear isolators. Limited studies have been reported with a hybrid use of inerters and the geometric nonlinearity of linkage mechanisms for vibration isolation. Many studies have shown that the introduction of inerter and / or nonlinearity to a vibration suppression device can bring performance benefits [2-4]. For instance, a negative stiffness mechanism can be used together with a linear spring to achieve high-static-low-dynamic stiffness nonlinear vibration isolator, beneficial for low-frequency vibration isolation. The current study explores the embedding of spring, damper and inerter in linkage mechanism for vibration suppression with enhanced performance.

Results and Discussions

Fig. 1(a) shows a configuration of nonlinear vibration isolator using passive spring and inerter connected in diamond-shaped linkage mechanisms with geometric nonlinearity. Fig. 1(b) shows that the natural frequency of the isolator can be reduced, suggesting an enlarged frequency range for effective isolation. The responses are obtained using analytical approximations and numerical integrations. Indices including force/displacement transmissibility and vibration energy flow variables are used to evaluate the performance of the proposed nonlinear isolators. Beneficial performance has been demonstrated by using the inerter devices and geometric nonlinearity of linkage mechanisms to achieve superior vibration suppression.

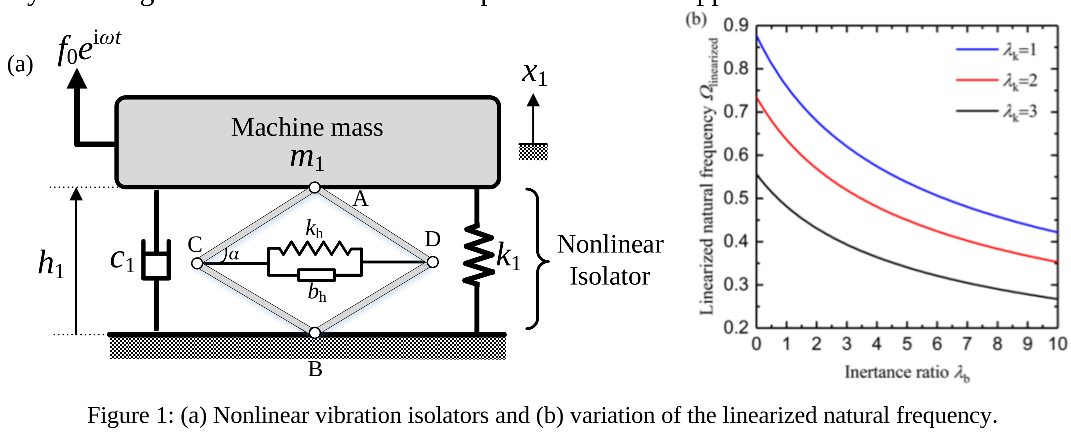

Figure 1: (a) Nonlinear vibration isolators and (b) variation of the linearized natural frequency.

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