Large Stroke Quasi-Zero Stiffnes Vibration Isolator by Exploring Geometric Nonlinearity of r-shaped Structure

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Abstract. Quasi-zero stiffness (QZS) is beneficial to reduce the resonance frequency of the system and widen the vibration isolation frequency band. However, conventional QZS isolators are developed by connecting the designed negative stiffness and positive stiffness spring in parallel, and they have a small working stroke with a limited load capacity. In this paper, we proposed a large stroke QZS isolator by exploring geometric nonlinearity of a r-shaped structure. The Static and dynamic models are developed to characterize the isolator.

Introduction

The QZS vibration isolator possesses high static and low dynamic stiffness (HSLDS), which solves the contradiction between isolation frequency band and load capacity in linear vibration isolation system [1,2,3]. However, conventional QZS isolator contains negative stiffness components, whose limited deformation capacity leads to the departure from the zero-stiffness region when facing large amplitude vibrations. Herein, we proposed a large stroke QZS isolator without negative element for Low frequency large amplitude vibration

Design and modeling

Figure 1(b) shows the r-shaped structure with two robs and an extension spring. The rod AC contains two parts rob AB with length L_1 and rob BC with length L_2. The joint D divides rod EB into L_3 and L_4. The horizontal distance between point E and F is d. The initial angle between the two robs is β_0, and the initial angle between the rob EB and the ground is a_0. The initial spring length is x_0. The height from the bearing platform to the base is h_0. The relationship of static force f and the compression displacement y could be obtained by geometric and static analysis.

$$\begin{cases} f = k\left(1-\dfrac{\sqrt{2L_1L_3\cos\beta_0+L_1^2+L_3^2}}{\sqrt{2L_1L_3\cos\beta+L_1^2+L_3^2}}\right)\dfrac{L_1L_3\sin\beta}{d-\left(L_3+L_4\right)\cos\alpha} \\ y=\sqrt{\left(L_3+L_4\right)^2+L_2^2-d^2-2\left(L_3+L_4\right)L_2\cos\beta_0}-\sqrt{\left(L_3+L_4\right)^2+L_2^2-d^2-2\left(L_3+L_4\right)L_2\cos\beta} \end{cases} \tag{1}$$

Systematic parameter analysis shows that the proposed r-shaped structure realized QZS over large displacement when the rod length ratio satisfies L_2 : (L_3+L_4) : d =1.9 : 1.0 : 1.5, as shown in Figure 1(c). In addition, the load capacity of the proposed r-shaped isolation system can be flexibly adjusted by changing the connection method of the spring.

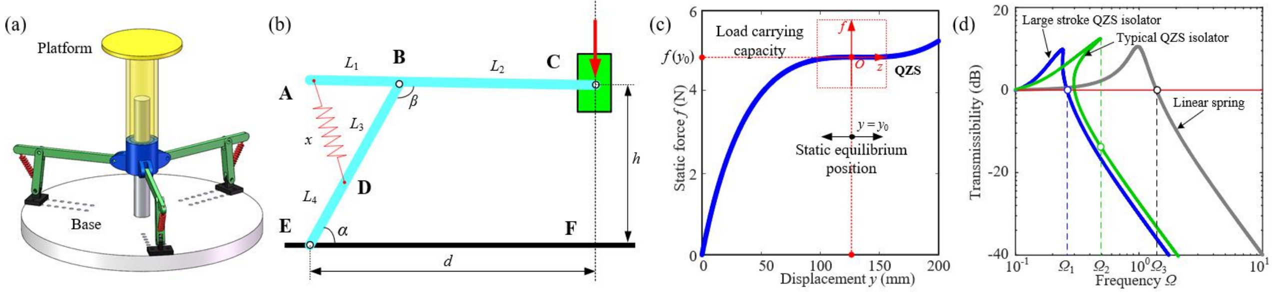

Figure 1: Structural design, static and dynamic analysis of the large stroke QZS isolator.

The dynamic equation of the proposed isolation system can be approximated by Duffing equation without a linear term,

$$M\left(\frac{z''}{L_3+L_4}\right)+c\left(\frac{z'}{L_3+L_4}\right)+\frac{\left(L_3+L_4\right)^2}{6}K''_{eq}(0)\left(\frac{z}{L_3+L_4}\right)^3=\frac{f_0}{L_3+L_4}\cos\left(\omega t\right) \tag{2}$$

As shown in figure 1(d), comparisons with existing QZS isolator [2] validates that realization of QZS over large stroke could effectively avoid the problem of frequency jump and improve system stability. The proposed isolator possesses lower resonance frequency and lower resonance peak, so that a better vibration effect is achieved in the low frequencies.

References

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