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On the transmissibilities of nonlinear vibration isolation system

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ABSTRACT

Transmissibility is a key parameter to quantify the effectiveness of a vibration isolation system. Under harmonic excitation, the force transmissibility of a linear vibration isolation system is defined as the ratio between the amplitude of the force transmitted to the host structure and the excitation force amplitude, and the displacement transmissibility is the ratio between the displacement amplitude of the payload and that of the base. For a nonlinear vibration isolation system, the force or the displacement responses usually have more frequency components than the excitation. For a harmonic excitation, the response may be periodic, quasi-periodic or chaotic. Therefore, the amplitude ratio cannot well define the transmissibility. The root-mean-square ratio of the response to the excitation is suggested to define the transmissibility. The significance of the modified transmissibility is highlighted in a nonlinear two-stage vibration isolation system consisting of two linear spring connected linear vibration isolators with two additional horizontal linear springs. Harmonic balance method (HBM) is applied to determine the responses with the fundamental and third harmonic. Numerical simulations reveal that chaos may occur in the responses. In both cases, the modified transmissibility works while the original definition cannot be applied to chaotic response.

1. Introduction

Nonlinear vibration isolation has been concerned by many engineers and scientists [1], for that it can achieve a low dynamic stiffness and hence low natural frequency, but at the same time having a low static deflection [2–8]. Thus, nonlinear vibration isolation comes at a cost of complexity, nonlinearity, which is perceived to be worthwhile in some applications, for example, vibration control of the integrated satellite system [9–11].

Transmissibility is always used to quantify the effectiveness of the isolation system and always defined as the form that the ratio of the amplitude of the transmitted force to the excitation force at each concerning frequency [1,2]. And such definition for the linear vibration isolator has been worked early [6,7], even widely application in the nonlinear vibration isolator with its appearance [1–5,9]. However, nonlinear vibration isolation has other harmonics, quasi-periodic response and chaotic motion rather than only fundamental harmonic when it responses to harmonic excitation [4–6]. So traditional

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transmissibility with linear form definition is used to nonlinear vibration isolation remains a fundamental limitation, however, with both the single- and two-stage nonlinear vibration isolators.

Some papers have explore the advantages that can be gained by incorporating geometric stiffness nonlinearity into a two-stage isolator to overcome the problems of high static deflection and low roll-off rate at high frequency [12,13]. Lu and Yang [13] incorporates geometric stiffness nonlinearity into a two-stage isolator to overcome the problems of high static deflection and low roll-off rates at high frequency. It has been found that nonlinearity in the lower stage has a profound effect, and significantly improves the effectiveness of the isolation system. In later work, the upper horizontal springs are connected to the secondary mass, rather than to the ground as described in reference [14]. The revised isolation model is employed to investigate the dynamics of the two-stage nonlinear isolation system and to see whether it can outperform other existing systems, it is found that both the force and displacement transmissibility are reduced in the isolation range as the horizontal stiffnesses at both stages are increased [14]. Although the problem of the definition is treated in the nonlinear vibration isolation system, overall the idea could be extended to other vibration controls.

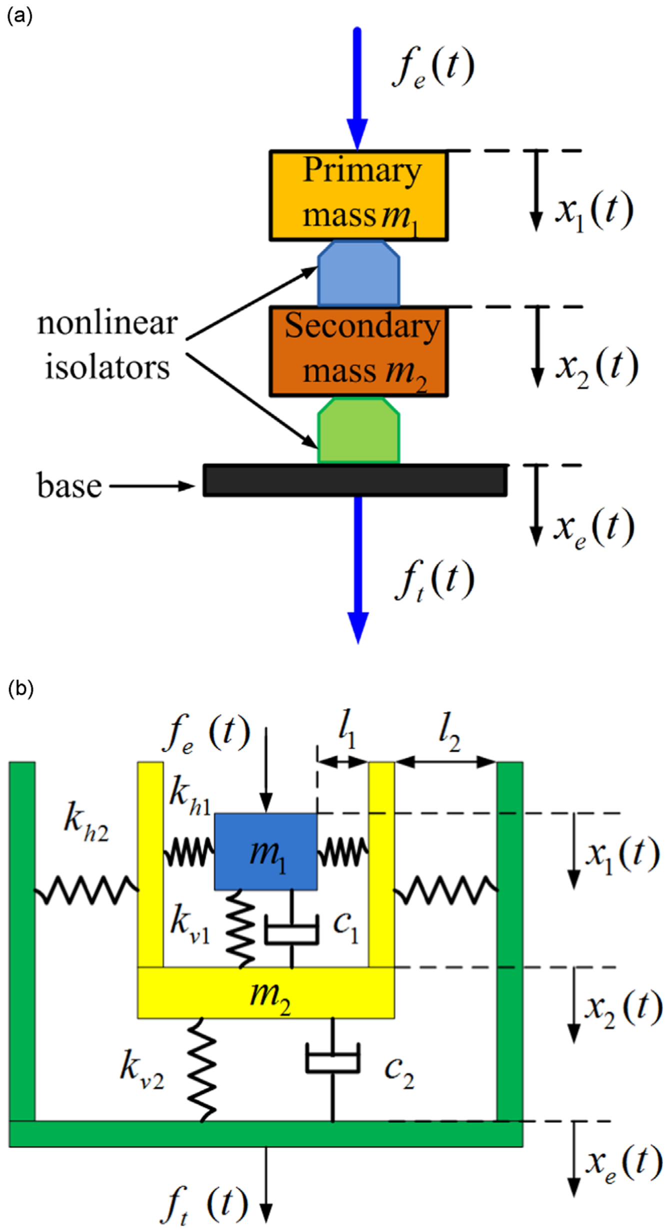

Fig. 1. Schematic of the two-stage nonlinear isolation system. (a) actual system, (b) equivalent lumped parameter model. The mass, m_1 is the suspended (primary) mass and m_2 is the intermediate (secondary) mass.