



The force transmissibility of MDOF structures with a non-linear viscous damping device

Z.K. Peng^{a,b,*}, Z.Q. Lang^b, L. Zhao^b, S.A. Billings^b, G.R. Tomlinson^c, P.F. Guo^b

^a State Key Laboratory of Mechanical System and Vibration, Shanghai Jiao Tong University, Shanghai 200240, PR China

^b Department of Automatic Control and Systems Engineering, University of Sheffield Mappin Street, Sheffield S1 3JD, UK

^c Department of Mechanical Engineering, University of Sheffield Mappin Street, Sheffield S1 3JD, UK

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ABSTRACT

In the present study, the concept of the Output Frequency Response Function (OFRF), recently proposed by the authors, is applied to theoretically investigate the force transmissibility of MDOF structures with a cubic non-linear viscous damping device. The results analytically show that the introduction of cubic non-linear damping can significantly reduce the transmissibility over all resonance regions for a Multiple Degree of Freedom (MDOF) structure and at the same time leave the transmissibility over the isolation region virtually unaffected. The analysis also indicates that a strong linear damping may shift the system resonances and compromise the beneficial effects of cubic non-linear viscous damping on the force transmissibility of MDOF structures. This suggests that a less significant linear damping together with a strong cubic non-linear damping can be used in MDOF structures to achieve a desired vibration isolation performance. This research work has a significant implication for the design of viscously damped MDOF structures for a wide range of practical applications.

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1. Introduction

Vibration isolation is an effective method of reducing the transmission of vibration energy so as to protect equipment or structures from vibration disturbances [1]. Generally speaking, vibration isolation systems fall into two categories: passive and active [2], and passive isolation systems can be either linear or non-linear. The design of isolation systems always presents a challenge to mechanical engineers because various criteria and indices have to be considered in practice. For linear isolation systems, which have been widely studied in the literature, the isolation criteria and indices can often be explicitly expressed in term of the design parameters, such as damping and stiffness coefficients. This greatly facilitates the design process so that an optimal design of linear isolation systems can be achieved relatively easily. For example, Soliman and Ismailzadeh [3] analytically derived the relationship between the transmissibility and the mass, stiffness, and damping ratios for linear isolators to explicitly relate the system resonant characteristics to these parameters. Most recently, various powerful optimization techniques such as the recursive quadratic programming (RQP) technique [4], the sequential quadratic programming (SQP) technique [5] and genetic algorithms (GA) [6] have been applied to design

linear isolation systems to achieve a better isolation performance. However, the design of non-linear isolation systems is much more complicated and is still a difficult challenge. The difficulty is that the analysis of non-linear systems is much more complicated, *per se*, since a closed-form analytic solution to non-linear differential equations is possible only for a limited number of special classes of non-linear differential equations [7]. Usually, researchers have to simplify the non-linear systems analysis by resorting to Single Degree of Freedom (SDOF) or low dimensional models. However, even with simplified models, the analysis of non-linear systems is still not an easy task. For the study of non-linear vibration isolation systems, an immediate difficulty is that it is hard to derive an explicit analytical description for the relationship between the system non-linear characteristic parameters and the transmissibility. As a result, most research effort has been focused on the analysis of relatively simple SDOF and 2-DOF non-linear isolators. In addition, for some non-linear vibration systems, the difficulties in analysis and design are also due to individualistic behaviors such as dependence on initial condition or energy and possible existence of multiple solutions and bifurcation phenomena. A very comprehensive survey about the recent developments of non-linear vibration isolators has been contributed by Ibrahim [8], in which many cited studies [9–16] have revealed that the introduction of non-linear damping and stiffness are really of great benefit in vibration isolation.

Although the design of linear isolation systems is relatively easier than the design of non-linear isolation systems, there is a well-known *dilemma* associated with viscously damped linear

* Corresponding author at: State Key Laboratory of Mechanical System and Vibration, Shanghai Jiao Tong University, Shanghai 200240, PR China.

E-mail addresses: pengzhike@tsinghua.org.cn (Z.K. Peng), z.lang@sheffield.ac.uk (Z.Q. Lang).