Modelling and nonlinear dynamic analysis of a cable considering the vibration of a tuned mass damper

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Abstract. Considering the vibration of a tuned mass damper (TMD), a cable-TMD system is established. Different from the other models, this model considers the participation of the TMD in energy transfer and coupling interaction between the cable and TMD. According to the partial differential equations of the cable and TMD, the one-to-one internal resonance of the system is studied when external primary resonance of the cable occurs. The Galerkin's method is applied to obtain the ordinary differential equations (ODEs). To solve the ODEs, the multiple time scale method is used and the modulation equations are derived. The stable solutions of the modulation equations are acquired by Newton-Raphson method and continued by pseudo arclength algorithm. Meanwhile, the parametric analyses of some key parameters, such as the sag of the cable, the stiffness, damping ratio and position of the TMD, are carried out through frequency-/force-response curves to explore the nonlinear behaviours of the system. Finally, some rich phenomena are presented and conclusions are drawn.

Introduction

Cables are used in a wide range of engineering applications, such as cable-stayed bridge, offshore marine cables and power transmission conductors. Therefore, cable dynamics have received an amount of consideration of many researchers in the last few decades. Cable dynamics have a long and rich history and are summarized in literature [1]. Due to its low damping and weight, cables are prone to vibration under the environmental excitations (e.g., seismic and wind-rain load). In view of this, many researches begin to focus on the vibration control of the cable. To suppress the vibration of the cable in cable-stayed bridge, a damper is usually installed near the lower end of the cable. The great majority of works in the literature mostly deal with the model by considering the equilibrium relationship of the force at the location of the damper and the motion of the damper is not taken into account [2, 3]. This will inevitably deviate from the understanding of the dynamic behaviours of the cable-damper model.

Hence, the reasons for this research mainly include the following two aspects. On the one hand, the damper is installed on the cable in the practical engineering and will inevitably affect the stiffness and damping of the structure, which may further change the dynamic characteristics of the cable. However, in the previous research, the role of the damper in the whole complex system has not been considered, and the coupling vibration of the cable and damper has never been involved. On the other hand, although previous studies have revealed the energy transfer mechanism between different modes of the cable, there has never been any relevant research involving the participation of the damper in the energy transfer. To this end, this paper focuses on a cable-TMD system, in which the viscous damping and the vibration of TMD are considered.

Results and discussion

Figure 1 shows the frequency-response curves of the cable (a_1) and TMD (a_2) when the stiffness of the spring K=50 and 300, respectively. It can be seen that Hopf bifurcations (HBs) and the peak of a_2 caused by internal resonance disappear with the increase in K. Moreover, the stable and unstable solutions are connected through saddle-node bifurcation (SN2) (see subfigures (c) and (d)). Obviously, a_2 is smaller when K=300 than that when K=50, while it is opposite for a_1. The reason may be that the energy is stored in the spring, causing the amplitude of the TMD to decrease. However, on the other hand, a part of the energy stored in the spring will also be release to maintain the large vibration of the cable, resulting in a slight increase in the amplitude of the cable. This indicates that TMD plays an important role in energy transfer.

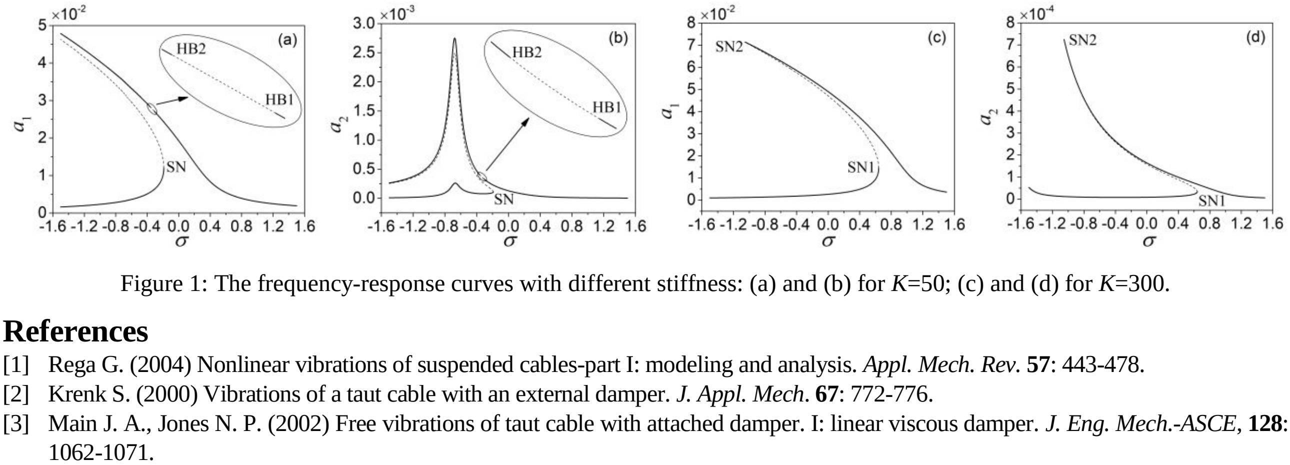

Figure 1: The frequency-response curves with different stiffness: (a) and (b) for K=50; (c) and (d) for K=300.

References

[1] Rega G. (2004) Nonlinear vibrations of suspended cables-part I: modeling and analysis. *Appl. Mech. Rev.* **57**: 443-478.

[2] Krenk S. (2000) Vibrations of a taut cable with an external damper. *J. Appl. Mech*. **67**: 772-776.

[3] Main J. A., Jones N. P. (2002) Free vibrations of taut cable with attached damper. I: linear viscous damper. *J. Eng. Mech.-ASCE*, **128**: 1062-1071.