Periodic Responses of a Taut Cable Attached with a Friction Damper Computed Using Multi-Harmonic Balance Method

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Summary

Friction is an effective and convenient source of energy dissipation for many mechanical and structural systems. For stay cables that are susceptible to multi-mode vibrations due to low intrinsic damping, friction damper is of particular significance because it is able to provide frequency-independent damping. However, the level of damping supplied by a friction damper for a cable has not been fully understood owing to its strong nonlinearity. This study concerns the periodic responses of the cable-friction damper system. The damper is considered using a macro-slip model where the compliance accounts for elasticity of the contact interface and damper support flexibility as well. The periodic response that represents a substantial subset of the dynamic characteristic of the nonlinear system, beside the free decay which is previously focused on in the literature, is solved using multi-harmonic balance method. Subsequently, frequency response of the nonlinear system in the vicinity of cable resonant frequencies are computed through a continuation procedure, based on which the control effect of the friction damper on cable can be appreciated. Eventually, the optimal friction damper parameters can be discussed on the basis of system resonant steady-state responses.

Keywords: Cable vibration control; friction damper; periodic response; harmonic balance method.

1. Introduction

Cables of cable-stayed bridges are subjected to multiple mode vibrations induced by varied excitations, including wind and rain. Hence, nonlinear dampers are advantageous for cable vibration control compared with linear dampers which can only be tuned to a particular cable mode [1,2]. Friction dampers, as one type of commonly used nonlinear dampers, have been implemented for cable vibration control, as on the Uddevalla bridge [3] in Sweden. However, due to strong nonlinearity of friction, the cable-friction damper system has not yet fully understood. A thorough investigation of this system is therefore of both practical and theoretical significance.

Cable damped by a friction damper has received considerable attention previously. A straightforward approximation of its dynamics has been obtained by linearizing nonlinear control force-velocity relationship based on energy equivalence or by minimizing the mean-square error in the dynamic force equilibrium at the damper [1,4]. This beforehand linearization leads to derivations of the estimated maximum control effect and optimal damper parameter from corresponding experimental or numerical results [5-7]. As a relatively accurate approach, numerical integration has been intensely used for semi-active or active control of cable vibrations [8]; it has also been used to compute cable responses under passive control [9] and further to appreciate the

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