Optimal design and seismic performance of nonlinear TMD with pinched hysteresis

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Abstract. This contribution deals with a nonlinear tuned mass damper (N-TMD) characterized by a peculiar pinched hysteretic behaviour, which is offered by mixed wire ropes made of shape memory alloys and steel undergoing bending. The optimal design of the N-TMD is performed in a stochastic framework. The nonlinear constitutive behaviour of the N-TMD is incorporated in the optimal design procedure via stochastic linearization technique (SLT) expressions, which are ad-hoc developed for the assumed modified Bouc-Wen model describing the pinched hysteresis of the device and validated against Monte Carlo simulation (MCS). Validation of the optimal design procedure based on the developed linearized expressions is carried via time-history analyses under a series ground-motion records, and the seismic performance of the N-TMD is comparatively analysed against that of the conventional linear TMD with different mass ratios.

Introduction

Optimal design and seismic performance of a nonlinear tuned mass damper (N-TMD) are investigated. Unlike conventional linear TMDs and alternative nonlinear TMDs that exploit hysteretic dampers or inelastic springs with bilinear force-displacement relation, the proposed device is characterized by a peculiar pinched hysteretic behaviour. This behaviour is offered by a series of mixed wire ropes made of shape memory alloys (SMAs) and steel undergoing bending, which provide a nonlinear restoring force due to concurrent interwire force and phase transformation [1]. Previous experimental findings demonstrated that the constitutive behaviour of this device can be well described by a modified Bouc-Wen model model with some additional terms governing the pinching phenomenon [2]. Also, previous numerical studies demonstrated the advantageous properties of this N-TMD system in comparison to linear TMD when applied to inelastic structures, due to the widening of the frequency band of vibration suppression and enhanced robustness against detuning conditions [3].

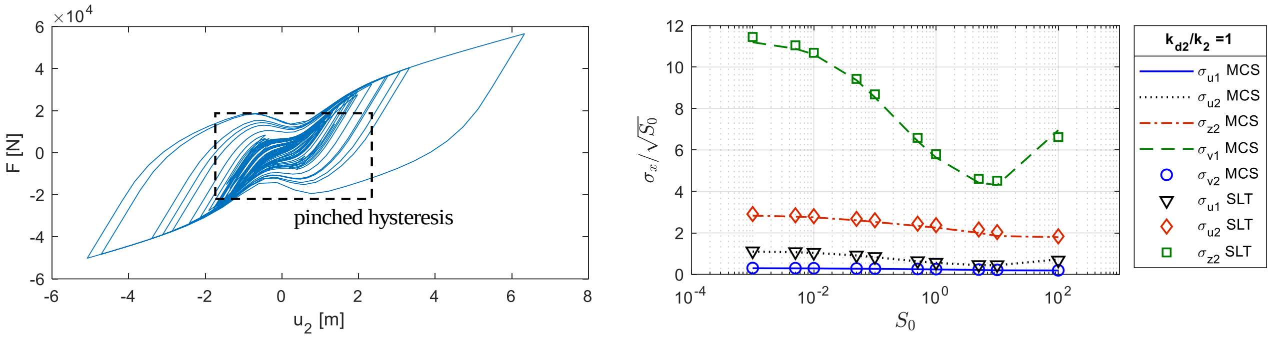

Figure 1: Typical pinched hysteresis of N-TMD device (left) and validation of SLT against MCS (right)

Results and discussion

In this paper, the optimal design of the N-TMD is performed in a stochastic framework to account for the uncertain nature of the seismic input: the base acceleration is modelled as a Kanai-Tajimi filtered stationary random process, with different filter parameters influencing the frequency content and related to soil characteristics of the installation site. The main structure to protect is assumed as a single-degree-of-freedom (SDOF) system. The nonlinear constitutive behaviour of the N-TMD is fully incorporated in the optimal design procedure via SLT expressions, which are ad-hoc developed for the assumed modified Bouc-Wen model describing the pinched hysteresis of the device. A wide parametric study is conducted to describe the optimal design parameters of the N-TMD and the seismic performance under a range of soil characteristics, TMD parameters and main system properties. The sensitivity of the system response with the N-TMD parameters is investigated in terms of the variation of the variance terms and compared to that of the linear TMD. Validation of the optimal design procedure based on the developed linearized expressions is finally carried via time-history analyses under a series of artificial and natural ground-motion records, and the seismic performance of the N-TMD is comparatively analysed against that of the conventional linear TMD having different mass ratios.

References

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