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Re-centering variable friction device for vibration control of structures subjected to near-field earthquakes

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ABSTRACT

This paper proposes a re-centering variable friction device (RVFD) for control of civil structures subjected to near-field earthquakes. The proposed hybrid device has two sub-components. The first sub-component of this hybrid device consists of shape memory alloy (SMA) wires that exhibit a unique hysteretic behavior and full recovery following post-transformation deformations. The second sub-component of the hybrid device consists of variable friction damper (VFD) that can be intelligently controlled for adaptive semi-active behavior via modulation of its voltage level. In general, installed SMA devices have the ability to re-center structures at the end of the motion and VFDs can increase the energy dissipation capacity of structures. The full realization of these devices into a singular, hybrid form which complements the performance of each device is investigated in this study. A neuro-fuzzy model is used to capture rate- and temperature-dependent nonlinear behavior of the SMA components of the hybrid device. An optimal fuzzy logic controller (FLC) is developed to modulate voltage level of VFDs for favorable performance in a RVFD hybrid application. To obtain optimal controllers for concurrent mitigation of displacement and acceleration responses, tuning of governing fuzzy rules is conducted by a multi-objective heuristic optimization. Then, numerical simulation of a multi-story building is conducted to evaluate the performance of the hybrid device. Results show that a re-centering variable friction device modulated with a fuzzy logic control strategy can effectively reduce structural deformations without increasing acceleration response during near-field earthquakes.

1. Introduction

In recent years, the damaging effects of near-field motions on civil structures have revealed the lack of conventional design methods and emphasized the need of innovative design strategies [1–3]. Numerous structures were damaged or collapsed during the 1994 Northridge, 1995 Kobe, 1999 Duzce, 1999 Chi-Chi and the most recent 2008 Winchuan earthquakes, leading not only to significant economic losses but also large loss of lives. Near-field earthquakes have long-duration pulses with peak velocities of the order of 0.5 m/s. The ground motions with such velocity pulses may cause significant damage to structures within the near-field region. Another characteristic of the near-field motions that adversely influences structural response is that the ground motion normal to the fault trace is richer than that parallel to the fault in long-period spectral components. Due to this normal component of the near-field motions, large displacement demands are imposed on to the structures.

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