Semi-Active Control Algorithm with Control-Structure Interaction for Magnetorheological Damper Used in Seismically-Excited Buildings

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Abstract. High control performance is achievable for active control if the interaction between the active control devices and structure is considered. For semi-active control, the dynamics of these dampers (e.g., magnetorheological dampers, MR dampers) should be included in the control design. This study aims to develop and experimentally verify a semi-active control algorithm that accounts for the MR damper-structure interaction in the designed controller. Moreover, this control algorithm can directly calculate the required input voltage (or current) to MR damper(s) at each time step and avoid the two-step approach that computes the required control force first and then converts the force into the input voltage. This study also conducts a series of numerical and hybrid simulations to verify the proposed method. As seen in the results, the proposed semi-active method in this study can reduce structural responses and produce more reactive input commands under seismic excitation.

Introduction

Semi-active control has been considered to be capable of achieving similar control performance to active control. However, most semi-active control strategies using magnetorheological (MR) dampers didn't account for the control-structure interaction, which has been proved to be more effective in active control applications [1]. Therefore, this study proposes a new semi-active control method that considers the interaction between MR dampers and structures. In this study, the time-variant control-structure system is realized by the first-order approximation of the state-space approach, while the MR damper is included in the state-space representation by a bilinear force-velocity relationship (i.e., bi-viscous model) per the input voltage [2]. Thus, the additional input to the structure-control system is the input voltage (or current) to the dampers. The instant optimal control command (i.e., input voltage) can be determined by the linear quadratic regulator (LQR) algorithm [3]; meanwhile, the state of the structure-control system can be estimated by the Kalman filter, as shown in Figure 1. An example of a single degree-of-freedom structure with an MR damper is provided. In addition, an experimental study is carried out to verify the proposed semi-active control method through hybrid simulation.

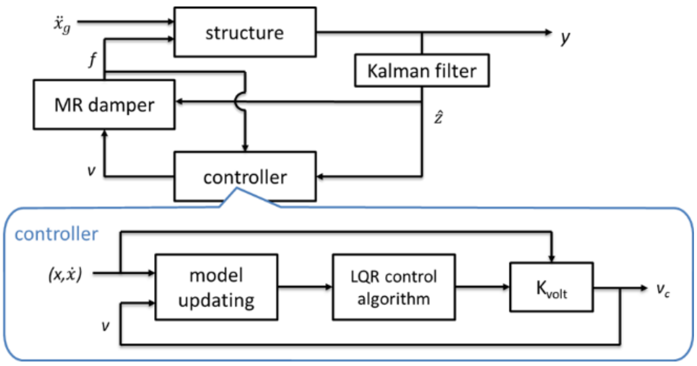

Figure 1: Semi-active control implementation for the proposed control method.

Results and discussion

This study successfully developed and implemented a semi-active control method that considered the control-structure interaction for MR dampers. In the numerical results, the proposed control method achieved similar performance to the clipped-optimal method; still, the input voltage history was more realistic and coherent with seismic excitation. As found in the experimental results, the proposed method was more adaptive than the clipped-optimal method against different levels of earthquakes. This adaptiveness needed less power to drive MR dampers and resulted in better performance for seismic protection of buildings. Moreover, higher energy dissipation was also found in the proposed method.

References

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