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EXTENDED ABSTRACT

Robust Analysis of the Designed Controller Based on the Critically Damped Condition

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Robust control, H_∞ Control, Critically damped condition, Parametric uncertainty, Time delay, Sensor faults, Actuator failure.

1. Introduction

In this research, the robustness of the controller designed based on the critically damped condition (CD) is evaluated against parametric uncertainty, time delay, sensor/actuator faults, and the failure of the actuators. Then, H_∞ robust controllers are designed in different conditions and the results are compared with the CD method. Linear matrix inequalities and Lyapunov theory are used to design the H_∞ controllers, and due to the fact that sparse and large matrices arise in the process of solving, the problem is suboptimally solved. Therefore, Yalmip toolbox and Mosek® solver are used for this purpose.

2. Methodology

The design of the controller based on the critically damped condition and its comparison with the H_∞ method is the aim of this paper. Therefore, first the formulation of the H-infinity problem is performed using linear matrix inequalities and Lyapunov stability, then the obtained inequalities are generalized to the robust analysis of the CD controller. The H_∞ robust controller is designed with the assumption of state feedback and is compared with the CD controller which is based on full velocity feedback. Considering the 3- and 8-story shear structures which are excited with a synthetic earthquake, the effect of each uncertainty such as parametric uncertainty, time delay, sensor/actuator faults, and the failure of the actuator are evaluated. The synthetic earthquake record, which is scaled to 0.35g, is illustrated in Fig. 1.

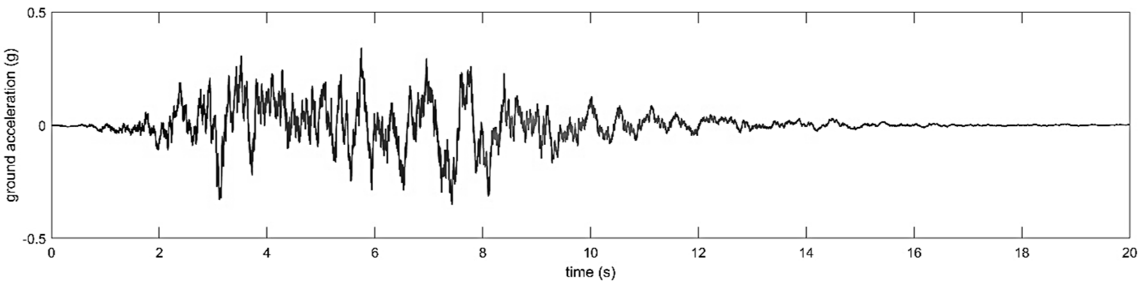

Fig. 1. Synthetic earthquake acceleration time history

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3. Results and discussion

To evaluate the robustness of the CD controller and compare it with the H_∞ controller, two 3- and 8-story shear structures are considered under the vibration of a synthetic earthquake. By examining the presence of parametric uncertainty and time delay in the structures controlled by CD and H_∞ methods, it was shown that the H_∞ controller guarantees a greater allowable time delay. Also, with the increase of the uncertainty of mass, stiffness, and damping parameters, the allowable time delay values of the H_∞ controller have a downward trend. But the allowable time delay values of the CD controller remain constant with the parametric uncertainty increasing the up to 15%. Also, by investigating the simultaneous presence of parametric uncertainties, time delay, and sensor/actuator faults, it was demonstrated that the increase in sensor/actuator faults does not have a negative effect on the allowable time delay values (Fig. 2 & 3).

The investigation of the structural responses represented that the CD controller is more suitable than the H_∞ controller in terms of controlling the acceleration of the structure. It also gives better results when actuators fail in the simultaneous presence of other uncertainties.

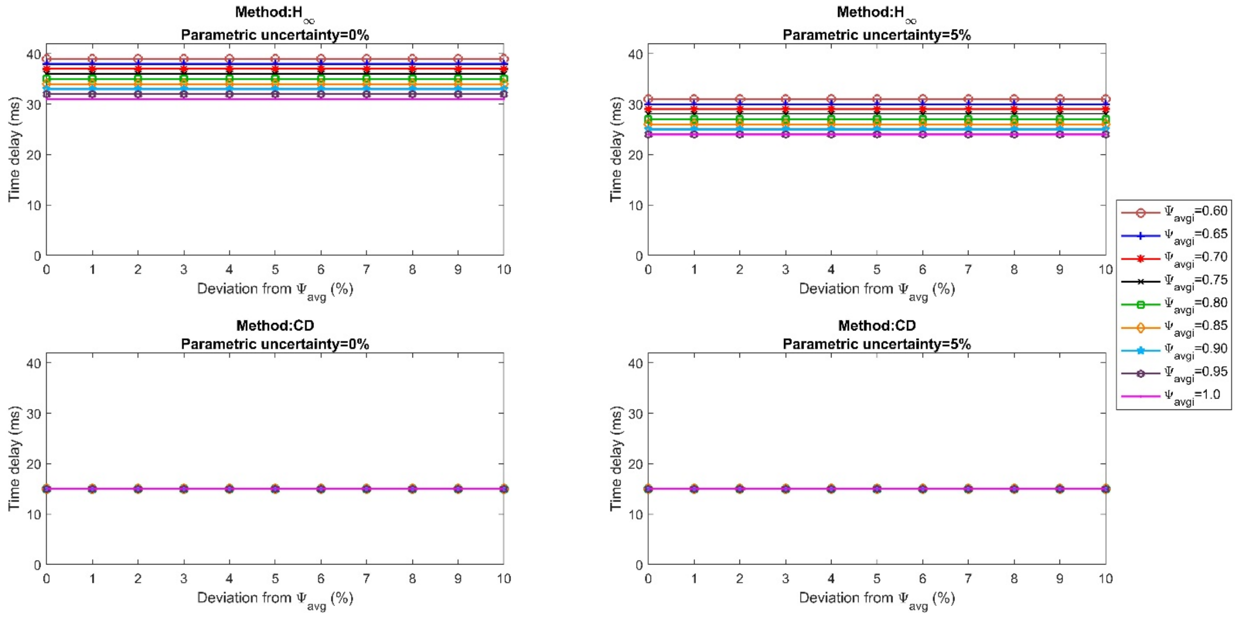

Fig. 2. Allowable time delay in the presence of parametric uncertainty and sensor/actuator error for 3-story shear structure

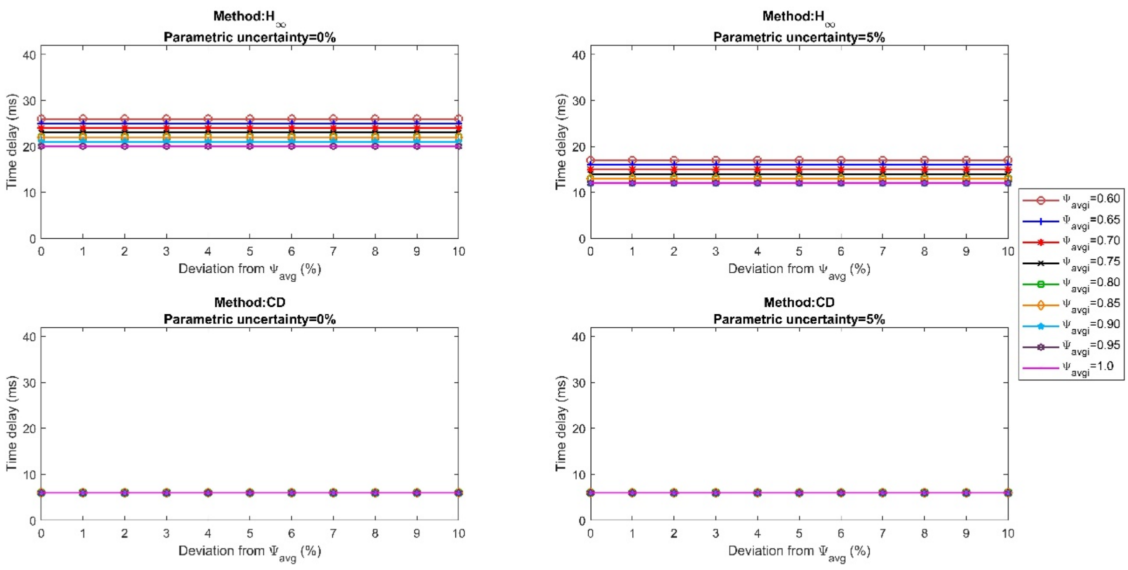

Fig. 3. Allowable time delay in the presence of parametric uncertainty and sensor/actuator error for 8-story shear structure

4. Conclusions

This paper has evaluated the robustness of the controller designed based on the critically damped condition (CD) in the presence of parametric uncertainties, time delay, sensor/actuator faults, and actuator failure. Also, results have compared with the H_∞ controller. Two 3- and 8-story structures excited by a synthetic earthquake were considered as numerical examples to assess the aforementioned controllers. The results showed that the CD controller ensures the stability of the system for a lower time delay compared to the H_∞ controller. On the other hand, it was represented that the allowable time delay of the system is not sensitive to increasing the sensors/actuators faults for the both H_∞ and CD controller in the presence of parametric uncertainty. By investigating the responses of the structure, the performance of the CD controller in acceleration control is evaluated more appropriately.