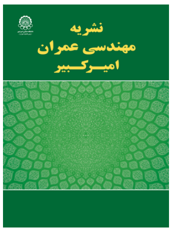

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Developing a Procedure for Simultaneous Vibration Control and Health Monitoring of Structures using Semi-Active Viscous Dampers

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ABSTRACT: Using control devices to enhance system identification and damage detection in a structure requiring both vibration control and structural health monitoring is an interesting yet practical topic. In recent decades several independent research studies have been conducted on the semi-active vibration control and health monitoring of the civil structures subjected to earthquakes, whereas both require similar software. Therefore, where there is a need for both vibration control and health monitoring systems in a building structure, integrating both systems using common equipment would be economical. Application of the viscous dampers for control of buildings, due to their proper seismic performance, lack of significant increase in the structural mass, and least interference with the present situation of the building is rapidly increasing. For this reason, the main goal of this research is to present a new integrated procedure for simultaneous health monitoring and semi-active control of the building structure using the viscous dampers with variable damping coefficients. Next, a scheme is presented for updating the building characteristic matrices and identifying the structural parameters. Finally, according to the updated system matrices, the efficiency of semi-active viscous dampers is investigated. For this purpose, a linear quadratic regulator optimal control algorithm is used for a building subjected to seismic excitations. The results show that the structural parameters are accurately identified; and, at the same time, the building structural vibration is significantly reduced.

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1. Introduction

In recent years, numerous research studies have been reported on the vibration control and health monitoring systems for the structures exposed to environmental disturbances such as earthquakes and wind. Nevertheless, most of them have considered two aspects of such systems independently. Although the implementation of vibration control and health monitoring system for a particular structure requires sensors, a data acquisition system, and a signal transmission system, yet the scope of function of each element differs from others depending on the main purpose persuaded by each of the sub-systems. Should the structure demands for both vibration control and health monitoring systems, the independent approach is way less than enough, both economically and practically, for achieving a smart structure with sensors (nervous system), processors (brain system), and force application jacks (muscular systems). In this respect, we need to present a new methodology for simultaneous vibration control and health monitoring of semi-active viscous damper-retrofitted structures, describing the main idea behind the present research [1, 2].

Previous studies have mostly considered the structural health monitoring simultaneously with the structural control using displacement- or acceleration-dependent dampers, while the current study presents an integrated vibration control and health monitoring system using semi-active (velocity-dependent) viscous dampers [2-9]. As of present, a remarkable research gap is evident when it comes to the combination of structural vibration control by viscous dampers with simultaneous structural health monitoring to make use of the data generated by the health monitoring system to optimize the structural control. Proposed herein, the idea of simultaneous vibration control and health monitoring of structures using semi-active viscous dampers for improving the control algorithm offers numerous advantages, as follows:

1. Application of the control force proportional to the identified damage by the structural health monitoring system,
2. Optimization of the control force applied to the structure,
3. The ability to identify the damage location across the structures equipped with vibration control equipment to make timely decisions for repairing the structure,
4. Optimal location of the control equipment by using the structural health monitoring system,
5. Developing a smart structure.

2. Integrated structural vibration control and health monitoring system

2.1. Vibration control system using a semi-active viscous damper

In an attempt to reduce the earthquake-induced vibrations, one can adopt semi-active and passive viscous dampers incorporated into the bracings of different stories to improve the vibration-induced energy dissipation capacity and hence

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reduce the seismic demand of the structure. Should a semi-active control system be used, one must begin with determining the type, location, and the required number of semi-active dampers for the considered structure [9-11]. To provide the control system with the required feedback information, the sensors, the data acquisition, and signal transmission systems must be designed properly so that the feedback information can be processed based on the control algorithm. Finally, the optimal control signal is dispatched to modify the parameters in such a way to achieve an economically efficient and optimal control force which is supposed to result in maximum reduction of the structural response. In this study, the semi-active viscous damper is used for integrated vibration control and structural health monitoring.

2.2. Structural health monitoring system

To identify the dynamic properties and parameters of the structure and detect possible damages to the structure following severe events or long service life, the systems of sensors, data acquisition, and signal transmission must be designed in such a way to provide the required information for system characterization and damage detection. Most of the existing damage detection techniques are based on vibration (dynamic methods), requiring the system matrix or the structural parameters of the healthy construction (before the incidence of damage), which are sometimes not readily available. Investigating the presented vibration control and structural health monitoring system, one can observe that both subsystems require sensors as well as data acquisition and signal transmission systems. Accordingly, from a practical point of view, simultaneous application of similar sensors and data acquisition and signal transmission systems for the structural health monitoring system is desirable.

2.3. Integrated vibration control and structural health monitoring system

This research aims to present an integrated vibration control and structural health monitoring system to update the model, reduce the seismic response, and detect possible damages through a systematic approach for a construction structure. To this end, the first step is to update the structural mass and stiffness matrices to identify the structural parameters based on increasing the specific stiffness of the semi-active viscous damper and the connected bracing. This model updating step can address the drawbacks of the existing methodologies. In this respect, updating the matrices facilitates the characterization of the existing structural parameters for structural vibration control, thereby providing a baseline for detecting the proceeding damages. The second step is to present a control algorithm for the structures equipped with such a semi-active viscous damper under seismic excitation. The primary goal of performing a quadratic linear optimal control algorithm is to achieve an economically efficient yet reliable control design. The application of this methodology provides for using the sensors simultaneously for structural health monitoring as well as damage detection, leading us toward common-sensor, common-data acquisition, and common-data transmission systems. The final step is to apply the proposed methodology for updating the model in damaged structures in an attempt to characterize the structural parameters of the damaged structure based on a particular stiffness using semi-active viscous dampers.

3. Conclusions

In this study, an integrated methodology was presented for simultaneous vibration control and structural health monitoring using a semi-active viscous damper. To characterize the system, a model updating design based on increasing the semi-active viscous damper parameters was presented considering the physical properties and the connection type of different structural components. For the sake of vibration control, a feedback-based strategy was proposed for the semi-active viscous dampers to attenuate the seismic response of the structure using the same sensors as those contributed to the damage detection system. A damage detection design was proposed, where the proposed system identification method is applied for both the main and damaged structures. The feasibility study and advantages of the proposed integrated system for vibration control and structural health monitoring using a semi-active viscous damper will be investigated numerically in Phase II of this research.

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