DSTA 2021
dys-ta.com
16th INTERNATIONAL CONFERENCE
Dynamical Systems – Theory and Applications
December 6-9, 2021, On-line

Analysis of practical application aspects for an active control strategy to Civil Engineering structures

FIDELIU PAULET-CRAINICEANU[1*], VITALIE FLOREA[2], SEPTIMIU GEORGE LUCA[3], CRISTIAN PASTIA[4], OCTAVIAN VICTOR ROSCA[5]

1. “Gheorghe Asachi” Technical University of Iasi, Romania [0000-0003-2337-4702]
2. “Gheorghe Asachi” Technical University of Iasi, Romania [0000-0002-8060-639X]
3. “Gheorghe Asachi” Technical University of Iasi, Romania [0000-0002-9022-2795]
4. “Gheorghe Asachi” Technical University of Iasi, Romania [0000-0002-6603-1294]
5. “Gheorghe Asachi” Technical University of Iasi, Romania
* Presenting Author

Abstract: Last years have brought the use of information technology in all domains. For Civil Engineering, the Smart City concept, involving the new technologies, is pointing to (among other aspects) the community safety. In this line, a structural active control strategy based on full states LQR optimal control has been relatively recent improved, numerically tested and verified. In order to apply this newer strategy, practical aspects are in the views of the present work: reduced order controller, observer introduction, time delay effects and their consequences on the effectiveness of the control strategy. The numerical simulations are performed on a multi-storey building loaded by strong earthquakes’ recorded accelerations. Using in-house software under Matlab, the seismic response of the structures is simulated and evaluated after introduction of Active Tuned Mass dampers. Time and frequency domain responses are obtained. The viability of the improved strategy involving application of practical considerations is determined and discussed.

Keywords: active control, seismic response, Active Tuned Mass dampers, reduced order controller

1. Introduction

Requirements of already continuous technological revolution, are pointing toward security of urban communities. Civil Engineering plays a major and, in many cases, critical role in assuring the safety of structures’ inhabitants or users. Strong earthquakes and strong winds are between the most stressing loads acting buildings and bridges. Therefore, any technological methods for obtaining a better behaviour to these loads is needed. Passive and active structural control are using devices, as Tuned Mass Dampers (TMDs) and Active Mass Dampers (AMDs), as possible solutions.

Optimal active structural control, in the form of Linear Quadratic Regulator (LQR), have been studied in [1] using a full state strategy. The weighting matrices Q and R had been proposed (based on an energy approach) in a simple manner to just one variable, r, as shown in Equation (1) and where $\mathbf{K}_S$ and $\mathbf{M}_S$ are the structure’s stiffness and mass matrices.

$$\mathbf{Q} = \begin{bmatrix} \mathbf{K}_S & 0 \\ 0 & \mathbf{M}_S \end{bmatrix} = \begin{bmatrix} \mathbf{Q}_1 & 0 \\ 0 & \mathbf{Q}_2 \end{bmatrix}, \mathbf{R} = diag\{r_1 \quad \cdots \quad r_m\} = \mathbf{R} = r\mathbf{I} \quad (1)$$

The methodology in [1] had been relatively recent improved in [2]. It was mathematically shown that the 2n-dimensional Riccati Equation (2)

$$\mathbf{PA} - \mathbf{PBL}_1\mathbf{R}^{-1}\mathbf{L}_1'\mathbf{B}'\mathbf{P} + \mathbf{A}'\mathbf{P} + \mathbf{Q} = \mathbf{0} \tag{2}$$

can be reduced to two one n-dimensional Riccati equations, (3) and (4).

$$\mathbf{P}_{12}\mathbf{A}_{21} - \mathbf{P}_{12}\mathbf{B}_2\mathbf{R}^{-1}\mathbf{B}_2'\mathbf{P}_{21} + \mathbf{A}'_{21}\mathbf{P}_{21} + \mathbf{Q}_1 = \mathbf{0} \tag{3}$$

$$\mathbf{P}_{21} + \mathbf{P}_{22}\mathbf{A}_{22} - \mathbf{P}_{22}\mathbf{B}_2\mathbf{R}^{-1}\mathbf{B}_2'\mathbf{P}_{22} + \mathbf{P}_{12} + \mathbf{A}'_{22}\mathbf{P}_{22} + \mathbf{Q}_2 = \mathbf{0} \tag{4}$$

Equation (3) is a symmetric Riccati equation while the Equation (4) is a non-symmetric one.

2. The methodology and applications

In reference [3], the proposed improved methodology was numerically tested and verified. Typical time response and spectral seismic response are shown in Figure 1 (left and center).

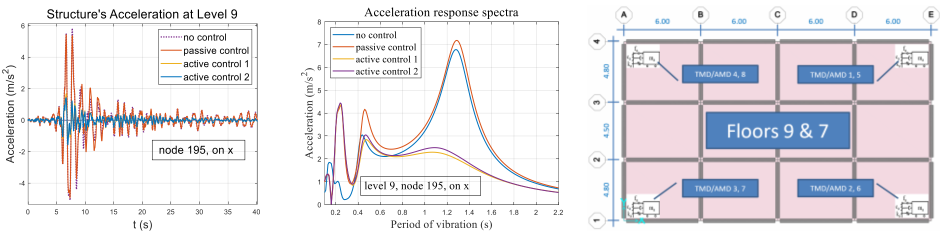

Fig. 1. Left and center: typical time and spectral seismic response; right: plan of TMDs/AMDs locations

The numerical simulations are performed on a multi-storey building loaded by strong earthquakes' recorded accelerations. In Figure 1 (right side), the plan of TMDs/AMDs typical locations on building is presented.

The initial methodology in [1] was used also in [4] for use with reduced order controller, observer and time delay effects. Their consequences on the effectiveness of the control strategy were evaluated. For the present study, the goal is to adapt the improved methodology in [3] for the same practical aspects of implementations.

3. Concluding remarks

Improvements had been made to an optimal active control strategy based on obtaining gain matrix calculations on two half size-dimensional Riccati equations. Results of implementing this new technique are shown. In addition, the extended paper is presenting the details and conclusions of simulations' results when practical aspects (as reduced order controller, observer introduction, time delay) are also implemented.

References

[1] PAULET-CRAINICEANU F: Seismic response control of long cable-stayed bridges. *Proc. the 2nd World Conf. on Structural Control*, Vol. 2, 959-964. John Willey & Sons: Chichester, 1999.

[2] PAULET-CRAINICEANU F, LUCA S-G, PASTIA C, FLOREA V: Improved strategy for optimal control of Civil Engineering structures. *15th Int. Conf. on Computational Civil Engineering*, IOP Conference Series: Materials Science and Engineering, Vol. 586, 1, 1-6 (online). IOP Science: Bristol, 2019.

[3] PAULET-CRAINICEANU F, FLOREA V, PASTIA C, LUCA S G, ROSCA O V: Performance analysis for an improved strategy in optimal control of Civil Engineering structures. *16th Int. Conf. on Computational Civil Engineering*, IOP Science: Bristol, 2021 (in print).

[4] BAKULE L, PAULET-CRAINICEANU F, RODELLAR J, ROSSELL J M: Overlapping Reliable Control for a Cable-Stayed Bridge Benchmark. *IEEE Trans. C.S.T.* 2005, **13**, 4, 663-669.

[5] THE MATHWORKS INC: *Matlab R2021a*, www.mathworks.com. 2021.