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Tuning and shaping semi-active tuned mass dampers for use on high-rise wind excited structures

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Oral presenter

Demetris Demetriou

University of Leeds

Introduction

Semi-active tuned mass dampers (STMD) are control devices that can be used to enhance the vibration mitigation capacity of structures subjected to dynamic loading such as earthquakes and strong winds, enhancing structural safety and occupant comfort. Such devices operate on the basis of online altering their damping and/or stiffness properties for maximum energy dissipation. The manner that these parameters change depends explicitly on the chosen control algorithm which is in a sense the brain of the control system. In this regard, the selection of an appropriate control algorithm becomes an integral part of the control system design process and can indubitably affect to a great extend the vibration attenuation performance of the control system. To date, a large volume of advanced control algorithms has been developed and reviewed for the case of semi-active control (Liedes, 2009), however, a comparison of different control algorithms for the control device (STMD) and the problem specific (high-rise structure) case has yet to be considered.

In this paper, the most famous feedback controllers, namely proportional-integral-derivative (PID), groundhook (both displacement based (DBG) and velocity based (VBG)) and linear-quadratic-regulator (LQR) are examined for the case of wind excited high-rise structures comprising a variable damping STMD, discussing both quantitatively and qualitatively the gains of the use of each control algorithm. It is believed that such an investigation is important so as to direct future research efforts in the most promising directions by providing a frame of reference to both practicing engineers and researchers interested in the area of STMD control of high-rise structures.

Methodology

To illustrate the effectiveness of different controllers at alleviating structural response, the 76-storey wind-excited benchmark structure proposed by Yang et al. (2004) was considered. Three alternatives, namely: passive, semi-active, and active controlled structures that comprise a tuned mass damper (TMD), an STMD and an active mass damper (AMD) respectively were used for the investigation of the relative performance gains of the semi-actively controlled system at different control algorithm configurations (figure 1).

For the fairness of the comparison, particular emphasis was given on the tuning of the damping ratios of the TMD so as to optimize its performance while at the same time not exceed strict device limitation such as maximum stroke etc. On the contrary, the optimum minimum and maximum achievable damping ratios by the STMD were found using the cumulative energy dissipated by the auxiliary device at different damping (min/max) configurations.

Concluding remarks

Through the numerical analyses it was shown that the choice of a control algorithm has considerable effects on the performance of the STMD controlled structure. This is evident by the fact that only two of the semi-active control algorithms managed to bring the system's acceleration response within the allowable limit (<15mg) (Yang et al. 2004). Yet, regardless of the choice of algorithm, the STMD as expected is shown to outperform the purely passive system, achieving behaviour similar to the actively controlled one (figure 2). Some additional interesting findings from the analysis include:

-DBG compared to VBG by default yield a better vibration attenuation performance for a given min/max damping ratio, however the latter algorithms can attain similar performance to the first when the maximum damping ratio of the device is reduced and the mass of the damper is allowed to move further (without exceeding the maximum stroke). Similar observations can be made for the case of PID controlled STMD.

-LQR controllers although being more complex to design (i.e. need of observers, full state feedback) by default yield a better performance compared to the other algorithms. Additionally LQR controllers allow the designer to choose the states to minimise, which implies that more control is obtained in terms of stroke minimization and vibration attenuation at certain locations.

References

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Further information:

Demetris Demetriou (E: cn09dd@leeds.ac.uk)

Konstantinos Daniel Tsavdaridis
(E: k.tsavdaridis@leeds.ac.uk)

Nikolaos Nikitas (E: n.nikitas@leeds.ac.uk)

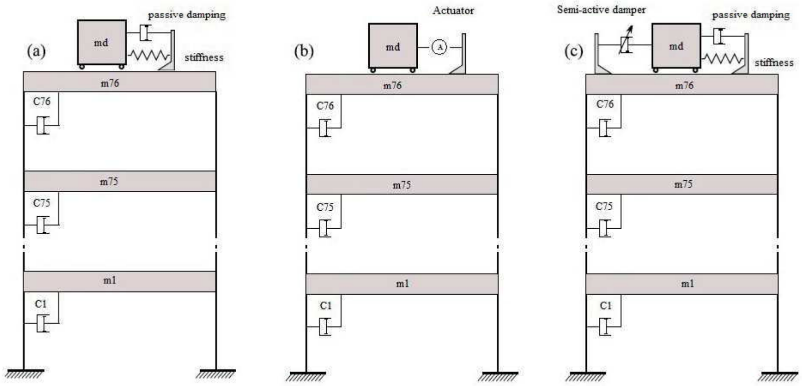

Figure 1. *Structural configurations of the 76-storey building (a) TMD, (b) AMD, (c) VD-STMD*

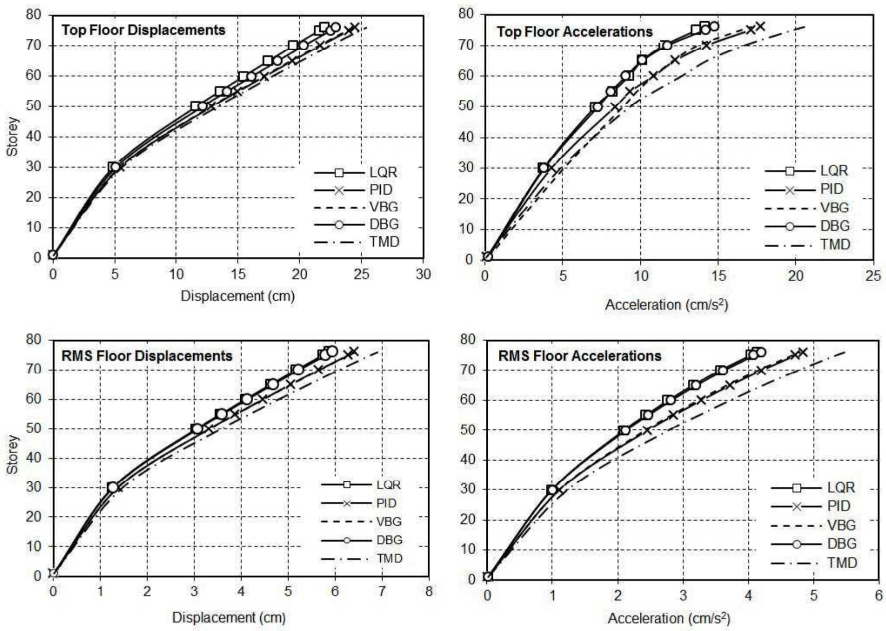

Figure 2. *Peak and RMS response of the STMD equipped structure using different algorithms*