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Analysis and design of multiple tuned mass dampers for flexible structure

Motivation

The multiple tuned mass damper (MTMD) system is a vibration absorb system composed of multiple single tuned mass dampers (TMDs). Compared with a single TMD, MTMDs can be placed not only on the top layer of the structure. MTMDs have been proven to have better robustness and can be tuned to different frequencies at the same time. The prerequisite for MTMD to work effectively is to be placed in a suitable position and to be designed with appropriate damping and stiffness parameters. In this study, the theory of Allen J. Clark and Den Hartog was used to carry out the placement and parameter design of MTMD for four different structures.

Maximum displacement procedure

This is a MTMD placement design process from Allen J. Clark. In this study, dual TMDs design was preformed, the specific steps are:

1. Perform modal analysis on the structure and obtain the modal shapes.
2. Select the maximum antinode amplitude location for the first two modes as the location of the TMD placement.
3. Use Den Hartog's closed form to design the parameter stiffness and damping

Den Hartog' closed form

Den Hartog derived the simplified formula of TMD parameters for single-degree-of-freedom structure design, and Rana verified that it is also applicable to multi-degree-of-freedom structures.

First, the optimum frequency ratio and optimum damping ratio are as follows:

$$f_{\text{opt}} = \frac{1}{1+\mu_i} \qquad \xi_{\text{dopt}} = \sqrt{\frac{3\mu_i}{8(1+\mu_i)}}$$

Then the optimum stiffness and optimum damping can be calculated as:

$$k_{\text{opt}} = f_{\text{opt}}^2 \omega_i^2 m$$

$$c_{\text{opt}} = 2\xi_{\text{dopt}} f_{\text{opt}} m (k_{\text{opt}}/m)^{1/2}$$

Conclusion

- The mass of the TMD had a great influence on its damping effect. The larger the mass of the TMD, the better the damping effect.
- The MTMD system, which was designed according to the maximum displacement method, effectively reduced the vibration response of the structure at different frequencies. The optimized parameters for the TMD calculated according to Den Hartog's closed formula produced effective results.

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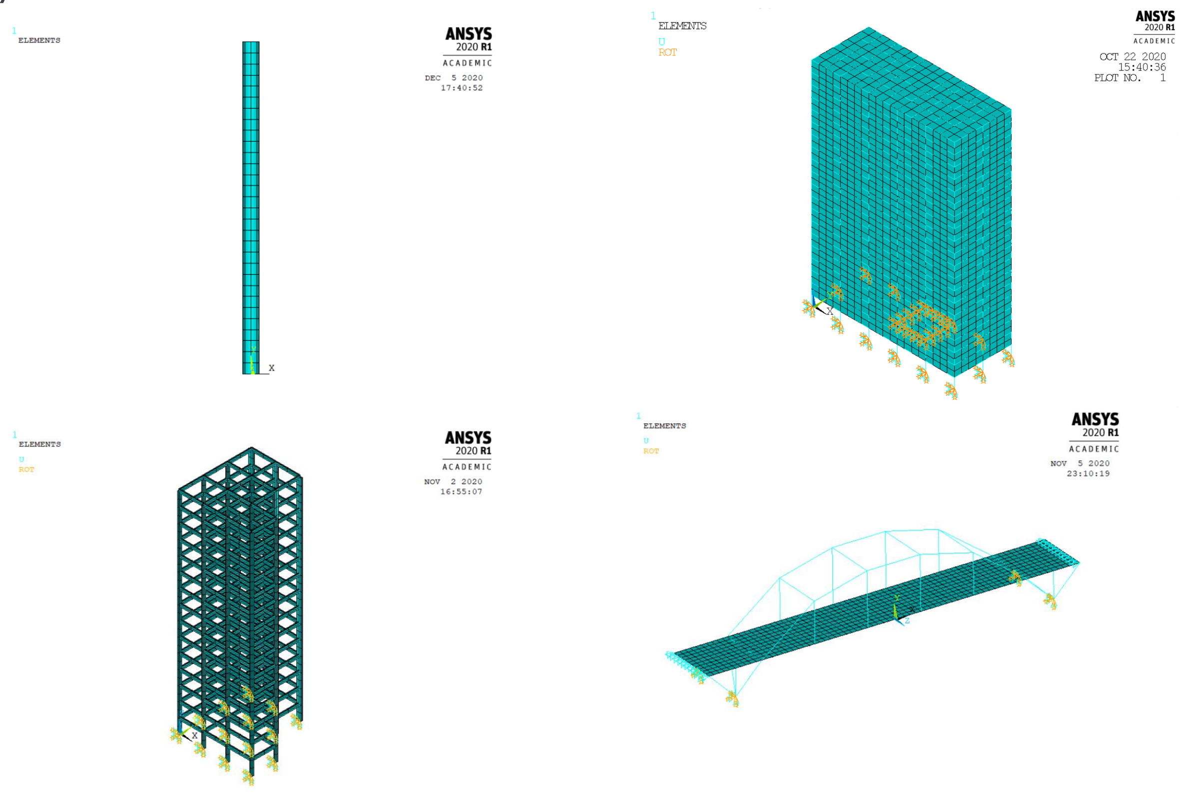
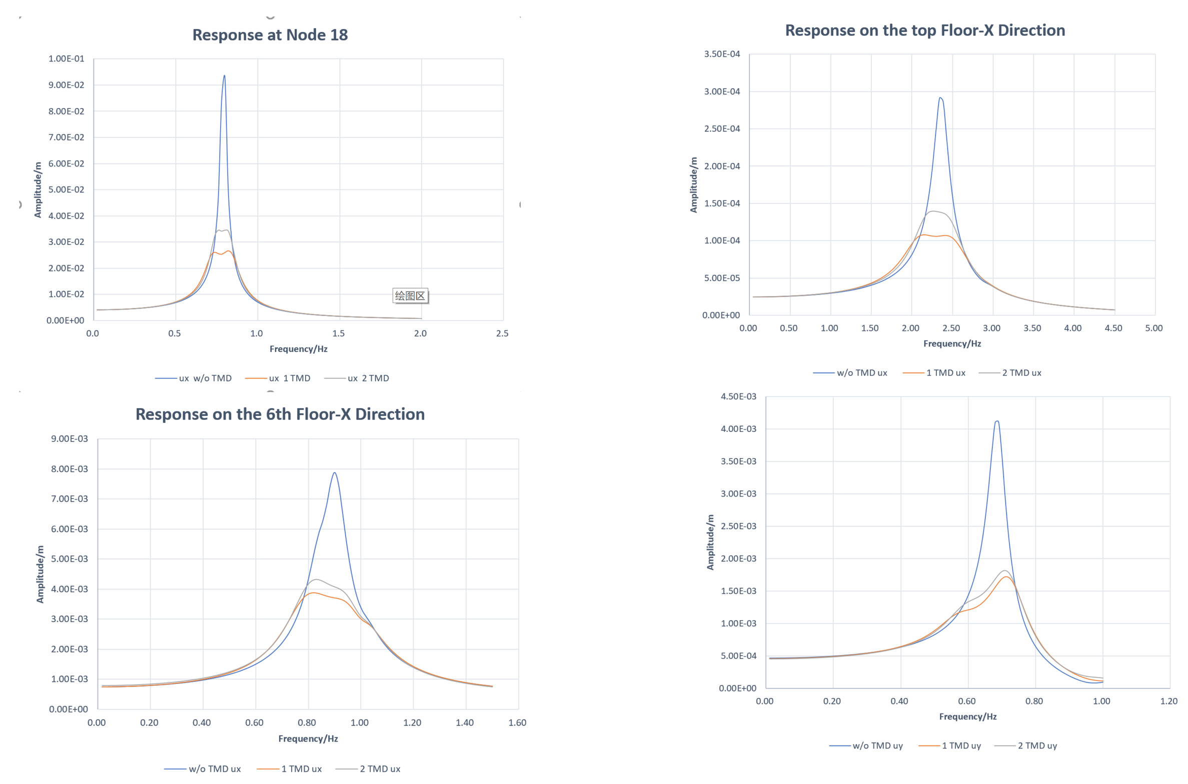
Numerical examples

Four different structures are selected modeled and analyzed in Ansys, the models are as follows:



The frequency-amplitude curve comparison of dual TMDs, single TMD and w/o TMD are shown below:



Literatur

Den Hartog, JP: Mechanical Vibrations,(1956), 87. In: MaGraw-Hill (1956)

Clark, Allen J.: Multiple passive tuned mass dampers for reducing earthquake induced building motion. In: Proceedings of Ninth World Conference on Earthquake Engineering (1988), p. 779–784

Rana, Rahul; Soong, TT: Parametric study and simplified design of tuned mass dampers. In: Engineering structures 20 (1998), No. 3, p. 193–204

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