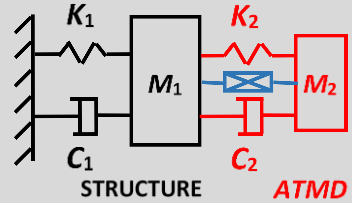
Active Tuned Mass Dampers

A passive tuned mass damper (TMD) is made-up of an inertia element (mass) suspended by an energy dissipating (damping) device and a restoring (resilient) element. The size of a TMD is characterized by its mass ratio of M2/M1.

The effectiveness of a TMD can be enhanced by addition of an active element, e.g., a linear actuator, into its make-up transforming it into an ***active TMD (ATMD)***.



The extent of vibration energy that a passive TMD dissipates as well as its effective frequency range (bandwidth) increase with increase in the mass ratio of the TMD. In addition, the amount of internal damping built into the make-up of a passive TMD increases with the size of that TMD.

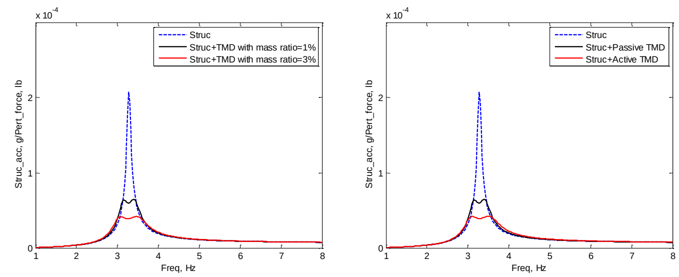
The TMDs used in very large structures, such as tall buildings, have very small mass ratios (mostly less than 1%) and correspondingly small damping ratios. The small size of their inertia elements limits their effectiveness and their low internal damping increases their excursion (their motion relative to the structure) especially when the structure is subject to high levels of perturbations. Moreover, such TMDs have a rather narrow bandwidth making their energy dissipation effectiveness highly sensitive to their tuning accuracy. Due to the change, over time, in the natural frequencies of a structure caused by deterioration, remodeling, etc. such TMDs are most likely in need of periodic re-tuning.

Note that in a tall building, a TMD with the small mass ratio of 1% becomes excessively large and massive weighting hundreds of Tons. Accommodating such massive TMD in the top floors and even supporting its weight could become a challenge.

When increasing the mass ratio of a passive TMD is not an option, an active TMD (ATMD) becomes an attractive alternative. An ATMD can provide as much damping, using a smaller mass, as an optimally designed passive TMD with substantially larger mass. This is of interest when the vibrating structure, e.g., a high-rise building, cannot support the weight of a massive passive TMD.

Figure 1 compares the frequency response functions (FRFs) of a structure without (the blue traces) and with two different passive TMDs with 1% and 3% mass ratios (black and red traces in Figure 1-a) as well as a passive and an active TMDs both with 1% mass ratios (black and red traces in Figure 1-b). Figure 1(a) shows that the larger passive TMD (the black trace) has substantially larger damping effectiveness than the smaller passive TMD (the red trace). Moreover, comparison of the red traces in Figures 1(a) and 1(b) shows that the active small TMD is as effective as the passive TND three times more massive.

An ATMD can be configured to remain passive and only engage the active feature when the structural vibration exceeds a certain pre-specified threshold.



(a) (b)

Figure 1 FRFs mapping the perturbation on the structure to the acceleration of the structure, without and with passive and active TMDs

Figure 2 compares the excursions of a passive TMD and an active one with the same mass ratios. Comparison of the two traces in Figure 2 indicates that the improvement in damping effectiveness of an ATMD over a passive TMD of equal mass ratio, is achieved without excessive increase in its relative motion (excursion).

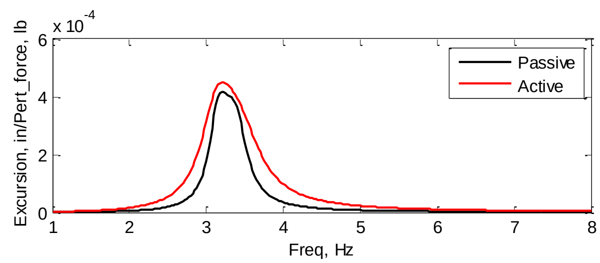


Figure 2 FRFs mapping the perturbation on the structure to the excursions of passive TMD (black) and active TMD (red)

An ATMD can also be tuned to more than one frequency eliminating the need for using multiple TMDs tuned to multiple frequencies. Figure 3 depict the FRFs of a structure without (blue trace) and with (red trace) an ATMD tuned to four frequencies.

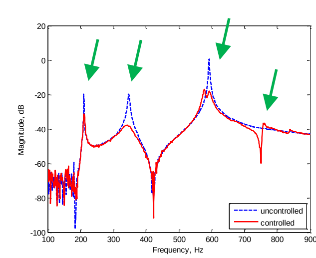


Figure 3 Multi-frequency tuning of an ATMD

A low-bandwidth (slow) supervisory scheme can also be programmed into the ATMD controller to automatically readjust the parameters of the ATMD so that it (the ATMD) stays optimally tuned.

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