Passive and Active Pendulum Tuned Mass Dampers

Tuned mass dampers (TMDs) are tuned damping devices commonly used for dampening the vibration of a structure at a particular resonant frequency. TMDs come in various configurations. The commonality between all of them is their make-up which includes an inertia element (mass) suspended by an energy dissipating (damping) device and a restoring (resilient) element.

Pendulum tuned mass dampers (PTMDs) are commonly used in adding damping to tall structures, including high-rise buildings, control and communication towers, stacks, etc. These multi-directional TMDs, which are made up of mass blocks suspended by steel cables or rods, can readily be tuned to the very low natural frequencies associated with the primary modes of tall structures. The length of the pendulum sets the tuning frequency of these TMDs, which could be many meters when the TMDs are tuned to very low frequencies. When there is not enough head room to accommodate a PTMD with simple pendulum configuration, compound (folded) pendulum configuration can be used.

Dynamic wind forces due to turbulence and vortex shedding cause tall structures to vibrate in cross-wind, along-wind, and torsional directions. Excessive vibration, especially at higher elevations of high-rise buildings and other tall structures (such as air traffic control towers, communication towers, steel stacks, etc.), can occur when the shedding frequency (which depends on the wind speed and the geometry of the structure) coincides with the primary structural natural frequencies.

Broadband damping schemes such as viscoelastic and viscous have been used to increase the damping of structures. Such damping mechanisms are commonly installed between two components of the structure, e.g., as braces between two consecutive floors in a high-rise. The small deflections, i.e., relative motion between the two ends, of these dampers limit their effectiveness necessitating the use of a large number of such dampers to introduce enough damping into the structure.

Pendulum tuned mass dampers (TMDs) targeting the primary modes of tall structures are used as an alternative to multiple broadband dampers.

The tuning frequency of the PTMD can be re-adjusted in the field by changing the pendulum suspended length. This is accomplished by changing the pivot point of the suspended mass using a sliding clamp or by changing the height along the auxiliary mass where the cable connects. Alternatively, an upper tuning frame can be incorporated into the make-up of the PTMD, the motorized raising or lowering of which re-adjusts the tuning frequency.

Energy dissipation in pendulum TMDs is commonly provided by viscous dampers which are attached to the mass at one end and to the vibrating structure at the other. Figure 1 depicts a pendulum TMD, suspended by 6 cables. Six viscous dampers provide the required energy dissipation.

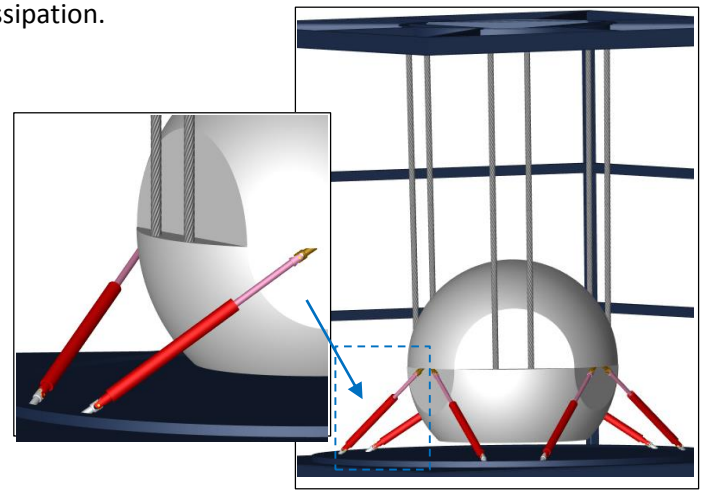

Figure 1 A pendulum tuned mass damper (PTMD)

To prevent the excessive motion of the mass, hydraulic snubbers are built into the design of pendulum tuned mass dampers.

Active PTMDs (APTMDs) are realized by using hydraulic actuators in place of (or in conjunction with) viscous dampers. Depending on how an Active PTMD is controlled, they can either

a) be tuned to different frequencies in different directions and as such eliminate the need for using multiple TMDs tuned to multiple frequencies or
b) provide
    I. higher damping effectiveness than an equally sized passive PTMD, or
    II. 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., the high-rise, cannot support the weight of a massive passive PTMD.

In addition to the above listed control strategies, a low bandwidth (slow) supervisory control scheme continuously readjusts the parameters of the APTMDs so that they are always optimally tuned.