Chapter 7

Tuned Liquid Column Gas Damper in Structural Control:

The Salient Features of a General Purpose Damping Device and its Application in Buildings, Bridges, and Dams

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ABSTRACT

Tuned liquid column damper (TLCD) show excellent energy and vibration absorbing capabilities appropriate for applications in wind- and earthquake engineering. The objective of this chapter is to demonstrate the outstanding features of the proposed Tuned Liquid Column Gas Damper (TLCGD) and present its wide spectrum of applications of three design alternatives. Among others it includes base isolation of structures, applications to lightly damped asymmetric buildings and other vibration prone structures like bridges (even under traffic loads) and large arch-dams as well as simple, ready to use design guidelines for optimal absorber placement and tuning. The evident features of TLCGDs are no moving mechanical parts, cheap and easy implementation into civil engineering structures, simple modification of the natural frequency and even of the damping properties, low maintenance costs, little additional weight in those cases where a water reservoir is required, e.g., for the sake of fire fighting, and a performance comparable to that of TMDs of the spring-mass- (or pendulum-)-dashpot type.

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INTRODUCTION

The basic idea of most vibration reducing devices is the absorption of vibrational energy, thereby reducing the ductility demand of the main structure and thus preventing it from serious structural damage. A well accepted damping principle is the transfer of energy from critical building vibration modes to dynamic damping devices which are designed to absorb and dissipate energy to protect a structure from excessive dynamic loads. This method of energy dissipation incorporates dynamic absorber like tuned mass damper (TMD), tuned liquid damper (TLD also called sloshing motion damper) or tuned liquid column damper (TLCD). A different concept is to prevent the accumulation of seismic energy by uncoupling the structure-base and the surrounding soil by base isolation elements. This type of earthquake protection is very effective because it reduces the energy dissipation demand of the higher structural vibration modes. If base isolation is combined with other earthquake defending measures a high level of protection can be achieved.

Besides base isolation, probably the most commonly used passive device is the tuned mass damper, which consists of a mass attached to the vibrating structure through a spring and a dashpot. TMD have been applied successfully in symmetric high raised buildings where the motion of a single mass can be used to absorb two bending and a torsional motion. However, it is difficult to guarantee a smooth, frictionless motion for huge masses, and in order to avoid the application of hydrodynamic bearings or friction compensating actuators the mass is often suspended vertically on cables, thereby forming a pendulum type mass damper which is used in high raise buildings, e.g. the Taipei 101 tower. Pendulum type absorbers represent the ideal alternative to TMD of spring-mass-dashpot type when considering symmetric high raised buildings.

For other applications TLD are optimal, e.g. to suppress wind induced vibrations of smokestacks or wind turbines, but they suffer from difficult tuning, variable damping and a comparatively low active mass. Tuned liquid column damper (TLCD) overcome these drawbacks by a controlled and guided liquid motion in a rigid piping system. Originally developed to reduce the rolling motion of ships, they were first proposed for civil engineering structures about 20 years ago. The working principle is to transfer structural vibration energy into a liquid movement and dissipate it by viscous and turbulent damping. Since the restoring forces are due to gravity, the extremely low natural frequencies in real size applications are in the range of about 0.1 - 0.5Hz. Although this excellent low frequency characteristic might be feasible for very large structures, the invention of the modified tuned liquid column gas damper (TLCGD) expands the possible field of applications to structures with critical natural frequencies, say up to 5Hz, see Hochrainer (2001). The classic TLCD is closely related to the TMD of pendulum type: both are only applicable for structures with extremely low natural frequencies (high raised buildings) and the restoring forces are due to gravity only. The main advantages of TLCGD include comparably low installation costs, easy application to new buildings or in retrofitting existing structures, a simple tuning mechanism which allows for adaptation to modified (degraded) building dynamics, no moving mechanical parts, virtually no maintenance requirements and little additional weight in those cases where a water reservoir is required, e.g. for the sake of firefighting.

TLCD have shown to be effective in reducing structural vibrations in recent years and the research work of the last decade has culminated in simple guidelines for optimal placement and tuning of the TLCD. So far, all research results indicate that the TLCD is competitive when compared to TMD (spring-mass-dashpot type) and it could replace the TMD in many structural application. Due to their salient features, TLCD have caused an increased research interest, resulting in both, analytical and experimental analyses.

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