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Earthquake vibration control of structures using hybrid mass liquid damper

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ABSTRACT

A tuned liquid damper (TLD) is a passive vibration control device consisting of a rigid tank filled with water that relies on the sloshing of water inside it to dissipate energy. In a standard TLD configuration the TLD is connected rigidly to the top of the building structure. Earlier research has shown that the TLD is more effective when its base acceleration amplitude is larger, as it dissipates more energy through increased sloshing. This characteristic has been utilized to design this alternate TLD configuration. In this alternate TLD configuration, the TLD is rigidly attached to a secondary mass that is attached to the primary structure through a spring system. This alternate configuration is, thus, defined as a hybrid mass liquid damper (HMLD). For particular values of the secondary spring's flexibility, the motion of the secondary structure is in phase with that of the primary structure and the TLD base is subjected to a large amplitude acceleration that increases its effectiveness. It should be noted that when the secondary spring is rigid, the alternate and standard TLD configurations are identical for very small values of the secondary mass. It is seen that, for a given structure with HMLD there exists an optimum value of the secondary spring's stiffness for which the HMLD effectiveness is maximum. An optimally designed HMLD configuration is shown to be more effective as a control device than the standard TLD configuration for both harmonic and broad-band earthquake motions.

1. Introduction

Research over the past few years has focused substantial attention on liquid dampers for controlling the earthquake response of structures. A tuned liquid damper (TLD) is one such device that has been studied to reduce vibrations of buildings subjected to wind and earthquakes. The TLD is essentially a rigid rectangular or cylindrical liquid container which is rigidly connected to the top of a structure. The liquid, in general, is water. It is a passive vibration control device which, when the fundamental sloshing frequency is tuned to the structure frequency, can reduce structural vibrations by the energy dissipation caused by sloshing of liquid inside the tank. TLDs are potentially attractive because of inherent advantages, such as lower cost, easy handling and few maintenance requirements, and have attracted increasing research interest in recent years. Many experimental and numerical research studies [1–6] were done over the past few years to illustrate the effectiveness of a TLD as a vibration control device for structures subjected to both harmonic and broad-band base excitations. Research [7,8] has been done to study the application of rectangular liquid dampers to reduce the vibration of multi-degree of freedom structures. In the past many researchers have also conducted experimental and analytical studies to improve the effectiveness of TLD. Chang et al. [9] designed a mechanism to actively control the tuning of the system by adjusting the length of the liquid tank with rotatable baffles to enhance the effectiveness of the device over a wide range of excitation frequencies. Tamura et al. [10] used floating particles in a TLD and observed that their presence improves the damper's efficiency. In order to increase the energy dissipation, Modi and Munshi [11] introduced a semicircular obstacle in the damper to accelerate and enhance the liquid sloshing. Gardarsson et al. [12] experimentally investigated the performance of a sloped bottom TLD. Modi and Akinturk [13] introduced of two identical wedges within the damper for improving the efficiency of a rectangular damper. Warnitchai and Pinkaew [14] carried out an investigation to increase the dissipation rate of sloshing energy with flow-dampening devices. Tait and co-researchers [15,16] investigated the sloshing fluid of a TLD equipped with damping screens. In all these cases the main intention was to increase energy dissipation inside the TLD to improve its effectiveness. Very recently, Samanta and Banerji [17] investigated a modified TLD configuration to improve the effectiveness of TLDs.

In the present investigation, an alternate TLD configuration has been proposed. The TLD is known to dissipate more energy when water sloshing is greater, which happens when the TLD base is subjected to a larger amplitude motion. This characteristic has been utilized to design the alternate TLD configuration, in which the TLD, instead of being rigidly connected to the structure,

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