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Modified liquid column damper for vibration control of structures

K.A. Al-Saif [a,b,*], K.A. Aldakkan [b], M.A. Foda [a]

[a] Mechanical Engineering Department, College of Engineering, King Saud University, P. O. Box 800, Riyadh 11421, Saudi Arabia
[b] King Abdulaziz City for Science and Technology, National Robotics and Intelligent Systems Center, P. O. Box 6080, Riyadh 11422, Saudi Arabia

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ABSTRACT

A modified version of the traditional tuned liquid column damper (TLCD) absorber is proposed as a passive vibration control device for structures vibrating at low frequencies. This new version, denoted as tuned liquid column ball damper (TLCBD), is equipped with a coated steel ball, in place of the orifice in TLCD, immersed inside the horizontal column of the damper. The current study examines the performance of TLCBD for a harmonic excitation which is a simplified model for the vortex shedding forces on structures in the cross wind direction. A parametric study to investigate the effect of the ball size and absorber mass on the suppression capacity is carried out. The absorber damping characteristics is identified experimentally using a single point laser vibrometer system and the measured damping factor is used in the mathematical model. Intensive numerical simulations were conduced and the results are compared with the traditional TLCD with optimum parameters. The results revealed an improvement of the vibration suppression capability of the proposed version that exceeds around 66% reduction.

1. Introduction

The use of light-weight, high strength materials and advanced construction techniques in the erection of high rise buildings and towers have led to increasingly flexible and lightly damped structures. These structures are very sensitive to environmental excitations such as wind and earthquakes, which cause unwanted vibrations resulting in occupant discomfort and possible structural failure. Hence it has become important to search for effective and practical devices for suppression of these vibrations. Among these devices is the tuned liquid column damper (TLCD), which initially was proposed by Sakai and his co-authors [1]. It consists of a U-shaped tube, filled with liquid, preferably water. At the center of the horizontal section of the tube an orifice exists, which causes energy dissipation in the vibration of the liquid. Since the TLCD was introduced, many analytical and experimental works are conducted aiming to assess its effectiveness and to find its optimal design parameters. In addition, many improvement ideas for the TLCDs have been proposed. Felixa et al. [2] motivated by the works of Yalla and Kareem [3,4], presented a numerical analysis of a vibration control liquid column damper that was mounted on a structural frame under excitation of an unbalanced DC motor. Ghosh and Basu [5] proposed a modified version of the LCD by connecting the LCD to the primary structure through spring-damper system as a passive vibration control of stiff structures subjected to earthquake excitations. Haroun and Pires [6] have introduced a hybrid liquid column damper which works by maintaining an optimal damping condition using a variable orifice in the tuned liquid column damper. Yalla et al. [7] utilized a semi-active suppression system that consists of an electro-pneumatic actuator driving a control valve to change the cross section of a tuned liquid damper, thus adjusting the properties of the damper. Ying et al. [8] developed a semi-active optimal control method for non-linear multi-degree-of-freedom systems based on the dynamical programming principle, statistical linearization method and variational principle. This method was applied to a tall building structure with magneto-rheological-tuned liquid column damper (MR-TLCD) for random wind response reduction. Wang et al. [9] devised a semi-active tuned liquid column damper with the use of magneto-rheological fluid (MR) to mitigate vibration of a tall building. The MR fluid can reversibly change from a free-flowing linear viscous fluid to a semi-solid when exposed to a magnetic field. Therefore the TLCD has alterable fluid viscosity which results in adjustable and control damping forces. Lee et al. [10] investigated the vibration mitigation of a tension leg offshore platform system when incorporated with the TLCD device and subjected to surge wave motion. Chaiviriyawong et al. [11] simulated the induced velocity distribution of the fluid inside a liquid column damper using the numerical potential-flow method aiming to estimate the effective length of liquid dampers, hence the natural frequency. The experimental and theoretical works conducted by

* Corresponding author at: Mechanical Engineering Department, College of Engineering, King Saud University, P. O. Box 800, Riyadh 11421, Saudi Arabia. Tel.: +966504488828; fax: +96614676652.
E-mail address: alsaif@ksu.edu.sa (K.A. Al-Saif).

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