LIQUID DAMPERS FOR MITIGATION OF STRUCTURAL RESPONSE: THEORETICAL DEVELOPMENT AND EXPERIMENTAL VALIDATION

A Dissertation

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by

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Abstract

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The current trend toward structures of increasing heights and the use of light-weight, high strength materials and advanced construction techniques has led to more flexible and lightly damped structures. Understandably, these structures are very sensitive to environmental excitations such as wind, ocean waves and earthquakes, leading to vibrations inducing possible structural failure, occupant discomfort, and malfunction of elevators and equipment. Hence, it has made it critical to search for practical and effective devices to suppress these vibrations.

The most commonly used passive device is the Tuned Mass Damper (TMD), which is based on the inertial secondary system principle. A Tuned Liquid Damper (TLD) is a special class of TMD where the mass is replaced by liquid (usually water). Tuned liquid column dampers (TLCDs) are a special type of TLDs that rely on the motion of a liquid column in a U-tube-like container to counteract the forces acting on the structure, with damping introduced through a valve/orifice in the liquid passage.

The thrust of this dissertation is to study and develop the next generation of liquid dampers for mitigation of structural response. New modeling insights into the sloshing

phenomenon, which incorporate the effect of the liquid slamming/impact on the container walls, are presented through experimental and analytical studies. The mechanical modeling of TLDs is developed using a Sloshing-Slamming (S^2) analogy and the use of impact characteristics functions which can describe with high fidelity the phenomenological behavior of the damper. A major focus of this study is the design and development of semi-active control systems which maintain the optimal damping level under different loading conditions. Experimental validation of such a system was performed in the laboratory using a prototype TLCD equipped with a valve controlled by an electro-pneumatic actuator and positioning system. Finally, the design, implementation, cost and risk-based decision analysis for the implementation of liquid dampers in structural vibration control is presented.

DEDICATION

This work is dedicated to my parents who instilled in me the value of learning.

न चोरह्यार्यं न च राजह्यार्यं न भ्रातृभाज्यं न च भारकारि ।
व्यये कृते वर्धत एव नित्यं विद्याधनं सर्वधनप्रधानं ।

It cannot be stolen by thieves, Nor can it be taken away by kings.

It cannot be divided among brothers and..

It does not cause a load on your shoulders.

If spent.. It indeed always keeps growing.

The wealth of knowledge..

Is the most superior wealth of all!