PARAMETRIC RESONANCE IN TUNED LIQUID COLUMN DAMPERS: AN EXPERIMENTAL INVESTIGATION

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Tuned liquid column dampers (TLCDs) are innovative vibration absorbing devices in the low frequency range, which have been studied extensively in the last decade, see e.g. Hochrainer [1]. Most research work focuses on the suppression of horizontal motions of structures, but there is still a demand to investigate the influence of vertical motions on the damping behavior of TLCDs, especially if the absorber is attached to earthquake excited buildings or long span bridges. For insufficient modeling in the latter case see Xue [2] et al. When considering vertical motions the TLCD dynamics becomes nonlinear and quite sensitive to parametric resonance. Consequently an unstable system might result that endangers the main structure. A mechanical model of a TLCD under horizontal and vertical excitation has been designed and analyzed numerically and experimentally. For this sake, a small-scale testing facility has been constructed in the laboratory of Structural Dynamics of the TU-Institute, shown in Figure 1.

The testing facility's main structure is a plane pendulum, which consists of two rigid bars, an upper and a lower one, made of aluminum. These bars are connected by two pairs of hangers made of aluminum with rectangular cross section. A set of roller bearings is placed at each joint in order to achieve a small damping coefficient of the structural model. The upper rigid bar is carried on a base framework, connected with a set of guiding Thomson bearings. The latter show negligible friction and due to vertical

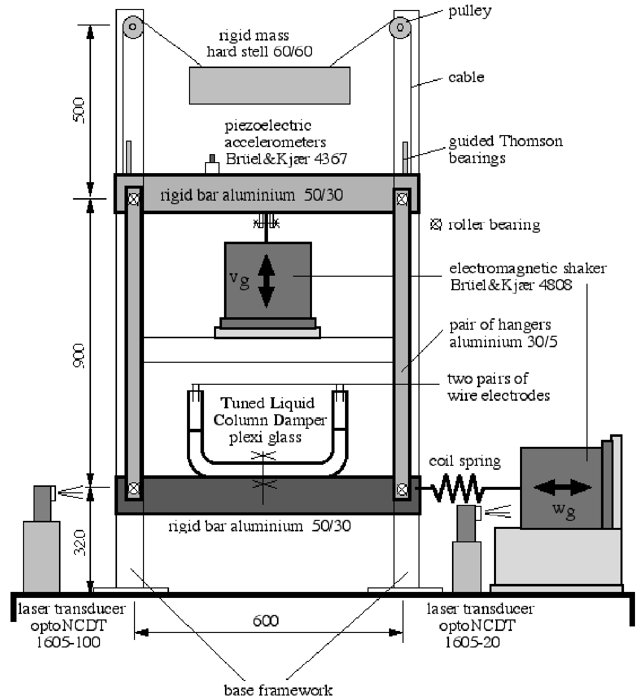

Figure 1: Small-scale testing facility

disposition of the bearings the upper bar is constrained to a vertical translational motion. One end of the lower bar is linked to an actuator, an electromagnetic shaker of Bruel&Kjaer Type 4808, through a coil spring with defined stiffness. Additionally, a second electromagnetic shaker of Bruel&Kjaer Type 4808, whose stroke amplitude is magnified by a simple lever construction, excites the upper bar vertically. Both shakers excite the structural model horizontally and vertically by time-harmonic signals provided by the software LabVIEW 3.1.1. In order to reduce the dynamic vertical forces, the structural model mass is counter-balanced by a pulley mechanism. Both the horizontal excitation acceleration and the response acceleration of the lower bar are measured by means of laser transducers, Type optoNCDT 1605. The vertical excitation acceleration is measured by means of a piezoelectric accelerometer, Bruel&Kjaer Type 4367. All measured signals are recorded by means of the software BEAM through the board of the Digital Amplifier System DMCplus (Hottinger Baldwin Messtechnik, HBM).

The TLCD made of a plexi glass pipe with rectangular cross-section, is fixed on top of the lower bar. The principle of TLCDs relies on the motion of a liquid mass in a tube-like container to counteract the external motion while a built-in orifice plate induces damping forces that dissipate kinetic energy, see Figure 2.

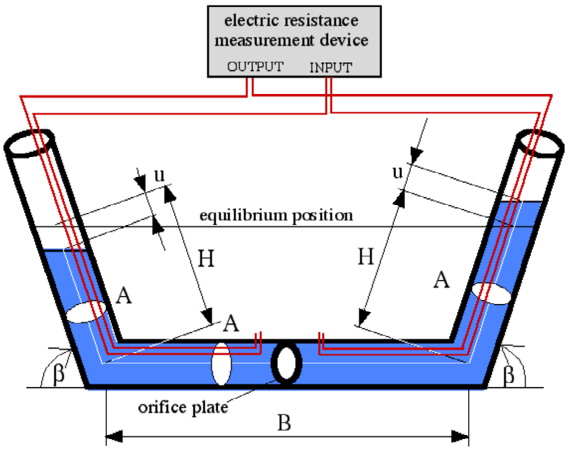

Figure 2: TLCD with moving liquid mass

For the sake of measuring the liquid surface displacement inside the TLCD a new electronic resistance measurement device has been developed by the authors. For this sake, the piping system is equipped with two pairs of wire electrodes, shown in Figure 2, whose resistance depends on the water level inside the pipe. To compensate several nonlinearities, the electrodes are in series connection for the actual resistance measurements. For further processing, the electronic signal is band-pass-filtered, in order to reduce the static drift and the high frequency noise. The measured signal is recorded by means of the software BEAM, whereby the measured changing of resistance is transformed into the equivalent displacement by means of a nonlinear transfer function, obtained by calibration of the TLCD.

The experimental results are compared with those derived by computational simulations. The substructure method is used for deriving the equations of motion for the TLCD/primary structure coupled system. In a first step, the modified Bernoulli equation along the relative non-stationary streamline in the moving frame, see Ziegler [3], is applied to the separated, horizontally and vertically floor excited TLCD. Having established the equation of motion for the TLCD, in a second step, the free body diagram of the primary system is considered under two component base motion, whereby the reaction forces from the TLCD are applied to the primary system. Using the conservation of momentum yields the second equation of motion for the coupled system. For example, Figure 3 shows the experimentally and, in comparison, the numerically derived results of frequency response functions.

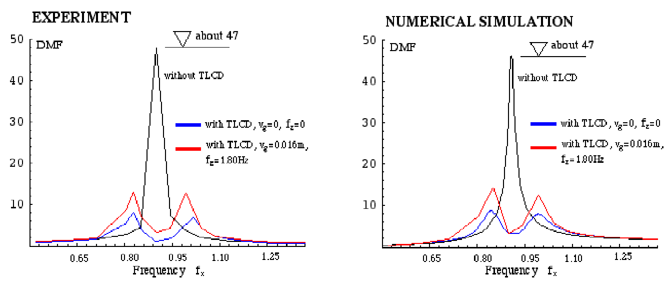

Figure 3: Frequency response function

In the particular investigations experimentally and numerically derived results are in excellent agreement. Experimental small-scale model investigations are cheap when compared to full-scale tests, and hence, mechanical models for numerical analyses can be verified easily.

References

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