Using a tuned fluid inerter for improving the seismic performance of structures isolated with friction pendulum system

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Abstract

The fluid inerter is the hydraulic realization of the inerter. It consists of a piston-cylinder device that conveys a fluid through an external helical channel, thereby generating rotational inertia of a fluid mass. Unlike other variants of the inerter (e.g. ball screw, rack-and-pinion inerter, and inerter with clutch), the assumption of linear behavior for the fluid inerter is largely inaccurate, because this device is characterized by a marked nonlinear damping effect. While identification and modeling of the fluid inerter were discussed in the relevant literature, the effect of its nonlinear damping contribution in relationship to structural vibration control remains unclear. Aim of this contribution is to present a feasibility study in which the nonlinear damping contribution of the fluid inerter is examined numerically. Some experimental findings relevant to a small-scale prototype of fluid inerter justify the assumption of nonlinear power law damping, in parallel with linear inertance. The fluid inerter is here employed in combination with low-damping rubber isolators as linear restoring terms, thus realizing a novel control scheme called Tuned Fluid Inerter (TFI). In this paper, the TFI is adopted to improve the seismic performance of isolated buildings. Optimal parameters of the fluid inerter are determined using random vibration theory, by modeling the base acceleration as a zero-mean Kanai-Tajimi stationary random process, and resorting to statistical linearization to handle the nonlinear terms. The seismic performance of structures equipped with friction pendulum system (FPS) is comparatively analyzed considering a classical Tuned Mass Damper (TMD), the Tuned Mass Damper Inerter (TMDI) with mechanical inerter, and the novel TFI. Based on a benchmark six-story building, the seismic performance of the various structural control systems is analyzed in terms of isolators' displacement demand, interstory drift and acceleration response. It is shown that the effect of the inherent nonlinear damping of the fluid inerter is crucial for reducing the peak response under pulse-like ground motions that may occur in near-field earthquake events.