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A novel horizontal universal viscous damping amplification device and seismic response analysis

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ABSTRACT

The application of damping amplification technology to dampers can effectively enhance the energy dissipation efficiency and address the issue of underutilization during small displacements. In this study, a novel horizontal universal damping amplification device (HUDAD) is proposed, and its construction and operational mechanism are detailed. A restoring-force model for the horizontal universal viscous damping amplification device (HUDAD-VD) is derived, which integrates viscous dampers, establishing its equations of motion and energy balance. Furthermore, pseudo-static tests are conducted to validate the damping amplification and energy dissipation capabilities of the HUDAD-VD. Finally, a seismic response analysis of a multi-degree-of-freedom damping system incorporating the HUDAD-VD is performed to evaluate its seismic performance. The results show the close alignment between the experimental and theoretical hysteretic curves of the HUDAD-VD, confirming the accuracy of the theoretical model. The HUDAD-VD demonstrates effective damping performance under all levels of seismic action, successfully controlling the displacement within the seismic isolation layer. In particular, the HUDAD exhibits a satisfactory amplification effect, effectively enhancing the damper energy dissipation.

1. Introduction

Energy dissipation structures employ dampers to provide additional damping or stiffness, to dissipate seismic energy and control the structural response during earthquakes [1,2]. Recently, damping amplification technology applied to dampers has emerged as a focal point of global research to enhance the energy dissipation efficiency and address the issue of underutilization during small displacements. Damping amplification technology utilizes mechanisms such as linkage [3,4], lever [5–7], gear [8,9], and rotation mechanisms [10–12] to amplify the relative displacement and velocity of dampers. These mechanisms not only enhance energy dissipation but also ensure the effective operation of dampers under conditions of small conditions.

Lever mechanisms are categorized into primary, secondary, and tertiary stages based on the leverage principle. The three-stage lever commonly used in shock attenuation devices features a power arm shorter than the resistance arm, thereby magnifying the force effect, which is often referred to as a force multiplier. Lever mechanisms have the advantages of a simple structure, high reliability, and large amplification ratio compared with other amplification mechanisms. Lever amplification mechanisms effectively synergize with velocity- or displacement-dependent dampers under seismic loading conditions.

A series of damping amplification devices have been developed based on the principle of leverage. Chou et al. [13] proposed a lever viscoelastic wall (LVEW) with viscoelasticity and friction dampers in a device. The LVEW amplifies the lateral displacement of the frame and the damper force on the frame structure. Ye et al. [14] and Li et al. [15] developed new types of rotational amplification viscoelastic node dampers. By using the lever principle, the relatively small angular deformation at the beam-column node was magnified several times, increasing the shear deformation and hysteretic energy dissipation of the viscoelastic materials. Zhang et al. [16] proposed a novel inerter-enhanced self-centering damping system by adding a lever-based inerter to the shape memory alloy (SMA)-based self-centering damping

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