Passive Displacement-Dependent Damper with Adjustable Stiffness for Seismic Protection of Civil Infrastructure

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Background

Resettable stiffness dampers can produce large displacement-dependent forces, and have been shown to be effective at controlling structures subject to near-field ground motions.

However, they add stiffness to the structure in which they are installed, leading to:
- Change in the dynamic properties of the structure
- Increase in the base shear forces
- Large forces at damper connections
- Decrease in damping efficiency with increasing damper stiffness

An ideal resettable stiffness damper would have independent damping and stiffness, so that these properties could be adjusted as needed.

The objective of the research presented herein is to investigate a new damping system based on resettable stiffness that can achieve different levels of damping for a desired damper stiffness.
Displacement-Based Adjustable Stiffness Energy Dissipation (D-BASED) System

Combines resetting passive stiffness damper (RPSD) with passive negative stiffness device (PNSD).

RPSD comprised of pneumatic cylinder, bypass loop, mechanical valve, and rack-lever device.

PNSD consists of two bars pinned together at B, pinned to rollers at A and C, and with pre-tensioned spring attached between rollers.

Fig. 1. Schematic of the RPSD.

Fig. 2. Schematic of the PNSD.
D-BASED Working Principle

Fig. 3 (a)-(c) represent simulated hysteresis plots for an example D-BASED system with $k_{DB} = k_{rs}$, $k_{DB}=0$, $k_{DB}=-k_{rs}$, and for increasing resetting and negative stiffness.

Fig. 3(d) represents the equivalent damping ratio for the D-BASED system in an undamped SDOF structure with mass $m$ and stiffness $k$.

Fig. 3. D-BASED system hysteresis with (a) $k_{DB} = k_{rs}$, (b) $k_{DB}=0$, (c) $k_{DB}=-k_{rs}$ and (d) equivalent viscous damping ratio.
Validation of the D-BASED Concept

Cyclic testing of a small-scale prototype D-BASED system was performed for the following cases:

- Case 1 - $k_{DB} = k_{rs}$ ($k_{ns}=0$)
- Case 2 - $k_{DB}=0$ ($k_{ns}=k_{rs}$)
- Case 3 - $k_{DB}=-k_{rs}$ ($k_{ns}=2k_{rs}$)

Fig. 4. D-BASED system (a) test setup, and hysteresis with (b) $k_{DB}=k_{rs}$ ($k_{ns}=0$), (c) $k_{DB}=0$ ($k_{ns}=k_{rs}$), (d) $k_{DB}=-k_{rs}$ ($k_{ns}=2k_{rs}$).
Numerical Investigation

Simulation of a linear five-story base-isolated building (Northridge, PGA=0.84g).

D-BASED system with (+), zero, and (-) $k_{DB}$ at the isolation level; RPSD for comparison.

D-BASED system with negative stiffness achieved best overall control performance.

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Table 1. Percent reduction in peak responses.
Come see my Poster!

**Today Poster Session:**

- **Time:** 5:15 – 7:00 pm
- **Room:** Pasadena (Exhibit Hall)
- **Poster location:** Number 143