ACTIVE VALVE CONTROL FOR CONTROLLED ENERGY RELEASE IN NON-LINEAR SEMI-ACTIVE DEVICES

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Motivation

- A main goal of a structure in a seismic event is to dissipate energy in a repeatable fashion
- Preferably in large amounts
- A diamond shaped resetable (Semi-Active) device has been shown to break existing compromises between reducing base shear and increasing dissipated energy with these devices
- HOWEVER, these solutions rely on an ideal linear shape for the device hysteresis loop → From a highly nonlinear device!

- This presentation presents a unique active valve control that provides this ideal, linearised shape using highly accurate, validated nonlinear device models [Mulligan et al, 2008; 2010]
Re-Shaping Hysteretic Behaviour Using Semi-Active Resetable Devices

Double-acting piston with controlled dissipation enables customisation of structural hysteresis
Device Design

Independent two chamber design allows broader range of control laws
A Diamond-Shaped Solution

- Increased energy dissipation
- No increase to base shear
- Reduced displacement
- Meets all goals

Problem: How to get this ideal linear behaviour from a nonlinear device
The Problem = Nonlinear Devices

- Typical device control laws yield **nonlinear** hysteresis loops:
How Nonlinear? ... Very

- Nonlinear device model and flow
- Works with mass flows of working fluid
- Includes: friction, nonlinear heat and mass transfer, valve size, and timing delays in valve opening and command

Exhibit force calculation

\[ F_{\text{friction}} = \frac{P_2(\text{open}) - P_1(\text{open})}{A} \text{Friction} \]
Solution: Active Valve Control

- Feedback loop sets desired shape
- PD control used to set valve diameter as control input
- Tested with sinusoidal input motions (for clarity)
As period shrinks the number of time steps to control shape per cycle declines significantly → Loss of control and inability to control shape.

At $T = 0.1$ sec with valve delay of 0.01 sec → Only 10 corrections are possible to control shape (100 for $T = 1.0$ sec and so on).
Results vs Valve Delay

- Similar to changing period. Reduced valve delay provides more cycles to make corrections and achieve good control.
- Valve delay and $T_n$ trade off in design.
- Realistic valve delays depend on valve size.
Results – Realistic Input

- SDOF spectral analysis case with $T_n = 5s$ and $1s$ (left / right)
- Actual system close to ideal linear except for 1-2 cycles at faster period
- Valve delay = 0.01s
Results – Spectral Analysis

- Spectral analysis across all 3 SAC suites with valve delay of 0.01s
- Ideal versus Nonlinear → Did we achieve the outcome of matching the linear, ideal case (robust over 60 ground motions)?
- At low Tn, valve delay → Tn and not a good match. OK after Tn = 1.0-1.5s

→ Repeat of plots from first presentation comparing to 1-4 and 2-4 devices
“Local” Conclusions

• Diamond shape active valve controlled resetable devices offer some significant potential for specific, high value applications

• Active valve control implemented using a validated, highly nonlinear model of semi-active devices

• Basic PD control can yield a highly linear, ideal device outcome for both sinusoidal and random earthquake (response) inputs

• Valve delay and natural period (Tn) must be considered in valve selection for obtaining desirable results
  • Tradeoff leads to selecting (e.g.) one large valve versus several smaller but faster valves to yield same total orifice area

• Spectral analysis shows the models and approach are robust over a wide range of periods and ground motions
So, ... From these 2 talks ...

- We can use resetable devices to further optimise hysteresis loops and maximise trade

- Accomplished by using active valve control to effectively “linearise” these devices

- When they act like a linear ideal device they are easily analysed, BUT also ideal (maximum) energy dissipaters

- But, could we do this passively by design alone for 1-4 and 2-4 devices that don't need active valve control?
The Real End ... OR What’s to come

- But, could we do this passively by design alone for 1-4 and 2-4 devices that don't need active valve control?

**YES**
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