Development and Spectral Analysis of an Advanced Control Law for Semi-Active Resetable 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

Existing research has investigated the use of emerging devices and technologies to accomplish this goal

- Resetable devices are one answer presented at this conference for certain application areas where a more complex device and behaviour are warranted.

Resetable devices are semi-active, but more importantly they offer the ability to customise the overall structural response behaviour to maximise energy dissipation

This presentation presents a novel structure and hysteresis loop that is enabled only by semi-active technology

- A further talk shows how to achieve it within the devices
Re-Shaping Hysteretic Behaviour Using Semi-Active Resetable Devices

Double-acting piston with controlled dissipation enables customisation of structural hysteresis
Independent two chamber design allows broader range of control laws
Overall Customised Hysteresis

Resist all velocity

Resist all motion

Resist motion away from 0

Resist motion toward 0

Viscous Damper

1-4 Resetable

1-3 Resetable

2-4 Resetable

Only the 2-4 control law does not increase base-shear
The Problem

- You get a choice with these devices:
  - *Reduced* base shear and displacement response, but **reduced** energy dissipation
  - *Reduced* displacement with increased energy dissipation, but with **increased** base shear

- **Neither choice is optimal**

- Goal: **Reduce** base shear (or don't increase it), **reduce** base shear, and **increase** energy dissipation
A Diamond-Shaped Solution

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

- Requires active control release of working fluid = Difficult to achieve with potentially nonlinear devices
  - See next talk!
Analysis

- Create design spectra and reduction factors (RFs)
- Ground motions = 60 EQ’s from SAC suites (Sommerville et al)
- Examine RFs for structural force (displacement) and base shear
- Compare to 2-4 and 1-4 devices that define the compromise
  - Note these devices do not require active valve control of release rate of working fluid
Results – Structural Force

- Results are suite invariant
- \(1-4 > \text{Diamond} > 2-4\) as might be expected
Results – Structural Force

- Diamond shape offers a reasonable tradeoff between the two passive semi-active device control laws.

- Difference shrinks at longer periods.
Results – Base Shear

- 1-4 and 2-4 as expected
- Diamond shaped offers equivalent or better than 2-4
- Extra displacement reduction due to greater energy dissipation is the key
Results – Base Shear

- Extra energy dissipation yields greater reduction in displacement
- Diamond shape thus outperforms 2-4 on base shear reduction
- Overall a relatively optimal tradeoff for this device
Equivalent Viscous Damping

- Increase viscous damping and compare displacement RFs
- No devices
- 2-4 → 10-15%
- 1-4 → 40-30%
- Diamond → 15-20%
Conclusions

• Semi-active control enables customisation of overall structural hysteresis in novel ways not available with passive systems

• Active valve control expands these unique tradeoffs to maximise performance

• A diamond shaped device control law and hysteresis loop can reduce base shear while adding significant extra energy dissipation versus strictly passive valve control on these devices

• Extra complexity of such a semi-active device may be readily justified in certain structures, sub-systems or high-value equipment/plant

• **BIG QUESTION**: Can we control the valves to get this unique shape and relatively ideal, **linear** device hysteresis loop?
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