A Novel Approach to Dynamic Force Control

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Real-time dynamic hybrid testing

- Combined use of earthquake simulators, actuators and computational engines for simulation
- Details later in the presentation
Force control – challenging problem

- Hydraulic actuator fitted with flow-regulating servo-valve
  - Inherently a velocity source
  - Designed to be mechanically stiff for good position control
  - Friction, stick-slip, breakaway forces on seals, backlash cause force noise
  - Stiff oil columns make force control very sensitive to control parameters often leading to instability
Innovative scheme for force control

Target Force $\rightarrow 1 / K_{LC}$

Command Signal

Actuator in Displacement Control

Series Spring, $K_{LC}$

Structure

Structure Displacement

Compensator

Measured Force
Explanation of force control scheme

Target Force = F

Displacement command = \( F / k_{spring} \) + Structure Displacement
Small-scale test setup
Actuator displacement control

- Tuned very well in displacement control
- Standard PIDF controller

- Time-delay = 5.6 ms
Time-delay effect on force transfer function

Need predictive capability in compensator
Smith predictor

Smith Predictive Compensator

\[ T = e^{-s\tau} \]

Corrective Displacement

Predictive Displacement

\[ \hat{T} = \frac{1}{\hat{m}s^2 + \hat{c}s + \hat{k} + \hat{K}_{LC}} \]

Model of Structure-Spring System

\[ \frac{1}{ms^2 + cs + k} \]

Structure

Series Spring

Actuator

1\(/K_{LC} \)

1\(/K_{LC} \)
Force transfer function with predictive compensation

![Graph showing force transfer function with predictive compensation. The graph compares the magnitude of force transfer frequency with and without compensation. The x-axis represents frequency (Hz) ranging from 0.0 to 2.0, and the y-axis represents magnitude ranging from 0.0 to 2.0. Two lines are plotted: one black line represents 'Without comp.' and one red line represents 'With comp.' The graph highlights the difference in magnitude at various frequencies, indicating the effectiveness of the predictive compensation.]
Thank you