Dynamical Substructured System link to structural testing

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Dynamically Substructured Systems



Control Issue

Negative damping and actuator delay

$$\delta E = \oint q \, \mathrm{d}x = \int_0^T q \, \frac{\mathrm{d}x}{\mathrm{d}t} \, \mathrm{d}t = \int_0^T (kx'') \, \frac{\mathrm{d}x}{\mathrm{d}t} \, \mathrm{d}t$$
$$= \int_0^T kA \sin(\omega_0 t - \omega_0 \delta t) \cdot A\omega \cos(\omega_0 t) \, \mathrm{d}t = \frac{1}{2} \, kA^2 \cdot 2\pi \omega_0 \delta t$$

$$\Delta E_{\rm P} = \iint f_{\rm P} dz_{\rm P} = \int_0^T f_{\rm P} \frac{dz_{\rm P}}{dt} dt = \int_0^T -(kz_{\rm P}) \frac{dz_{\rm P}}{dt} dt$$
$$= -kA_{\rm E}^2 \omega_{\rm N} \int_0^T \left[\sin\left(\omega_{\rm N} t - \omega_{\rm N} \tau\right) \cdot \cos\left(\omega_{\rm N} t - \omega_{\rm N} \tau\right) \right] dt$$
$$= -\frac{1}{2} kA_{\rm E}^2 \omega_{\rm N} \int_0^T \left[\sin\left(2\omega_{\rm N} t - 2\omega_{\rm N} \tau\right) + \sin\left(0\right) \right] dt = 0$$

Horiuchi, T., Inoue, M., Konno, T., and Namita, Y. (1999). "Real-time hybrid experimental system with actuator delay compensation and its application to a piping system with energy absorber." Earthquake Eng Struct Dyn, 28(10), 1121-1141.

Control Issue

Parameters affecting the stability and efficiency



$$\frac{z_{\rm N}(s)}{z_{\rm P}(s)} = \frac{-m_{p2}s^2}{m_1s^2 + cs + k} \qquad \Rightarrow \qquad \frac{m_{p2}}{m_1}$$



$$\frac{z_{\rm N}(s)}{z_{\rm P}(s)} = \frac{-k_p}{m_1 s^2 + cs + k} \qquad \Rightarrow \qquad \frac{k_p}{k}$$

Control Issue

Parameters affecting the optimalisation



$$\frac{z_{\rm N}(s)}{z_{\rm P}(s)} = \frac{-m_{p2}s^2}{m_1s^2 + cs + k} = 1$$



$$\frac{z_{\rm N}(s)}{z_{\rm P}(s)} = \frac{-k_p}{m_1 s^2 + cs + k} = 1$$

Substructurability Index: ONE is optimal

Conclusion and Future Work

Delay Control

- An issue in many cases but not always the cases
- Delay control: the essence for science and engineering advance

Control Reliability and Efficiency

- Design and suggest an efficient experimental method
- Repeatable control with reliability
- Beneficial to the testing of structural system