The enhanced nonlinear friction bearing isolators using negative stiffness inertial amplifiers

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Abstract. The inertial amplifier and negative stiffness inertial amplifier coupled nonlinear friction bearing isolators, such as inertial amplifier resilient friction bearing isolators (IARFBI), negative stiffness inertial amplifier resilient friction bearing isolators (NSIARFBI), inertial amplifier friction pendulum systems (IAFPS), and negative stiffness inertial amplifier friction pendulum systems (NSIAFPS) are introduced in this paper. H_2 optimization method applies to derive the exact mathematical formulation for optimal design parameters for each nonlinear isolator. The stochastic linearization method applies to linearize each element of the highly nonlinear governing equations of motion of the dynamic systems isolated by each nonlinear isolator. The frequency-domain responses are determined analytically through transfer function formation. A numerical study has been performed to assess the vibration reduction capacity of the nonlinear isolators applying the Newmark-beta method. The vibration reduction capacities of IARFBI, NSIARFBI are 36.36 %, 48.48 % and IAFPS, NSIAFPS are 41.76 %, 52.94 %, superior to TRFBI and TFPS.

Introduction

The base isolators [1] are widely applied passive vibration control devices due to their superior vibration reduction capacity. Recently, inerters [2], inertial amplifiers, and negative stiffness devices [3] have been installed inside traditional base isolators to increase their vibration reduction capacity without affecting the static mass. However, the inertial amplifiers and negative stiffness inertial amplifiers are not applied to the traditional nonlinear friction bearing isolators, such as resilient friction bearing isolators and friction pendulum systems. A research scope has been identified from the existing state of the art. Hence, the negative stiffness inertial amplifier nonlinear friction bearing isolators are introduced in this study. Therefore, the nonlinear equations of motion of a single degree of freedom system (SDOF) isolated by the novel isolators are derived as

$$m_d\ddot{x}_b + F_{iarfbi,iafps} - c_s\dot{x}_s - k_s x_s = -m_d\ddot{x}_g \; and \; m_s\ddot{x}_s + m_s\ddot{x}_b + c_s\dot{x}_s + k_s x_s = -m_s\ddot{x}_g$$

$$F_{iarfbi} = c_d\dot{x}_b + k_d x_b + \mu m_d g\,\mathrm{sgn}(\dot{x}_b) \; and \; F_{iafps} = k_d x_b + \mu m_d g\,\mathrm{sgn}(\dot{x}_b)$$

$$m_d\ddot{x}_b + F_{nsiarfbi,nsiafps} - c_s\dot{x}_s - k_s x_s = -m_d\ddot{x}_g \; and \; m_s\ddot{x}_s + m_s\ddot{x}_b + c_s\dot{x}_s + k_s x_s = -m_s\ddot{x}_g$$

$$F_{nsiarfbi} = c_d\dot{x}_b + (k_d - k_n)x_b + \mu m_d g\,\mathrm{sgn}(\dot{x}_b) \; and \; F_{nsiafps} = (k_d - k_n)x_b + \mu m_d g\,\mathrm{sgn}(\dot{x}_b)$$

$$x_{s,b} = \mathrm{Re}\,lative\ displacement\ of\ structure\ and\ isolator,\ \mu = poisson's\ ratio,\ m_d = m_b + m_a\left(1 + \frac{1}{2\tan^2\theta}\right)$$

Results and discussion

The differences in the dynamic responses of the SDOF systems isolated by TRFBI, IARFBI, NSIARFBI and IAFPS, NSIAFPS, TFPS versus time subjected to the Loma Prieta earthquake have been shown in Figure 1 (a) and Figure 1 (b).

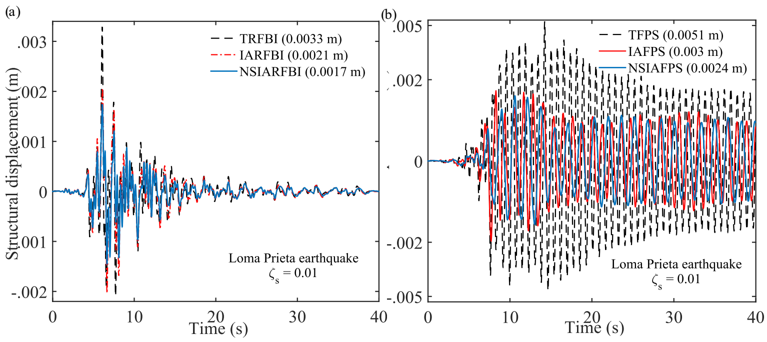

Figure 1: The variations of displacement responses of structures isolated by (a) TRFBI, IARFBI, NSIARFBI and (b) TFPS, IAFPS, NSIAFPS versus time subjected to Loma Prieta earthquake.

Hence, the dynamic response reduction capacities of IARFBI and NSIARFBI are significantly 36.36 % and 48.48 % superior to TRFBI. The dynamic response reduction capacities of IAFPS and NSIAFPS are significantly 41.76 % and 52.94 % superior to TFPS.

References

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