The optimum inerter based isolation systems for dynamic response mitigation of multi degree of freedom systems

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Abstract. The inerter based isolation systems (Inerter-BI) to control the structural responses of multi-storey buildings, the conceptualized versions of multi degree of freedom systems, are introduced in this paper. H_2 optimization method implements to derive exact closed-form expressions for the optimal design parameters of Inerter-BI. The linear and nonlinear stiffnesses are applied for the superstructural stiffness and the stochastic linearization method applies to linearize each nonlinear element of governing equations of motion. The frequency domain responses are determined through transfer function formation analytically. A numerical study performs with earthquake base excitations to evaluate each isolator's displacement and acceleration reduction capacities using the Newmark-beta method. The dynamic response reduction capacities of Inerter-BI are significantly 71.28 % and 93.61 % superior to dynamic response reduction capacities classical base isolator (CBI) subjected to harmonic and random base excitations.

Introduction

Passive vibration control devices mitigate the structures' dynamic responses to prevent structural damage during natural disasters such as earthquakes and storms. The base isolators [1] are one of the widely applied passive vibration control devices due to their superior vibration reduction capacity. Recently, inerters [2] have been installed inside conventional isolators to increase their vibration reduction capacity without affecting the static mass, stiffness, and damping. However, the inerter and negative stiffness inerters are not applied to the conventional base isolators to mitigate multi-storey building's dynamic responses. The exact closed-form expressions for dynamic responses and optimal closed-form solutions also do not exist in any literature. Therefore, a research scope has been identified from the existing state of the art. To address this research scope, the inerter based isolation systems are introduced in this paper. The governing equations of motion for muti-storey buildings isolated by Inerter-BI are derived using newton's second law and expressed as

$$m_1\ddot{y}_1+\left(m_1+m_{nb}+m_{in}\right)\ddot{y}_{nb}+c_{nb}\ddot{y}_{nb}+k_{nb}y_{nb}=-\left(m_1+m_{nb}\right)\ddot{u}_g$$

$$[M]\{\ddot{y}_s\}+[C]\{\dot{y}_s\}+[K]\{y_s\}=-[M]\{1\}\left(\ddot{u}_g+\ddot{y}_{nb}\right)$$

Results and discussion

From Figure 1, a higher inerter mass ratio recommends to design optimum Inerter-BI.

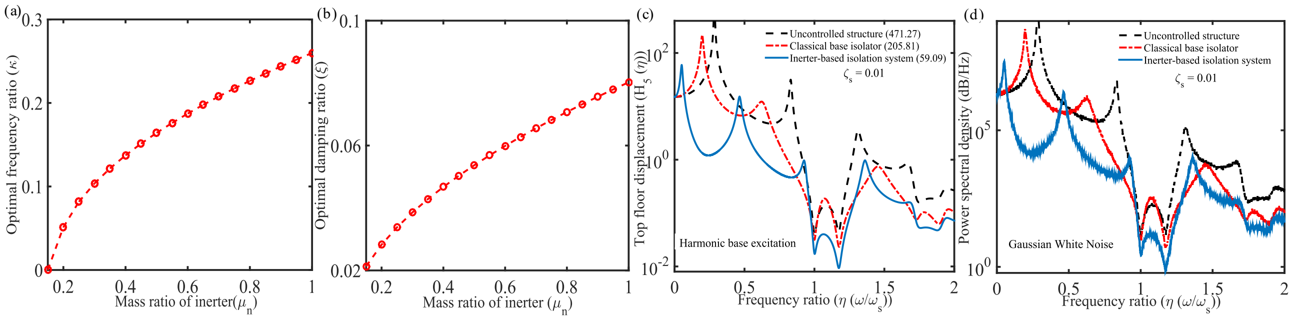

Figure 1: The variation of optimal (a)frequency ratio and (b)damping ratio versus mass ratio of inerter of inerter based isolation system. The variations of displacement responses of multi-storey buildings isolated by classical base isolator and inerter based isolation system subjected to (c) harmonic and (d) random white noise versus frequency ratio.

The variations of CBI and Inerter-BI controlled multi-storey building's dynamic responses have been shown in Figure 1 (c) and Figure 1 (d). The dynamic response reduction capacity of Inerter-BI is significantly 71.28 % superior to CBI. In addition, the maximum dynamic responses of CBI and Inerter-BI controlled structures are determined as 5.53×10^8 dB/Hz and 3.53×10^7 dB/Hz. Accordingly, the dynamic response reduction capacity of Inerter-BI is significantly 93.61 % superior to CBI.

References

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