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Reducing Response of Structures by Using Optimum Composite Tuned Mass Dampers

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Abstract

In this paper, the optimization of composite tuned mass dampers in reducing the response of structures subject to earthquake are discussed. Composite tuned mass dampers are mass dampers that consist of two mass dampers connected in series. The mass of the auxiliary dampers is in general relatively smaller than the one of the first damper. However, in this paper the mass ratio of the auxiliary damper to total mass of dampers is varied from 0.1 up to 0.9; and the optimum stiffness and damping of the first and auxiliary dampers are obtained using real coded genetic algorithm (RCGA). From the result of optimization, it is found that the mass ratio of the auxiliary dampers does not significantly affect the response reduction of structures. It is also found that for a certain mass ratio, the resulting stiffness and damping are not unique for achieving the same performance.

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Keywords: composite tuned mass dampers; vibration control; optimization; real coded genetic algorithms;

1. Introduction

The use of tuned mass dampers (TMDs) to reduce the response of structures has been proposed by researchers in the past. These include the classical Den Hartog [6] and Warburton [13] methods. In Den Hartog [6] method, the reduction of response of undamped structures subject to harmonic loading is considered by the addition of a spring mass damper. The extension of analysis was carried out by Warburton [13], where a general mass including spring

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and damping was considered with the addition of a spring mass damper. The loading is also not necessarily a harmonic loading and might be applied either on the main mass or at the support.

In addition to the analytic methods, several numerical methods have also been proposed. Hadi and Arfiadi [8] proposed optimization method by using binary coded genetic algorithms. Bekdas and Nigdeli [3] estimated optimum parameters of TMD by using harmony search. Several discussions on this method are also available ([10], [4], [11], [5]). Leung et al. [9] proposed particle swarm optimization method to optimize the TMD.

In this paper, a composite TMD composed of two dampers in series on structure, similar to Nishimura et al. [12], is considered. The optimization method is done by using a modification of real coded genetic algorithms proposed in Arfiadi and Hadi [1][2] and Frans and Arfiadi [7]. However, different from [12] the mass ratio of the dampers is investigated to see this effect on the response reduction of structures.

2. Composite tuned mass dampers formulation

A single degree of freedom structure equipped with a mass damper and an additional mass damper is considered in this paper, as shown in Fig. 1. The equation of motions of the structure can be written as:

$$\mathbf{M_S}\ddot{\mathbf{U}}_\mathbf{S} + \mathbf{C_S}\dot{\mathbf{U}}_\mathbf{S} + \mathbf{K_S}\mathbf{U_S} = -\mathbf{M_S}\mathbf{1_S}\ddot{u}_g \tag{1}$$

where $\mathbf{M_S} = \begin{bmatrix} m_s & 0 & 0 \\ 0 & m_d & 0 \\ 0 & 0 & m_a \end{bmatrix}$, $\mathbf{C_S} = \begin{bmatrix} (c_s + c_d) & -c_d & 0 \\ -c_d & (c_d + c_a) & -c_a \\ 0 & -c_a & c_a \end{bmatrix}$, $\mathbf{K_S} = \begin{bmatrix} (k_s + k_d) & -k_d & 0 \\ -k_d & (k_d + k_a) & -k_a \\ 0 & -k_a & k_a \end{bmatrix}$,

$\mathbf{U_S} = [u_s \quad u_d \quad u_a]^T$, $\dot{\mathbf{U}}_\mathbf{S} = [\dot{u}_s \quad \dot{u}_d \quad \dot{u}_a]^T$, $\ddot{\mathbf{U}}_\mathbf{S} = [\ddot{u}_s \quad \ddot{u}_d \quad \ddot{u}_a]^T$, $1_\mathbf{S} = [1 \quad 1 \quad 1]^T$, m_s, m_d, m_a = mass of the structure, the first damper, and the auxiliary damper, respectively; c_s c_d, c_a = damping of structure, the first damper, and the auxiliary damper, respectively; k_s, k_d, k_a = stiffness of the structure, the first damper, and the auxiliary damper, respectively; u_s, u_d, u_a = displacement of the main structure, the first damper, and the auxiliary damper, respectively; the over dot (.) is a derivative with respect to time, and $\ddot{u}_g$ = ground acceleration.

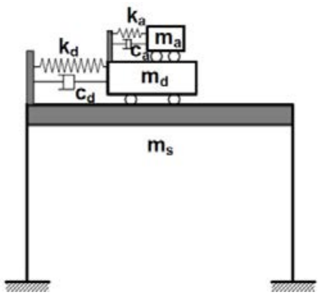

Fig. 1. Composite tuned mass damper.

In this problem the properties of composite mass damper system are optimized for various mass ratios of auxiliary to the total mass of dampers.

The equation of motions can be converted to a state space equation as:

$$\dot{\mathbf{Z}} = \mathbf{A}\mathbf{Z} + \mathbf{E}w \tag{2}$$

where $\mathbf{Z} = \begin{Bmatrix} \mathbf{U_S} \\ \dot{\mathbf{U}}_\mathbf{S} \end{Bmatrix}$, $\mathbf{A} = \begin{bmatrix} \mathbf{0} & \mathbf{I} \\ -\mathbf{M_S}^{-1}\mathbf{K_S} & -\mathbf{M_S}^{-1}\mathbf{C_S} \end{bmatrix}$, $\mathbf{E} = \begin{Bmatrix} \mathbf{0} \\ -\mathbf{1_S} \end{Bmatrix}$, and $w = \ddot{u}_g$