Chapter 3

Optimal Placement of Viscoelastic Dampers Represented by the Classical and Fractional Rheological Models

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ABSTRACT

The problems of the optimal location of viscoelastic (VE) dampers and determination of the optimal values of parameters of dampers are considered in this chapter. The optimal distributions of dampers in buildings are found for various objective functions. The optimization problem is solved using the sequential optimization method and the particle swarm optimization method. The properties of VE dampers are described using the rheological models with fractional derivatives. These models have an ability to correctly describe the behaviour of VE dampers using a small number of model parameters. Moreover, generalized classical rheological models of VE dampers are also taken into account. A mathematical formulation of the problem of dynamics of structures with VE dampers, modelled by the classical and fractional rheological models is presented. The results obtained from numerical calculation are also discussed in detail.

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INTRODUCTION

Passive damping systems consist of various mechanical devices which are mounted on structures and dissipate a portion of the energy introduced by excitation forces affecting the structures. Different kinds of mechanical devices, such as viscous dampers, viscoelastic dampers, tuned mass dampers, or base isolation systems, can be used as passive systems. In contrast with the active and semi-active systems, the passive ones require no amount of energy to operate. Online measurements of the dynamical state of the structure are not necessary. Books by Soong and Dargush (1997), by Constantinou et al. (1998), and Hanson and Soong (2001) contain important basic information concerning many aspects of passive control of civil structures. Moreover, fundamental information concerning passive control systems can be found in books by Mead (1998), by Jones D.I.G. (2001), and De Silva (2007).

In civil engineering, VE dampers are successfully applied to reduce excessive vibrations of buildings caused by winds and earthquakes. It was found that incorporation of VE dampers in a structure leads to a significant reduction of unwanted vibrations; see the paper by Soong and Spencer (2002). A number of applications of VE dampers in civil engineering are listed in a book by Christopoulos and Filiatrault (2006).

The VE dampers’ behaviour depends mainly on the rheological properties of the VE material and the dampers are made of. In the past, several rheological models were proposed to describe the dynamic behaviour of VE materials and dampers. Both the classical and the so-called fractional-derivative models of dampers and VE materials are available. In the classical approach, the mechanical models consisting of springs and dashpots are used to describe the rheological properties of VE dampers, see, for example the paper by Park (2001). A good description of the VE dampers requires mechanical models consisting of a set of appropriately connected springs and dashpots. In this approach, the dynamic behaviour of a single damper is described by a set of differential equations. The rheological properties of VE dampers could be also described using the fractional calculus and the fractional mechanical models. This approach has received considerable attention and has been used in modelling the rheological behaviour of VE materials and dampers (Bagley and Torvik, 1989; Rossikhin and Shitikova, 2001; Chang and Singh, 2002). The fractional models have an ability to correctly describe the behaviour of VE materials and dampers using a small number of model parameters. A single equation is enough to describe the VE damper dynamics, which is an important advantage of the discussed model. However, in this case, the VE damper equation of motion is the fractional differential equation.

An optimal distribution of the damping properties of dampers and optimal positioning of dampers are important from the designer’s point of view. The optimal positioning of a single viscous damper based on the energy criterion was considered by Gurgoze and Muller (1992). Takewaki (2009) used a gradient-based approach for the optimal placement of passive, mainly viscous, dampers and modelled by the simple Maxwell model by minimizing the norm of the response transfer function calculated for the undamped fundamental frequency of structure. Singh and Moreschi (2001) used a gradient–based optimization procedure to obtain the optimal distribution of viscous dampers. Moreover, the genetic algorithm was used by Singh and Moreschi (2002) to find the optimal size and location of viscous and viscoelastic dampers. Tsuji and Nakamura (1996) described a method to find the optimal storey stiffness distribution and the optimal damper distribution for structures subjected to a set of earthquakes. A sequential search algorithm was presented by Zhang and Soong (1992) and by Garcia and Soong (2002) for the design of an optimal damper configuration. Aydin et al. (2007) considered the optimal distribution of viscous dampers, as used for the rehabilitation of an exist-