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DETERMINATION OF DYNAMIC CHARACTERISTICS AND THEIR DESIGN SENSITIVITIES FOR STRUCTURES WITH VISCOELASTIC DAMPERS

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Viscoelastic (VE) dampers are often used to mitigate excessive vibrations of structures. The properties of VE materials or fluids used for manufacturing VE dampers depend on the temperature and excitation frequencies of the forces acting on dampers. Many rheological models, including the classical rheological models and rheological models with fractional derivatives, are proposed for a correct description of the dynamical behavior of VE dampers.

The dynamic characteristics of structures with VE dampers, such as natural frequencies, non-dimensional damping ratios and modes of vibrations, can be obtained as a result of solution to linear or nonlinear eigenvalue problems. A solution to the linear eigenvalue problem is obtained when the state-space approach is used [1] whereas the nonlinear eigenvalue problem must be solved if equations of motion are written in a traditional form or when the fractional models are used to describe the behaviour of dampers [2]. The dimension of the linear eigenvalue problem is more than twice as great as that of the nonlinear eigenvalue problem.

The analysis of sensitivity is one of the most important elements of designing, optimization, identification and monitoring of the technical condition of engineering structures. It allows evaluating the influence of the changes of physical and geometric parameters on structure behavior. In the recent years studies on the sensitivity analysis of systems with viscoelastic dampers or with layers made of viscoelastic material have been started [3]. In the paper [4], an algebraic method was proposed to calculate the derivatives of eigenvalues and eigenvectors of nonviscously damped system were calculated as the solution to a set of algebraic equations. The sensitivity analysis of structures with VE dampers, described with the help of fractional derivatives, has not been presented as yet.

Elastic structures with VE dampers described using the so-called fractional rheological models are considered in this paper. The advanced rheological model, which contains all the usually adopted fractional rheological models, is used. The considered system is nonviscously damped. The dynamic characteristics of this type of structures are of primary interest.

Nonlinear eigenvalue problems resulting from the equations of motion, written as a set of second-order differential equations, are derived. The continuation method is proposed to solve the above-mentioned eigenvalue problem. The normalization condition for the eigenvector is adopted as the constrained equation and the artificial main parameter is introduced in the continuation method. The method does not require any assumption concerning low viscoelasticity of dampers. Complex solutions to the eigenvalue problem considered are determined in a systematic way. The effectiveness and accuracy of the method are justified based on the results of calculation made, taken from literature and for typical planar frames with VE dampers.

The direct method is proposed to calculate the first order design sensitivity of the system at hand. The obtained formulas enable determination of the sensitivity of eigenvalue and eigenvectors of structures with viscoelastic dampers with respect to the chosen design parameter. It enables, too, the sensitivity analysis of other dynamic characteristics, such as: non-dimensional damping factor and natural frequencies. The considered damper model can be used for the analysis of structures with different dampers described by the chosen rheological models with fractional derivatives. The effectiveness and accuracy of the method are justified based on the results of calculation made, taken from literature and for typical planar frames with VE dampers. The results of a sensitivity analysis concerning the structures with VE dampers treated as fractional ones are presented for the first time.

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