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avoids using this numerically demanding state-space formulation. The determination of complex eigenvalues is based on the approximate solution of the characteristic equation that is derived in the modal space. The perturbation approach is adopted to reflect the differences in the eigenvalues of proportionally and non-proportionally damped systems. The complex eigenvectors are calculated afterwards with the use of a significantly reduced modal system and obtained eigenvalues. The proposed procedure is easily programmable and enables the calculation of the individual complex eigenvalues and eigenmodes separately, which significantly reduces computational time. The method requires only a prior knowledge of eigensolutions of the proportionally damped and undamped systems. An application of the procedure is demonstrated on a numerical example of a real structure. The approximate eigensolution is calculated for various combinations of the input computational and structural parameters in order to determine their influence on accuracy and computational time. The analysis of the results revealed the choice and total number of real eigenmodes of the undamped system, which were used in the calculation, as the most significant parameters. Usually only limited number of real eigenmodes is necessary to obtain a sufficient accuracy. The possible suggestion for the selection of these eigenmodes is presented. The recommendations and limitations for engineering application of the proposed method are outlined and discussed.

Robust simultaneous optimization of friction dampers for the passive vibration control in a colombian building

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The dampers robust optimization is a new area that has been studied in the last years, having a big impact in the optimal robust design of devices for the vibration control in structures subjected to dynamic loads due to natural hazards such as earthquakes. In this paper a new approach is presented taking into account the robust optimization of friction dampers, which is carry out using the Genetic Algorithm integrated with the computational routine based on the Central Finite Differences Method developed by the authors, which is able to deal with optimization problems involving discrete (positions of the dampers in the structure) and continuous (mechanical parameters of the dampers, in this case, the friction forces) design variables. Taking into account uncertainties in both structural and load properties, the dynamic structural response becomes stochastic. It is noteworthy that such methodology applied to friction dampers is innovative because there is a lack of studies on robust optimization associated with this type of damper in the literature. This device stands out among the passive devices due to the low cost of construction, installation and maintenance, as well as the high performance for vibration control. For illustration purpose, a typical concrete building from a Colombian city (Ccuta) was considered, which is located in the northeast of the country, where a high seismic activity occurs. In this case of study the objective function is the minimization of the failure probability, this is, the failure occurs when the maximum inter-story drift is greater than 1\% of the story height, as suggested by the Colombian Seismic-Resistant Standard (NSR-10). The results show that the proposed method was able to reduce the failure probability achieving good results using this sort of passive device.

Mathematical modelling of adaptive skeletal structures for impact absorption and vibration damping

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The concept of adaptive skeletal structures is based on replacement of standard passive members by semi-active dissipaters with smart fluids or fast-operating valves and application of the paradigm of real-time adaptation to actual impact loading. Exact mathematical modelling of adaptive skeletal structures and precise simulation of their response to dynamic excitation is still a challenging theoretical and numerical task, which seems not to be fully resolved in the literature. The probable reason is that in case of adaptive skeletal structures with semi-active dissipaters the derivation of the mathematical model cannot be directly based on classical methods of linear dynamics effectively utilizing the formalism of mass, stiffness and damping matrices. Instead, their modelling requires dedicated, highly-specialized approaches taking into account specific properties of semi-active dissipaters and resulting non-classical dynamical models, which often appear to be relatively complex and hard for the numerical solution. The paper proposes a complete approach for the exact mathematical modelling of the adaptive skeletal structures based on three subsequent, distinct stages. The first step is exact thermodynamic modelling of a single semi-active dissipater with the use of mass and energy conservation laws combined with constitutive equation of the fluid taking into account its compressibility and viscosity as well as the analytical model of the controllable internal flow. This step is aimed at reliable representation of dissipative behavior and controllable characteristics of the applied semi-active devices. In turn, the second step is global description of entire skeletal structure considered as an assembly of semi-active dissipaters in certain geometrical configuration. This is obtained by constructing global matrix equations of the system, which combine previously derived models of dissipaters and data concerning their initial configuration and mutual connections. Finally, the third step involves taking into account real-time control of the fluid flow inside semi-active dissipaters providing instantaneous adaptability to actual dynamic loading, which is considered as an inherent feature of adaptive skeletal structures. The proposed approach seems to provide holistic and universal methodology for the modelling of the adaptive skeletal structures composed of various types of semi-active dissipaters and dedicated for diverse applications.

Use of flat-type multilayer rubber-metal package for vibration mitigation

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Elastomeric materials (natural and synthetic rubber) have a capability of absorbing input energy much better than other construction materials, therefore they are widely used in manufacturing of the compensating devices, shock-absorbers, vibration isolators, joints, etc. Elastomers offer many engineering advantages because of their small volume compressibility and ability to maintain large elastic deformation, i.e. to withstand the large elongation without breaking. Alongside with immediate elastic deformation rubber exhibit retarded elastic deformation, viscous flow (creep) and relaxation, so its mechanical properties strongly depend on the time of application of external loads. Reinforced elastomeric structures consist of alternating thin layers of rubber and adhesive bonded reinforcing layers of much more rigid material (usually metal or hard plastic); geometric shapes and number of layers of such multilayered package may be different. Package is essentially anisotropic elastic element having a high load capacity (more than 30 MPa in normal to layer direction) and higher compliance in transverse direction. The elastic properties of rubber in such supports allows reverse backward to its original position under dynamic load action. Elastomeric compensation device mounted between the vibrating base and protecting object is the main element of any the passive vibration protection system. In this paper rubber absorber of prismatic form with parallel flat ends under axial harmonic kinematic excitation is considered. For the estimation of mitigation properties of the rubber vibroabsorber two approaches are applied: using the mechanical models based on combination of elastic and viscous elements and using analytical representation of integral equations of creep and relaxation. In this article Maxwell and Burgers mechanical models and Rabotnov's kernel for analytical representation are used. Damping properties are expressed by the ratio of amplitude of the driving vibration to the amplitude of the forced oscillations of object. Numerical calculations for each method are fulfilled and results are compared.