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FEA of Impact Responses for Damped Frame Structures Supported by Multiple Nonlinear Springs with Hysteresis

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Springs are often used not only for heavy structures but also for lightweight structures such as mobile phones to insulate them from external vibrations and shocks. However, in many cases, the stiffness of a lightweight structure is not sufficiently high for the structure to be considered rigid. Thus, in dynamic analysis, it is necessary to deal with these structures as elastic bodies. If the structures comprise resins, they should be treated as viscoelastic bodies.

Many researchers have studied for the nonlinear vibrations of concentrated masses with springs (1). The authors previously proposed a fast numerical method to compute the nonlinear vibrations in an elastic/viscoelastic block with a nonlinear spring (2).

To reduce vibrations, viecoelastic damping materials are often laminated on the metal structures. Damping characteristics (e.g. modal loss factors) of these laminated panels are affected by not only properties of the viscoelastic materials but also stiffness of the metal panels. To calculate the modal loss factors, which corresponds to modal damping when the structure are deformed as eigenmodes at resonant frequencies, complex eigenvalue analysis are often used. To compute the modal loss factors using FEM under linear problem, Johnson proposed Modal Strain Energy Method (i.e. MSE Method) (3). Using this method, the modal loss factors can be computed using material loss factor for each element and the ratio of modal strain energy for each element to total modal strain energy. This method is very useful to investigate damping mechanizm in the metal structures with viscoelastic layers. However, there are few reports to treat nonlinear vibration problem of the metal structures with viscoelastic damping layers supported by nonlinear spring.

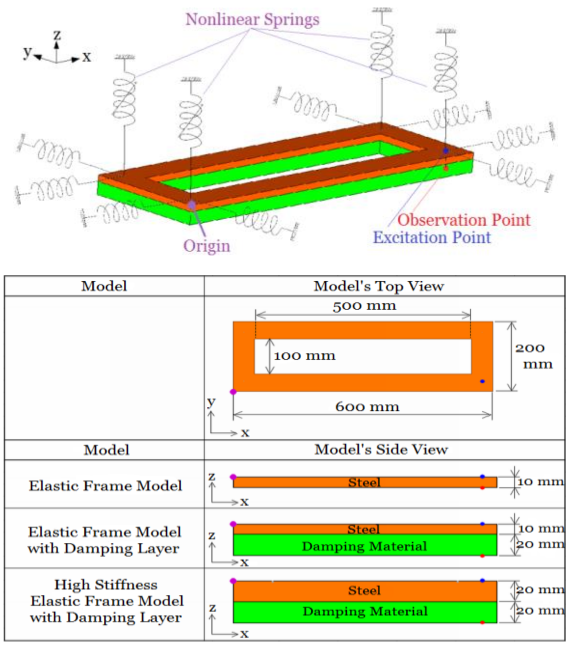
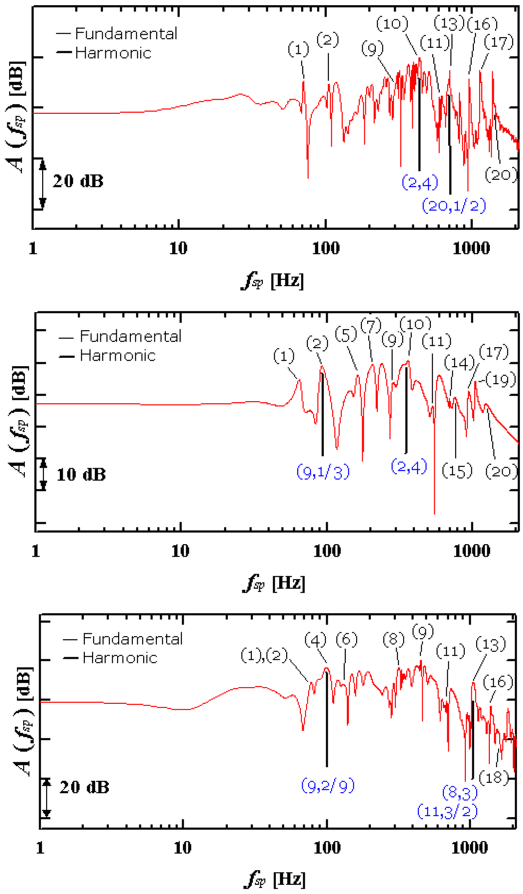


Fig.1 FEM models of elastic frames with viscoelastic damping layers supported by nonlinear springs with hysteresis

This paper describes vibration analysis using FEM for elastic structures with viscoelastic layers connected with nonlinear springs with hysteresis. The restoring force of the spring is expressed as power series of its deformation. A complex spring constant is introduced for the linear component of the restoring force. The finite elements for the nonlinear spring are expressed and they are attached to the elastic / viscoelastic structures, which are modeled as solid finite elements with a complex modulus of elasticity. We obtain the nonlinear discrete equations of motion for the whole structure.To get modal loss factors, we introduce small parameters concerning damping to complex eigenvalue problem of the eqations under small deformation. And we obtain asymptotic equations from the zero and first orders. Then, the approximate modal loss factors are obtained like MSE. Further, by introducing normal coordinate corresponding to eigenmodes. the nonlinear discrete equations in physical coordinates are transformed into nonlinear ordinary coupled equations. The transformed equations are rapidly computed to obtain the nonlinear transient responses with a fairly small dof.

As a numerical example of this proposed FEM, we deal with elastic frames with damping layers supported by multiple nonlinear springs with hysteresis as shown in Fig.1. We investigate FEM models having theree different frames. Model a (Elastic Frame Model) has low damping because of this frame has no damping layer. And model b (Elastic Frame Model with Damping Layer) has high damping. Model c (High Stiffnes Elastic Frame Model with Damping Layer) has higher rigidity than model b because thickness of this frame in model c is twice of the model b. But damping of model c is lower than that of model b becasuse nuetral plane of the frame with viscoelastic layer is apart from the damping layer. Using the proposed method, we show new phenomena including nonlinear coupling between nonlinear springs with hysteresis and elastic frames and viscoelastic layers. We clarify influences of amplitude of the impact force on nonlinear transient responses. Under a very large impact force as a severe condition, there exist the complicated nonlinear couplings in Fourier spectrum in Fig.2. There are not only harmonic components of eigenmodes but also many super harmonic, subharmonic and ultra subharmonic components and internal resonances in Fig.2(a) for model a. Due to high damping of model b in Fig.2(b), nonlinear peaks and internal resonances are diminished. Due to lower damping than that of model b having high rigidity, the spectrum of model c in Fig.2(c) includes more nonlinear peaks.



(c)High Stiffness Elastic Frame Model with Damping Layer

Fig.2 Fourier spectrum of the nonlinear transient response under large input force

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