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Viscoelastic Material Models Based Active Vibration Controllers: *An Energy Approach*

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Abstract: Viscoelastic polymers have been employed for passive vibration mitigation in structures and rotating machines, however, its mechanical properties change with time. Taking inspiration from this passive technique of vibration reduction, this paper presents the fundamentals of designing control laws based on the constitutive relationship of a viscoelastic material for an active vibration control scheme. To this end, energy absorbed by the material model for a viscoelastic material model is formulated and compared for different models. The control law based on these material models will be designed based on maximization of energy absorbed by the material model in order to effectively mitigate vibrations from the system. The control laws based on the viscoelastic material models are shown to perform better as compared to conventional control laws. This analysis paves way for designing control laws based on the viscoelastic material models.

Keywords: active vibration control, viscoelastic material model, passive vibration

1. Introduction

In this paper a new approach to build control laws based on viscoelastic material models is presented. Viscoelastic material are known to improve stability and vibration characteristics when used in rotating machinery support [1], [2]. In recent literature, some control laws have been designed by taking inspiration from the viscoelastic material model ([3] [4],[5], [6]), however, an energy analysis-based design of such control laws, which forms the basis, has not been presented. This work therefore provides a theoretical framework behind the design of control laws based on energy absorbed by the viscoelastic material models.

2. Results and Discussion

Fig. 1(a) shows a schematic of a single degree of freedom discrete system mounted on a 2-element support (a stiffness and a damper) and acted upon by a harmonic force. Energy dissipated in one cycle in steady state is found using the following relation, $E_2 = \int_0^{2\pi/\omega} c\dot{x}^2\, dt$. For Three element model (Fig. 1(b), two stiffness and one damper), the governing equation is, $m\ddot{x} + c(\dot{x} - \dot{y}) + kx = Fcos(\omega t)$. Now, energy dissipated in one cycle at steady state can be found using the following relation, $E_3 = \int_0^{2\pi/\omega} c(\dot{x} - \dot{y})\dot{x}\, dt$. Evaluating the integral, one finds E_3. Similarly, the energy dissipated by the four element model (figure 1(c)) can be evaluated. The Non-Dimensional Energy absorption Ratio for three element model to two element model ($NDER_{32}$) and four element model to three element model ($NDER_{43}$) is shown in **Fig. 2**, where ξ is the damping ratio and λ is the stiffness ratio equal to $\frac{k_3}{k}, \frac{k_4}{k}$, for three element model and four element model respectively. The values of the ratios > 1 promise efficacy of higher element model over conventional 2-element model.

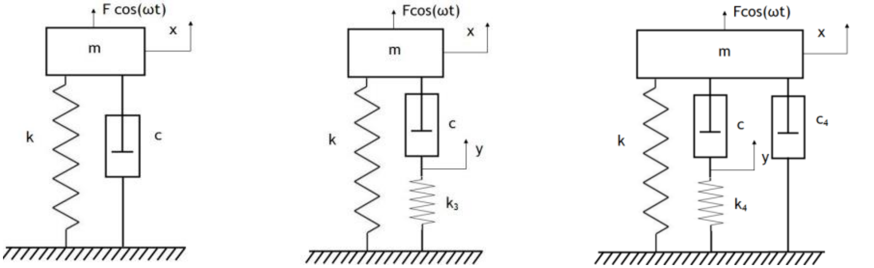

Fig. 1: (a) Two element model (b) Three element model (c) Four element model

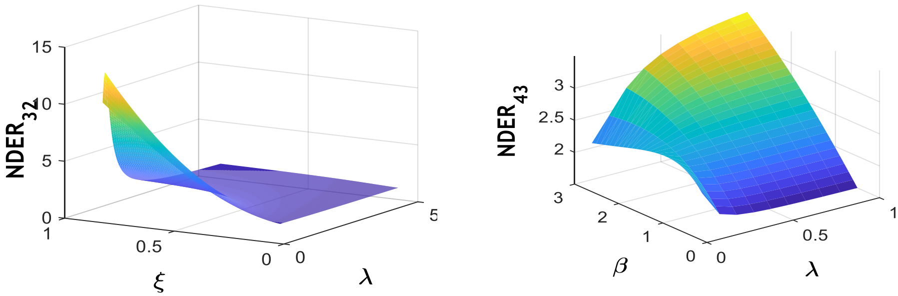

Fig. 2: Non dimensional energy rato between (a) three element model and two element model (b) four element model and three element model

3. Concluding Remarks

This paper proposes novel approach in building control laws for active vibration control by taking inspiration from passive viscoelastic material properties. Energy absorbed by the viscoelastic material model is considered as a criterion for designing control laws. Properly designed higher element models promise very efficient energy dissipation and ensure better stability and vibration control over conventional controllers.

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