Dynamic Modelling and Analysis of a Rotating Flexible Beam with Segmented Constrained Layer Damping Treatment

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EXTENDED ABSTRACT

The damping performance of the active constrained layer damping (ACLD) treatment for vibration control of flexible structures has been studied by many scholars. One way to improve the traditional ACLD is segmented constrained layer damping (SCLD). By generating a zone of concentrated shear deformation at the incision location, SCLD cuts off both the constrained layer and the constraining layer to improve the damping properties. In 1970, based on the passive constrained layer damping (PCLD), Plunkett and Lee [1] first examined SCLD by cutting the constrained layer to boost damping. Kress [2] suggested cutting off both the constrained layer and the constraining layer simultaneously. The "notch effect" is a shear deformation concentration area that the confining layer will create at the cut-off site. Limited damping property of the damping layer structure can be improved when using the method. The effectiveness of the segmentation approach was examined by Tian et al [3]. The results showed that the segmentation method only applied to low shear strain levels within the viscoelastic layer.

Unlike the cantilevered beams studied in Ref. [3], this paper considers the rotation of the beam and studies the flexible beam with full covered SCLD treatment. Fig. 1 shows a schematic diagram of a flexible beam with SCLD treatment attached to a rotating rigid hub. In the SCLD treatment, the space between the cuts is not taken into account.

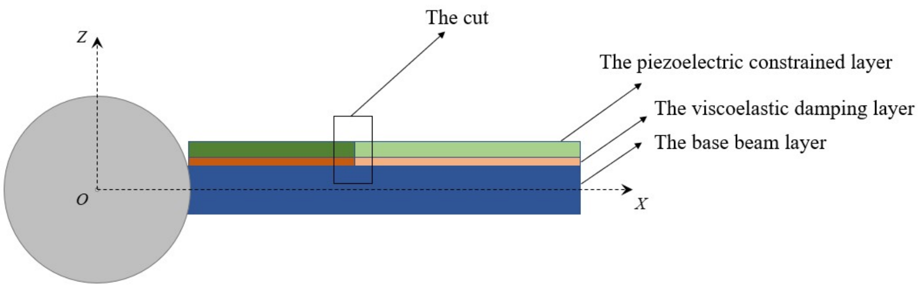


Fig. 1: A flexible beam with SCLD treatment attached to a rotating rigid hub

The deformation of the SCLD beam is discretized by the finite element method in this paper. The kinetic energy, potential energy, and generalized force of the discretized unit can be substituted into Lagrange's equations of the second kind to obtain the dynamic equations of the i-th element. The cutout is placed at the node between two elements during the finite element assembly. The degrees of freedom at the node where the notch is located are expanded from the original $\left\{ w_1^{(k)} \; w_3^{(k)} \; w^{(k)} \; w'^{(k)} \right\}$ to $\left\{ w_1^{(k)} \; {w_{3r}}^{(k)} \; {w_{3l}}^{(k)} \; w^{(k)} \; w'^{(k)} \right\}$. The dynamic equations of the system can be obtained as:

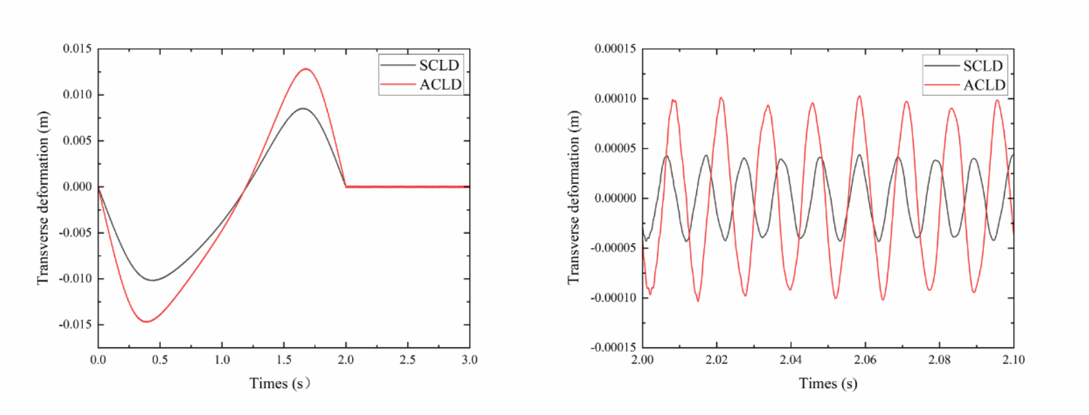
$$\begin{bmatrix} M_{11} & \boldsymbol{M}_{12} \\ \boldsymbol{M}_{21} & \boldsymbol{M}_{22} \end{bmatrix} \begin{bmatrix} \ddot{\theta} \\ \ddot{\boldsymbol{q}} \end{bmatrix} = \begin{bmatrix} Q_\theta \\ \boldsymbol{Q}_q \end{bmatrix} \tag{1}$$

The dynamic response analysis is performed for the flexible hub-beam with SCLD treatment. To speed up the solution of the dynamics equations and manage the dissipation of the numerical damping, the system dynamics equations are solved by the HHT-α method utilizing MATLAB programming.

For the dynamic response analysis, the radius R of the hub is neglected. The driving moment of the structure is set as:

$$\tau = \begin{cases} \tau_0 \sin\left(\dfrac{2\pi}{T} t\right), & 0 \le t \le T \\ 0, & t > T \end{cases} \tag{2}$$

Fig. 2 shows comparison of the tip transverse deformations of the beam with ACLD and SCLD treatment. The segmentation method reduces the maximum amplitude of the rotating beam. Additionally, at t > T, i.e., when there is no driving moment, the maximum vibration amplitude of the rotating beam with SCLD treatment is substantially smaller than that of the beam with ACLD treatment.



(a) (b)

Fig. 2: Tip transverse deformation of the rotating ACLD/SCLD beam in open-loop case

A new dynamic model for active and hybrid vibration control of flexible beam structures under large overall rotational motion is presented in this study. By ignoring the cutout's gap and positioning it at the node between the elements, the dynamics of the hub-beam with SCLD treatment are studied by using the floating frame of reference method. In finite element assembly, the notch is achieved by the discontinuity of the displacement between the elements. The segmentation method of the ACLD beam has a more significant vibration suppression effect when suitable material and dimensional parameters are adopted.

Acknowledgments

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