力学学报　2004 36 (5): 540-548　ISSN: 0567-7718 CN: 11-2063/O3

阶梯压电层合梁的波动动力学特性

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收稿日期　修回日期　网络版发布日期　接受日期

摘要　采用行波理论系统地研究了压电阶梯梁的自由振动分析以及强迫响应的分析方法．基于分布参数理论研究了压电阶梯梁的波传播特性，忽略柔性梁横向剪切和转动惯量的影响，给出了梁的轴向和横向的简谐波解．将压电阶梯梁离散化为单元，考虑压电片的刚度和质量的影响，建立了节点散射模型．应用位移连续和力平衡条件，推导了节点的波反射和波传递矩阵，在此基础上，引入波循环矩阵的概念，给出波循环矩阵、波传递系数矩阵的确定方法．应用波循环矩阵可以有效地计算结构的固有频率．另外，应用波传递系数研究了压电陶瓷作动器位置对其驱动能力的影响．得出两个主要结论：1)作动器靠近悬臂梁固定端将有较强的驱动能力，悬臂梁边界反射行波产生弯曲消失波有利于增大压电波的模态传递系数；2)模态传递系数与固有频率的灵敏度密切相关，波传递系数越大，对应该处固有频率变化灵敏度越大．另外，数值算例表明了行波方法比有限元方法具有更高的计算精度.

关键词　行波,波循环,波传递,层合梁

分类号

Wave mode characteristics on piezo-electric stepped beam

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Abstract

In this paper, a systematic approach for the free vibration analysis and forced-response of the beam bonded with PZT patches is presented employing the travelling wave method. The wave propagation characteristic of the stepped beam bonded with PZT patches is studied based on distributed parameters theories. Neglecting the effect of transverse shear and rotary inertia, harmonic wave solutions are found for both flexible and axial vibration of beam models. Then, the system is simplified into a node model considering multiple point discontinuities due to attached masses, and actuated moment of PZT patches. And wave scattering matrices including wave reflection and transmission matrices in nodes are formulated by applying the compatibility of displacements and equilibrium of forces at the junctions. Based on the above work, the concept of the wave loop, which is the process when the vibration wave comes through a periods along the wave propagation paths, is introduced, and wave loops and transmission matrices are derived accounting for general boundary conditions. Therefore, the wave loops matrices combined with the aid of field transfer matrices provides a concise and efficient method to solve the free vibration problem of beam bonded with PZT patches. The frequencies and response solutions are exact since the effects of attenuating wave components are included in the formulation. Furthermore, the general relations between the flexural wave transmission factor and the position of the PZT actuator in structures is discussed too. The numerical results give two major conclusions: 1) the PZT patch bonded position near by the fixed-end in beam has the powerful actuated capability, because the attenuating wave components created by the active wave incident upon the discontinuities boundary enhance the transmission effectiveness of the active traveling wave propagation; 2) the modulus of the mode transmission factor has a close relation with the sensitivity of the nature frequencies. The bigger modulus of the mode transmission factor, the bigger sensitivities factor of the nature frequencies is. In addition, a comparison of eigenvalues and frequency response function obtained by finite element method (FEM) and the wave method respectively is also presented. It is indicated that the result by the wave method is more exact than one by FEM.

Key words　wave propagation　wave reflection and transmission　wave loops　stepped beam

DOI:

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