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基于谱元法的裂Lamb纹梁波传播特性研究

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LAMB WAVE PROPAGATION IN A CRACKED BEAM USING SPECTRAL FINITE ELEMENT METHOD

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摘要

首次提出用一种无质量弹簧元来模拟含横向裂纹梁的轴弯耦合效应,并结合谱元法分析含裂纹梁内Lamb波的传播特性.由卡氏定理和断裂力学方法推导弹簧元的刚度,以此构建裂纹处的平衡条件和位移协调条件,建立损伤谱元模型.通过和传统的有限元模型进行比较,表明在显著提高计算效率的同时,所提出模型在分析结构固有特性和Lamb波传播特性上都具有较高的精度.在所提出模型的基础上又推导出基于谱元法的能量计算公式,通过裂纹处的能量守恒再次验证损伤模型的正确性和有效性,同时研究结果表明裂纹处转化生成的Lamb 波各模态能量随裂纹深度的变化具有单调性,该结论可以为结构健康监测中定量识别裂纹提供实用依据.

关键词: 结构健康监测 Lamb波传播 谱元法 能量 横向裂纹

Abstract:

A massless spring, coupling the longitudinal and rotational vibration, is proposed to model the transverse crack and to analyze wave propagation in a cracked beam, based on a spectral finite element method. The stiffness of the spring is obtained from Castigliano’s theorem and laws of fracture mechanics. The spring is used to establish force equilibrium and displacement compatibility conditions, by which a cracked spectral finite element model is developed. Compared with the conventional finite element method, the proposed model is proved to obviously improve calculation efficiency and have high accuracy in modal analysis and Lamb wave propagation. Power reflection and transmission are demonstrated to meet with an energy conservation law. Energy of Lamb wave modes varying with the crack depth is also calculated and changes monotonously, which may provide some practical foundations for the quantitative crack identification in structural health monitoring.

Key words: structural health monitoring Lamb wave propagation spectral finite element method energy (power) transverse crack

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