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压电振动能量采集器的力电耦合模型及其功率优化

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摘　要：

为提高传统压电振动能量采集器集总参数模型的性能预测精度，本文考虑悬臂梁的振型信息与轴向应变分布情况，提出了一种改进的力电耦合模型，该模型引入无因次幅值修正因子，通过曲线拟合方法确定了修正因子与振型函数和振动幅值之间的关系表达式；利用Rayleigh-Ritz模态分析法确定了力电耦合模型中的集总等效参数（如质量、刚度等），并根据弹性动力学原理建立了能量采集器的运动控制方程，得到了稳态时能量采集器的力、电输出响应表达式；最后，利用改进的模型对能量采集器的负载电阻和输出功率进行了优化，得到了负载短路和负载开路时能量采集器的最优输出特性。仿真结果与实例对比验证了本文提出模型的正确性，表明改进的力电耦合模型具有较高的预测精度。

关键词：能量采集器；力电耦合模型；功率优化；仿真分析；曲线拟合

A force-electric coupling model and power optimization of piezoelectric vibration energy harvester

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Abstract:

In order to overcome the disadvantages of the traditional lumped parameter model of piezoelectric vibration energy harvester (PVEH) , this article presents an improved force-electric coupling model (FECM) to predict the output performances of the PVEH by considering the dynamic mode shape and the strain distribution of the bender. A dimensionless correction factor is adopted in the FECM to formulate the relationship expression between the mode shape and the vibration amplitude of the PVEH with curve fitting method. The equivalent parameters (such as mass, stiffness) of FECM are obtained by using the Rayleigh-Ritz modal analysis method, the governing motion equations and the exact analytical solution of cantilevered piezoelectric vibration energy harvester excited by persistent base motions are developed according to the elastic dynamics principle. The steady state electrical and mechanical output response expressions are derived for arbitrary frequency excitations. Finally, the optimizations of the load resistance and the output power of the PVEH are carried out and the optimized output power under short circuit and open circuit conditions are obtained, respectively. The accuracy of the output performances of FECM is identified from those of the coupled distributed parameter model (CDPM). A good agreement is found between the analytical results of FECM and CDPM, which tests the validity of the proposed FECM and can improve the predictions of output performances of PVEH.

Keywords: vibration energy harvester; force-electric coupling model; power optimization; numerical analysis; curve fitting

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