[25] LIANG X, ZHANG R, HU S, et al. Flexoelectric energy harvesters based on Timoshenko laminated beam theory[J]. Journal of Intelligent Material Systems and Structures, 2017, 28(15): 2064-2073.
[26] YAN Z. Modeling of a piezoelectric/piezomagnetic nano energy harvester based on two dimensional theory[J]. Smart Materials and Structures, 2017, 27(1): 015016.
[27] ERTURK A, INMAN D J. 压电能量收集[M]. 舒海生, 赵丹, 史岩硕, 译. 北京: 国防工业出版社, 2015: 19-111.
[28] TANG L, WANG J. Size effect of tip mass on performance of cantilevered piezoelectric energy harvester with a dynamic magnifier[J]. Acta Mechanica, 2017, 228(11): 3997-4015.
[29] LIANG X, HU S, SHEN S. A new Bernoulli-Euler beam model based on a simplified strain gradient elasticity theory and its applications[J]. Composite Structures, 2014(111): 317-323.
[30] CHU B, SALEM D R. Flexoelectricity in several thermoplastic and thermosetting polymers[J]. Applied Physics Letters, 2012, 101(10): 103905.
[31] BASKARAN S, HE X, WANG Y, et al. Strain gradient induced electric polarization in α-phase polyvinylidene fluoride films under bending conditions[J]. Journal of Applied Physics, 2012, 111(1): 014109.
[32] ZHOU Y, LIU J, HU X, et al. Flexoelectric effect in PVDF-based polymers[J]. IEEE Transactions on Dielectrics and Electrical Insulation, 2017, 24(2): 727-731.
[33] ALADWANI A, ALDRAIHEM O, BAZ A. A distributed parameter cantilevered piezoelectric energy harvester with a dynamic magnifier[J]. Mechanics of Advanced Materials and Structures, 2014, 21(7): 566-578.

Effect of tip mass on performance of cantilever beam flexoelectric energy harvesters

LIN Xiaohui[1], SU Yaxuan[2], CHEN Benqiang[1], ZHOU Zhidong[1]*

(1. Fujian Key Laboratory of Advanced Materials, College of Materials, Xiamen University, Xiamen 361005, China; 2. Chengyi University College, Jimei University, Xiamen, 361021, China)

Abstract: The tip mass has a significant influence on the performance of flexoelectric energy harvesters. In this paper, based on Euler–Bernoulli beam assumption and the electric Gibbs free energy, the dynamic electromechanical coupling governing equations and the corresponding boundary conditions of flexoelectric energy harvesters are derived using the variational principle method. The modal orthometric conditions and parameters for the normalized mode of vibration are obtained by the separation of variable method. Furthermore, the mode superposition method is used to derive the analytical expressions of the displacement and electric potential responses of the flexoelectric energy harvester with the extrinsic harmonic mechanical excitation. The numerical results indicate that the increase of the value of mass and decrease of the size of the tip mass could not only increase the output power density and decrease the resonant frequency of the energy harvester, but also adjust the optimal resistance. In addition, when the size of mass is fixed, the

value of mass of the tip mass is larger, and the error caused by considering the tip mass as a particle is more distinct.

Key words: tip mass; flexoelectric energy harvester; modal analysis; power density; variational method