Reliability of fractional-order hybrid energy harvesters under random excitations

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Abstract. Reliability of a fractional-order hybrid energy harvester driven by Gaussian white noise is investigated in this paper. Firstly, the approximately equivalent system can be derived with the help of variable transformation and stochastic averaging method. Then the backward Kolmogorov equation governing the conditional reliability function and the generalized Pontryagin equation governing the statistical moments of first-passage time are obtained from the averaged equations. Finally, influences of system parameters on reliability function and first-passage time are presented by numerically solving the corresponding equations.

Introduction

Vibration energy harvester, which can convert the mechanical energy into electrical energy to achieve the self-powered of the micro-electromechanical systems (MEMS), has received extensive attention. To improve the efficiency of vibration energy harvesters, many approaches have been adopted including the combination of two conduction mechanisms, the use of the advanced materials and stochastic loading [1]. Some research results have shown that fractional-order models are suitable to describe the viscoelastic properties of advanced materials [2]. And the response of the fractional-order hybrid energy harvester driven by random excitation has been studied [3]. First-passage problem aims to determine the probability that systems response reaches the boundary of a bounded safe domain of state space within its lifetime. As one branch of reliability in mathematics, it can exactly describe the response feature and fatigue life of structures such as offshore platform, civil construction, etc. To the best of authors' knowledge, there is little work on the reliability analysis of the fractional-order hybrid energy harvester driven by random excitation.

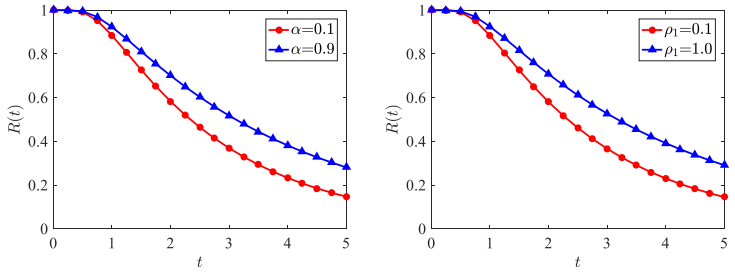

Figure 1: Reliability function for different fractional order (a) and electro-mechanical coupling coefficient (b).

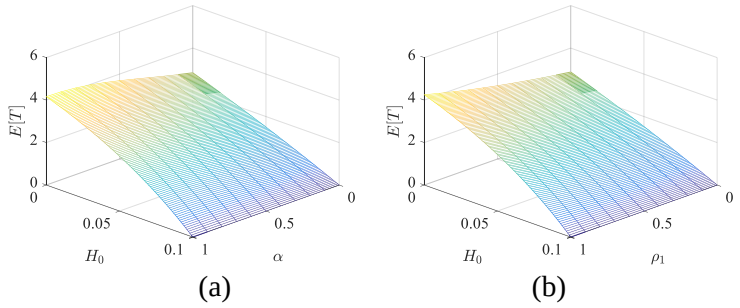

Figure 2: Mean first-passage time for different fractional order (a) and electro-mechanical coupling coefficient (b).

Results and discussion

The reliability analysis of a fractional-order hybrid energy harvester subject to Gaussian white noise has been presented in this paper. As shown in Figs. 1 and 2, the reliability function is monotonically decreasing for time and the mean first-passage time is also monotonically decreasing for initial energy. In addition, the reliability function and the mean first-passage time increase as the fractional order α and the electro-mechanical coupling coefficient ρ_1 increase.

References

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