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The College of Graduate Studies and the College of Engineering Cordially Invite You to a

Master Thesis Defense

Entitled

DEVELOPMENT OF PIEZOELECTRIC ENERGY HARVESTING SYSTEM FOR LOW FREQUENCY VIBRATIONS

by

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Abstract

Harvesting energy from vibration sources has attracted the interest of researchers for the past three decades. Researchers have been working on the potential of achieving self-powered MEMS scale devices. Piezoelectric cantilever harvesters have caught the attention in this field because of the excellent combination of high-power density and compact structure. The main objective of this thesis is to develop a novel and optimum piezoelectric harvester system using lumped parameter model (LPM) for given vibration sources. Finite element model (FEM) is used in this work as an original approach to be utilized for optimal design optimization. Three types of validations are accomplished to solidify the use of FEM in mimicking the distributed parameter model (DPM) for linearly tapered piezoelectric cantilevers. The first two validations are accomplished using beam deflection and relative transmissibility functions. Comparisons between the FEM and the DPM developed by the literature are performed. The third validation is carried for an electromechanical piezoelectric cantilever in FEM. Results confirmed the effectiveness of the developed FEM. Number of significant contributions are achieved while fulfilling the aim of this work. First, a dimensionless parameter, Power Factor (PF), is derived and used to understand the impact of the geometry on the piezoelectric harvester performance. The PF showed an optimum performance at a taper ratio of 0, taking the full length of the cantilever and thickness ratio of 0.7. Second, the accuracy of the LPM for linearly tapered piezoelectric harvesters and optimal design are investigated. Results indicated that the percentage of the deflection error between the LPM and the FEM reaches 9% when the taper ratio is zero. However, when tip-mass to cantilever ratios are larger than 2, the error decreases to less than 0.5% leading to more accurate results in the vibrational response of the beam. Further studies on the accuracy are accomplished using the relative transmissibility function. Results showed that as the taper ratio decreases towards zero, the percentage error of using the LPM to predict the vibration response increases significantly to 55%. These results lay the foundation for the third contribution of developing correction factors for tapered and optimal piezoelectric cantilever harvesters using FEM. Comparisons of the corrected LPM and FEM for different configurations are examined. Results indicated that as the taper ratio decreases, the surface power density increases. However, the developed optimal design exhibits the highest surface power density of 1.40×104 [(mW/g2)/ m2] which is 16.4% more than the best following shape of a taper ratio 0.2 and 58% more than the taper ratio 1. Furthermore, a parametric study of the optimal design is performed to scrutinize the effect of various parameters on the harvester performance. Finally, detailed criteria for designing the optimal piezoelectric harvester for different conditions are structured.

Keywords: Energy harvesting, optimal piezoelectric harvester, correction factor, lumped parameter model, finite element model, analytical analysis.