ABSTRACT

Vibration energy harvesting is the process of converting natural and human-made vibrations into usable electrical energy. Electromagnetic, electrostatic, and piezoelectric materials are the conversion techniques used to convert mechanical vibration energy into electrical energy. Among these techniques, piezoelectric material has more power density compared to others. Smart electronic devices and wireless sensors use electrochemical batteries and external power supplies to power themselves. In the last few decades, the performance of electronic devices grow steadily but the performance of batteries remains stagnant. The batteries need charging, maintenance and replacement over the time. Researchers found that piezoelectric energy harvesting is one of the ways to overcome this problem.

In this thesis, investigation on different geometries of the beam for piezoelectric energy harvesting has been done. The effect of placement of piezoelectric material on the beam for energy harvesting and analysis of effect of proof mass (material, shape, size, and orientation) on frequency, optimal load, voltage and power was done. Analysis of unimorph and bimorph energy harvesters with multipatch piezoelectric materials was also done.

Among the various beam geometries proposed for piezoelectric energy harvesting, the selected beams were Rectangle (REC), Triangle (TRI), Taper in width (TAP W), Taper in thick (TAP T), Taper in thick & width (TAP TW), Inverted taper in width (INTAP W), Inverted taper in thick (INTAP T) and Inverted taper in thick & width (INTAP TW) based on stress and strain analysis. Five beams namely REC, TRI, TAP W, TAP TW, and INTAP TW beams were considered and the resonant frequency, open circuit voltage, optimal load, voltage, and power under load were determined by experimental

and numerical methods. Since the deviation between the experimental and numerical method is less, the same methodology was applied for numerical analysis of the other beams. From numerical analysis, it was found that the INTAP TW beam produce 0.73 mW per unit volume.

The distance between the fixed end of the beam and piezoelectric material was varied and the performance was analysed numerically. It was observed that when the piezoelectric material is placed at the fixed end, the energy harvester produces maximum power of 97.65 % compared to piezoelectric material placed at a distance of 60 mm. The piezoelectric material placed at a distance of 0 mm from the fixed end has wide operating range of 80 Hz to 110 Hz due to more strain induced near to the fixed end. The piezoelectric material placed at a distance of 60 mm from the fixed end has an operating range of 75 Hz to 80 Hz. The effect of different materials of proof mass at the free end of the beam was analysed numerically and the effect of proof mass at various positions and shape over the beam were also analysed. The material, volume, and size of the proof mass do not have any significant effect on the power, resonance and operating frequency range of energy harvesting performance. It was found that the type of placement of the proof mass /shape of the proof mass has an effect of 1.92 % on power and 10.93 % on the resonant frequency of the beam.

The performance of various geometries of uni-morph and bi-morph piezoelectric energy harvester with two piezoelectric materials was analysed numerically using COMSOL Multiphysics 5.3a. The beam geometries considered for energy harvesting with multiple piezoelectric materials are REC, TRI, TAP W, TAP T, TAP TW, INTAP W, INTAP T, and INTAP TW beam. From numerical analysis, it was found that INTAP TW, INTAP T, and INTAP W unimorph energy harvester produced 48.38 %, 34.34 %, and 21.56 % more power per unit volume than REC unimorph energy harvester. TAP W, TAP T, TRI, and TAP TW unimorph energy harvester produce 33.75 %, 38.03 %, 60.69 %, and 61.25 % less power per unit volume than REC energy harvester. From the numerical analysis of bimorph energy harvesters, it was observed that INTAP TW, INTAP W, INTAP T, TAP W, TAP T, TRI, and TAP TW bimorph energy harvester produced 14.68 %, 27.27 %, 32.51 %, 36.01 %, 43.70 %, 81.46 %, and 81.81 % less power per unit volume compared to REC bimorph energy harvester.

A prototype energy harvester was designed and developed using 3D printer. INTAP TW beam was used along with the movable proof mass. The developed energy harvester could work in the resonant frequency range of 17.5 Hz to 25.24 Hz. The energy harvester charges 60 mAh battery in 34.28 hours with given acceleration of 0.5g.