Design and Simulation of Piezoelectric MEMS Cantilever

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Introduction: The vibration due to unevenness in the road surface are assumed to transfer onto the piezoelectric material through the surface of tyre. The figure also explains a schematic model where the tyre is assumed to behave as a linear spring system with k and c the equivalent stiffness and damping constant of the tyre.

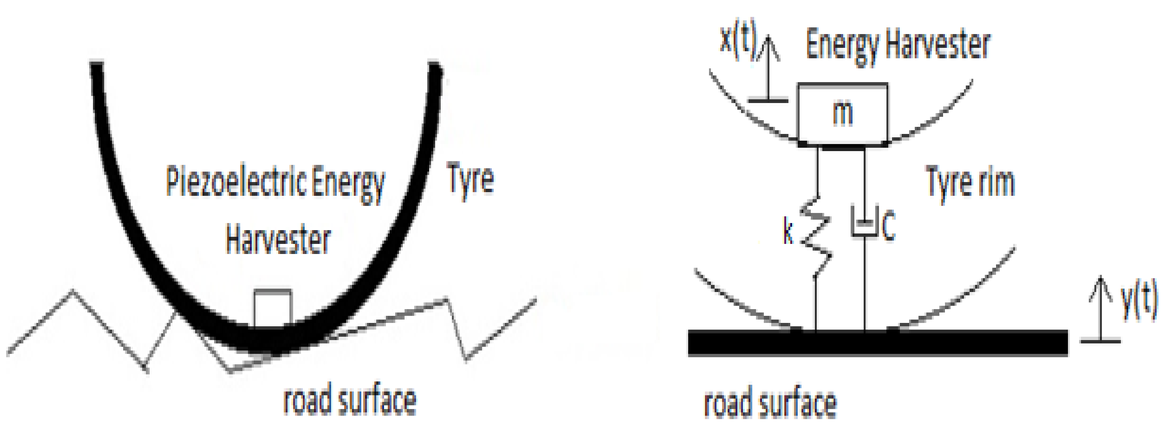

Figure 1. Effect of road surface on Piezoelectric Harvester

Computational Methods: The cantilever structure under consideration consists of five layers, viz. Poly-Silicon as metal base, Silicon dioxide (SiO_2) as insulation material, Aluminium (Al) as metal electrodes, Nickel (Ni) as proof mass and Zinc oxide (ZnO) as the piezoelectric material as shown in Figure 2.

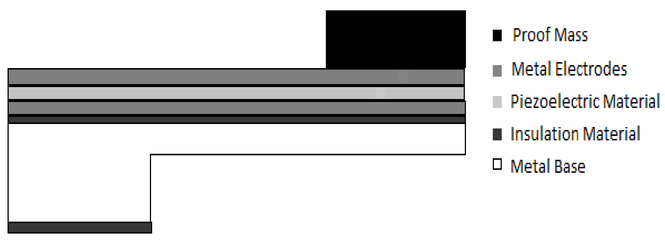

Figure 2. Schematic Diagram of Cantilever Design

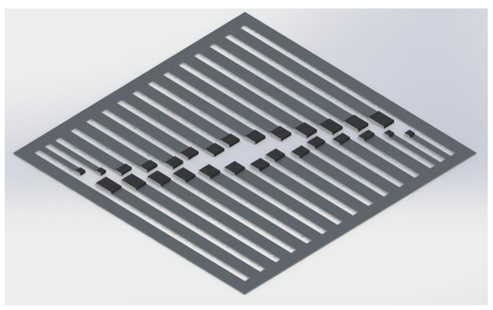

Figure 3. 3D cantilever model array

Simulations were performed for d_{31} mode varying the cantilever dimension to harness the range of ambient frequency as would have been encountered in a normal road condition. Steady state analysis and frequency analysis simulation were performed on individual cantilever.

Figure 3 shows the concept of the array intended to be used to harness ambient vibrational energy in a car tyre.

Results: The steady-state analysis and the frequency analysis is conducted to simulate the resonance frequency and maximum displacement of the cantilevers. The output achieved of individual cantilever and the array model are shown in the figures below

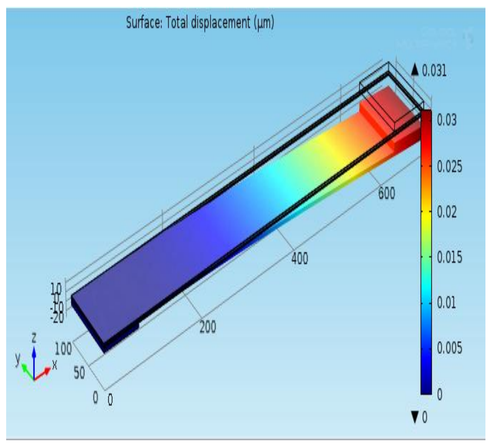

Figure 3. 3D Model of simulation

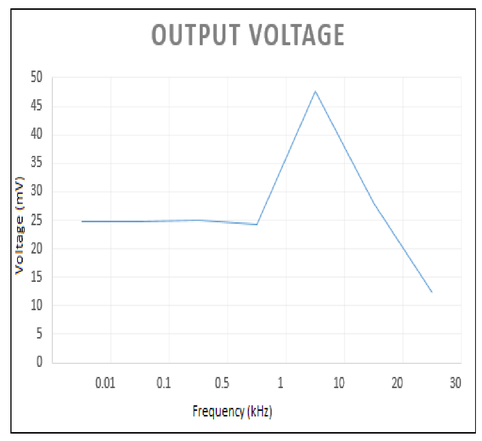

Figure 4. Array output voltage v/s frequency of vibration

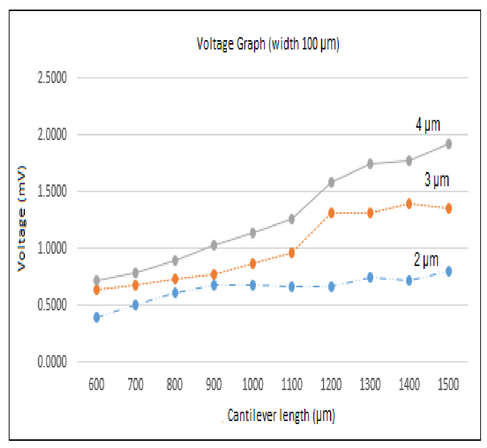

Figure 5. Voltage v/s cantilever length for 100 μm width

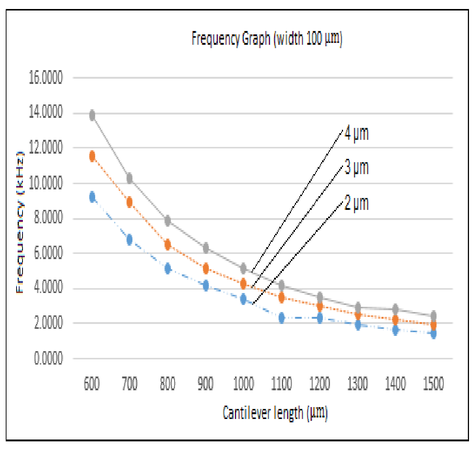

Figure 6. Frequency v/s cantilever length for 100 μm length

Conclusions: An array of cantilevers was designed and a frequency analysis was performed revealing a maximum voltage of 47.52mV attained at a frequency of 10 kHz. The main purpose of the array device, to harness a range of vibration and sustain a harsh environment viz. tyre surface, can be achieved through the proposed design.

References:

1. Jing-Quan Liua, Hua-Bin Fang, Zheng-Yi Xu, Xin-Hui Mao, Xiu-Cheng Shen, Di Chen, Hang Liao, Bing-Chu Cai, “A MEMS-based piezoelectric power generator array for vibration energy harvesting”, Micro-electronics Journal 39 (2008) 802–806, Elseiver