Design, Simulation and Optimization of Bimorph Piezoelectric Energy Harvester

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Introduction: Sustainable power generation is the key factor towards successful device miniaturization. Built in energy harvesters is a popular approach for small wireless devices. For energy devices to yield optimum results it is important that their design configurations maximize the level of power transfer. The main objective is to find parameters that give lowest resonant frequency and highest output power.

Computational Methods: The model in COMSOL is analyzed by making variations in load resistance, width and length of piezoelectric plate. The power generated depends on the resonant frequency and the load resistance by the expression:

\[ P = \frac{V_{\text{rect}}}{R} \left( \frac{2a}{\pi R C p \omega_p} + \frac{2 \pi R C p \omega_p}{a R} \right) \]  

Which gives us:

\[ P = \frac{V_{\text{rect}}}{R} \]  

The power harvester consists of a piezoelectric bimorph clamped at one end with a proof mass mounted on the other end. The bimorph has a grounded electrode embedded within it and two electrodes on the exterior surfaces of the cantilever beam.

Load resistance 12 kΩ

Width of piezo plate 14 mm

Length of piezo plate 21 mm

Proof mass dimensions 4 mm x 1.7 mm

Figure 1 – Configuration of bimorph piezoelectric harvester in COMSOL

Results: The parameters varied are Load resistance, width of piezo plate, length of piezo plate and all other values are kept constant. Table 2, table 3 and table 4 shows the effect of the variation of these parameters on the resonant frequency and the electrical power output.

Table 1 – Initial values of the parameters

<table>
<thead>
<tr>
<th>Load resistance (kΩ)</th>
<th>Voltage (V)</th>
<th>Resonant frequency (Hz)</th>
<th>Mechanical power (mW)</th>
<th>Electrical power (mW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>4.85</td>
<td>74.5</td>
<td>0.955</td>
<td>0.955</td>
</tr>
<tr>
<td>8</td>
<td>5.075</td>
<td>79.5</td>
<td>1.05</td>
<td>1.05</td>
</tr>
<tr>
<td>10</td>
<td>5.51</td>
<td>68.5</td>
<td>1.32</td>
<td>1.32</td>
</tr>
<tr>
<td>12</td>
<td>5.385</td>
<td>72</td>
<td>1.69</td>
<td>1.69</td>
</tr>
<tr>
<td>14</td>
<td>5.675</td>
<td>76.5</td>
<td>2.12</td>
<td>2.12</td>
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<tr>
<td>16</td>
<td>6.75</td>
<td>74.5</td>
<td>2.89</td>
<td>2.89</td>
</tr>
<tr>
<td>18</td>
<td>6.2</td>
<td>77</td>
<td>3.09</td>
<td>3.09</td>
</tr>
<tr>
<td>20</td>
<td>6.4</td>
<td>77.5</td>
<td>3.66</td>
<td>3.66</td>
</tr>
</tbody>
</table>

From the readings of table 4 it can be observed that the electrical power output is maximum value of 1.326 mW (marked yellow) when the voltage is maximum and load resistance is towards the higher scale at a low scale resonant frequency.

Conclusions: Above comparison provides the optimized parameters for best harvester design. With the proof mass being constant, load resistance variation, yields that the output power is inversely proportional to load resistance and resonant frequency is directly proportional. When the width of the piezo plate is increased, the damping factor reduces which causes a higher resonant frequency and an increase in power output. Increase in length of the piezo plate increases the damping factor and hence causes a drop in the resonant frequency and the output power. In all the cases the proof mass dimension is kept a constant and varying the proof mass dimensions along with the length and width of the piezoelectric plate might give a different output which is included in future study. Thus COMSOL simulative study emerges as the effective tool to provide confidence to designers to design time and cost effective designs.

References: