Research Experiences for Teachers and Young Scholars in Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST)

Simulating Resonating Cantilevered Energy Harvesting Using SolidWorks

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Introduction

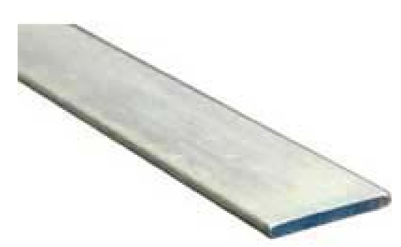
Energy Harvesting From Piezoelectric material (PZT) is an important part of the ASSIST initiative. It's a possible way to power the entire device. The energy is created when the PZT is bent or strained. One way to create that strain is to attach the PZT to a cantilever system. The cantilever system would need to resonate at a low frequency so as to work with human motion.

Methods

To verify the accuracy of the SolidWorks simulation various models were run and compared to measured and theoretical results.

Aluminum Test

To show SolidWorks would give accurate results, a simulated test was run on aluminum that was being measured in the lab. The results of the simulation would be compared to the results measured in the lab.



Results

Modes	First	second
Lab results	13 Hz	83 Hz
SolidWorks	13 Hz	81 Hz

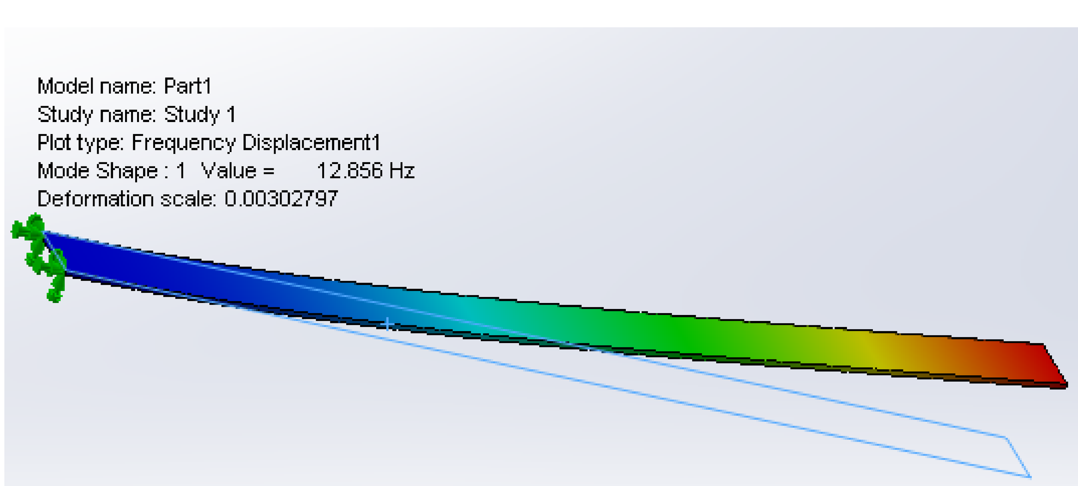


Figure 2: The Deflection of the aluminum is shown in the first mode.

The Above Table Shows that SolidWorks is accurate and it gave the same results as the test being performed in the lab. The second mode was off by 2 Hz. The Type of aluminum being tested was not known.

Verifying Measurements with piezoelectric

The Parameters used by Inman and Erturk were input into SolidWorks and a simulation was run. The Results for the 100 mm long beam with a layer of PZT showed similar resonating frequencies. The SolidsWorks models does not account for any electrical or fluid resistance which could account for the differences in the frequencies

Inman and Erturk	47.8 to 48.8 Hz
SolidWorks	43.0 Hz

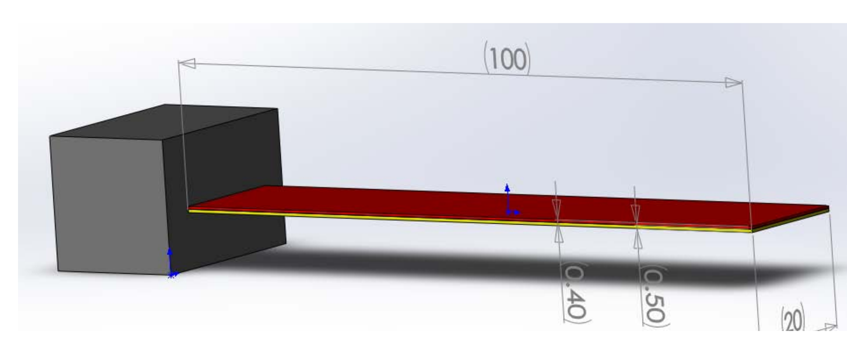


Figure 3: The beam as used by **Inman** and Erturk

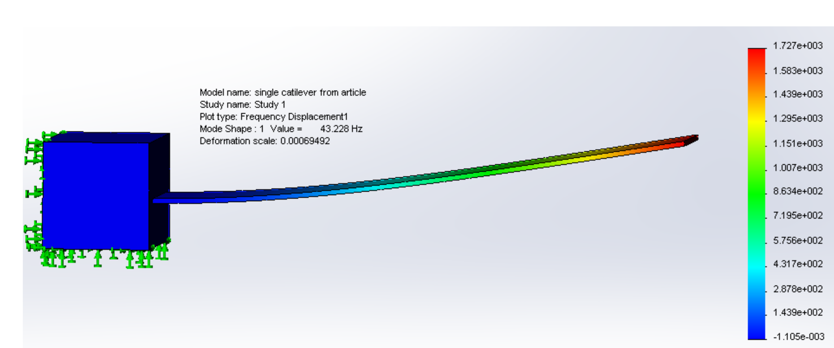


Figure 4: The beam deflection causes the PZT material to strain

The deflection of the beam is necessary to strain the PZT . As the material is strained energy is created. The energy can be taken from the PZT by adding electrodes to the PZT. The Inman and Erturk model is a large scale model that needs to be reduced in size and to have the frequency reduced for use on the human body.

Reducing Frequency

Lower frequencies are ideal because the objects will resonate from human movement and humans do not respond well to sudden accelerations.

Single Beam

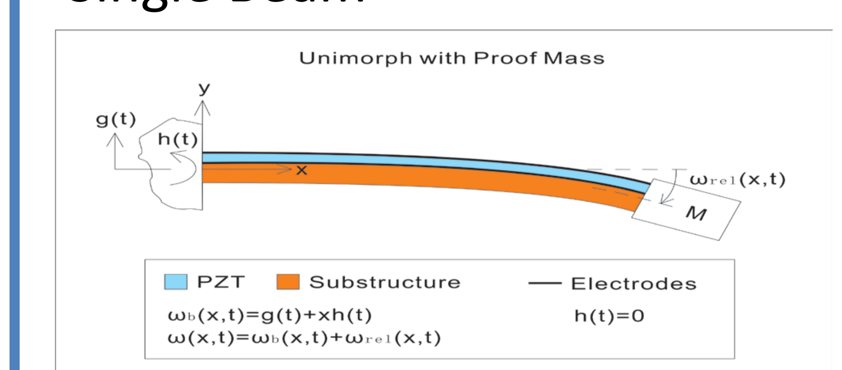
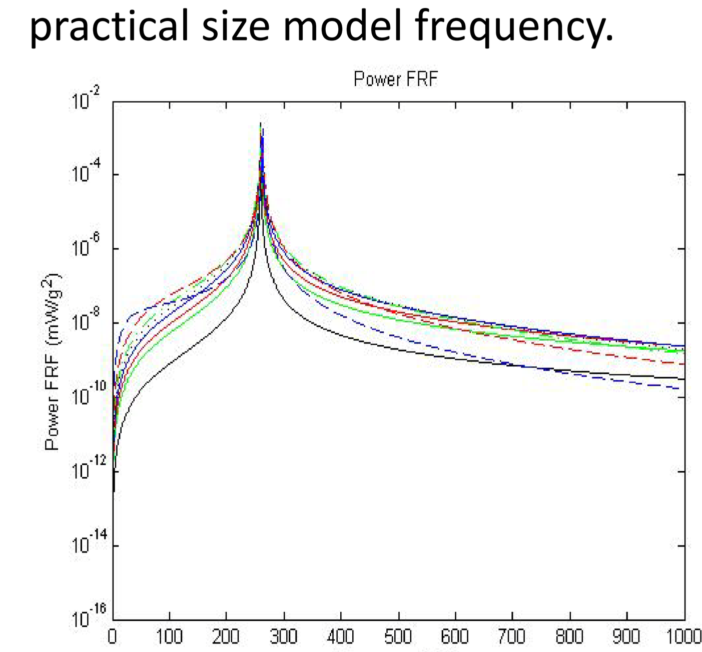


Figure 5: The smaller 1.5 mm long beam was put through the Euler Bernoulli beam model to examine a practical size model frequency.



Graph 1: Single cantilever has a peak power around 260 Hz and the power can be changed depending on the resistance.

Multiple Beams

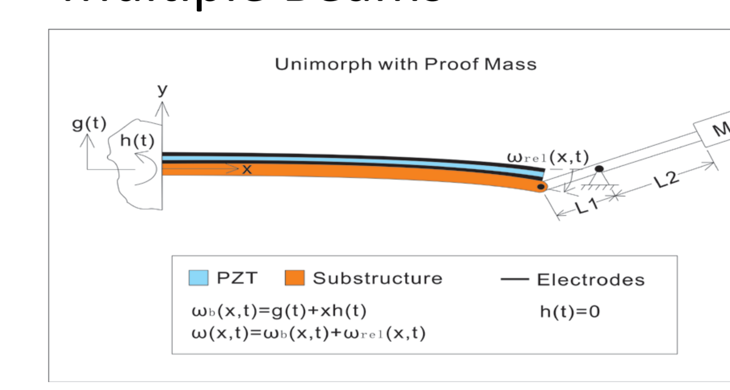
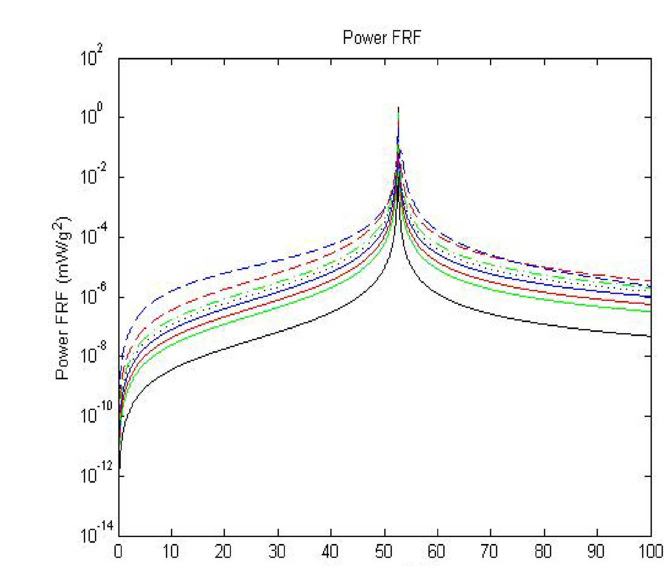


Figure 6: The multiple cantilever model that was also analyzed using the Euler Bernoulli beam model.



Graph 2: The multiple cantilever model reduces the frequency for peak power to 53 Hz

The Multiple beam model reduces the frequency by at about 5 times. This model treats the right beam as rigid and the mass as a point mass. For a practical model the hinges will not be present and the beam will be able to flex.

Three Beam Model

This is the most practical model and it acts like a multiple cantilever model. The outside two beams are made rigid by making the material thick and the middle beam on the left has the PZT attached to it. Its made thin so it can be strained. The right hand beam is also made rigid by increasing the thickness of the parylene bea material. A ratio of 1 to 5 for the right beam was used to lower the frequency.

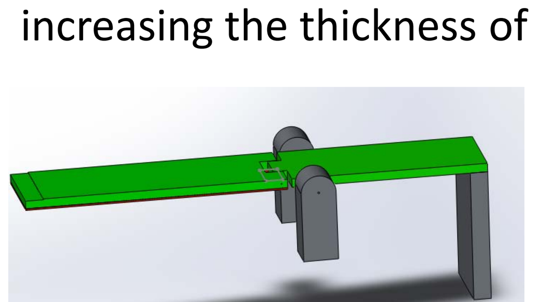
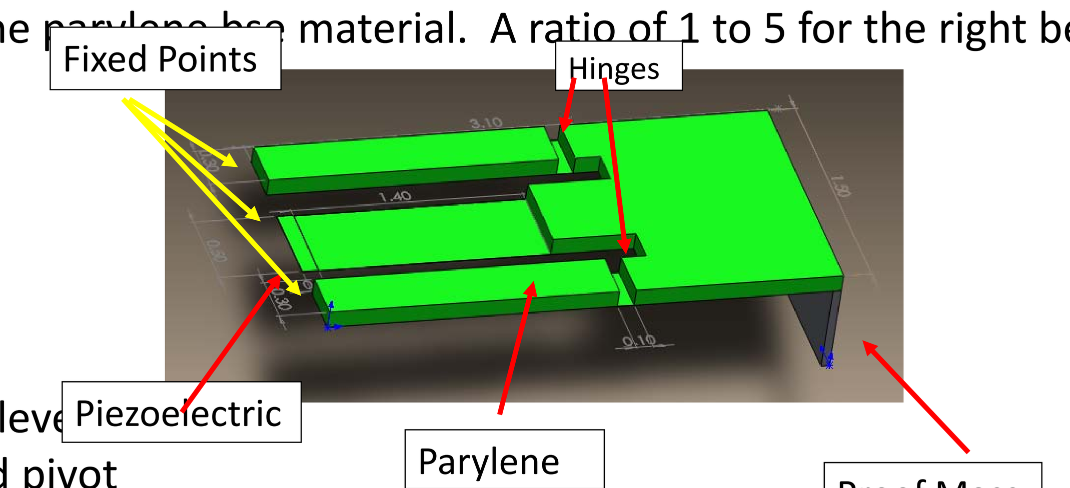


Figure 7: Is the multiple cantilever model with typical hinges and pivot points.



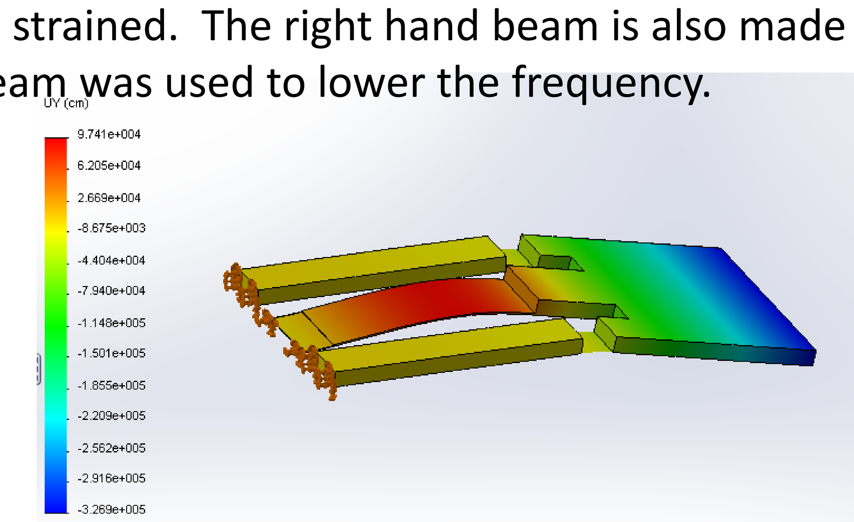


Figure 8 &9 : A three beam model with used to simulate the multiple cantilever model. The hinges were created by thinning the material where we wanted it to bend. The goal is get the lowest frequency possible while still straining the PZT.

Three beam Results

Theoretical results = 25.9 Hz
SolidWorks results = 43.8 HZ

The three beam model was the best design at reducing frequency and at simulating a structure that could possibly be built with thin films. The theoretical and simulated results are not that close. Perhaps the dimensions can be modified some to reduce the frequency

Conclusion

SolidWorks Can be used to simulate resonating systems. The aluminum test results were the same as the lab and the results by Inman and Erturk were similar. The more complicated multiple cantilever with hinges as shown in figure 7 did not give any results. Meshing errors prevented the simulation. The more complicated the systems the more difficulty SolidWorks has with meshing. This is especially true for thin material such as the 1 µm thick PZT. The current dimensions of the three beam model gives a lowest frequency of about 44 Hz in SolidWorks. This Frequency will need to be reduced to at least 10 Hz. It may be possible to reduce frequencies by changing the parameters of the three beam model.

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