HAMLINE UNIVERSITY
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Analyzing Piezoelectric Materials for Renewable Energy Applications

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Background

The piezoelectric effect is the ability of certain crystals to produce a voltage when stress is applied to them. As the crystal is deformed from its unstressed condition, the realignment of ions or polar molecules creates an electric potential difference, which may then be used to generate a current. Some materials can be exploited to respond only to a specific direction of applied stress through polarization. The different crystals have properties that make them suitable for harvesting their environment's energy from a specific source including direct shock, mechanical vibrations, sound waves, or simply bending the material.

Our ultimate objective is to utilize a bendable piezoelectric generator to charge a battery by harvesting energy from walking. By constructing a panel that allows the strip to bend when stepped upon, mechanical energy from an everyday activity can be converted to electrical energy. If the design proves to be a reliable source of electricity, it may be possible to implement it in areas of high foot traffic to offset energy use from traditional sources. Barring this achievement, we may at least walk away with a little more knowledge about the limits in applications of piezoelectricity.

Motivation

Early in the summer, our team met with Hamline physics alumnus and 3M innovator Roger Appeldorn, who referenced his time working at 3M as he described the process of innovation. The way of thinking it required had much in common with tenets of liberal arts such as looking to connect various areas. Coming up with a product also meant efficient manufacturing, effective marketing, an apparent need in society, etc., lest a company deem it too risky to pursue. Meanwhile, some solutions to problems Roger and his co-workers encountered as innovators were simple yet ingenious.

We kept these things in mind while searching for ideas for a project. While we weren't necessarily looking to create a product for mass-production, we still needed to try building something that could be considered an innovative upgrade and deemed useful in a variety of settings.

Preliminary Tests and Early Design

After ordering piezoelectric materials of various types, we performed some simple tests to figure out which one would work best with our intentions. With an oscilloscope attached, we subjected the strips to various conditions such as careful bending or different tones of sound from computer speakers and kept track of the voltage generated. What we believed to prove the best material and action performed on it was the ACX strip with a sort of "flick," bending it far enough to slip and release back to its original position. Because the release allows it to vibrate after the applied force has been removed, the strip can continue generating voltage after a controlled bending would stop doing so.

A wooden frame was constructed to contain the panel. The piezoelectric strip is mounted inside on an elevation, then a block of wood with springs attached is slotted in. Originally, the spring panel had a metal strip on the underside that was aligned in order to bend and hopefully flick the piezoelectric generator when the springs were compressed. The function of the panel is once again tested using an oscilloscope. One of the issues encountered early on was that the generator would rotate about clips attached to the side rather than bend, so an additional clip was added to the rear. After that, the flick couldn't be achieved even after trying different thickness of metal strips. The solution proposed was to clip the generator closer to the point of contact to restrict how far it could bend before slipping, but problems with the generator shifting from the hold of the clips led to a re-work in the design of holding the generator in place and in the mechanism of bending it from the springs' compression.

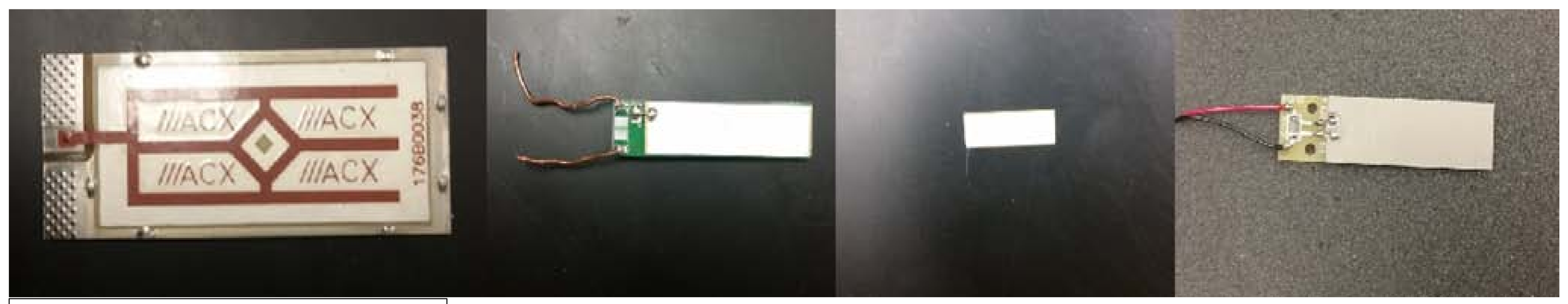

Fig. 1
Assortment of piezoelectric materials we received

Fig 2
Front and back of the ACX strip we used for further testing in the frame

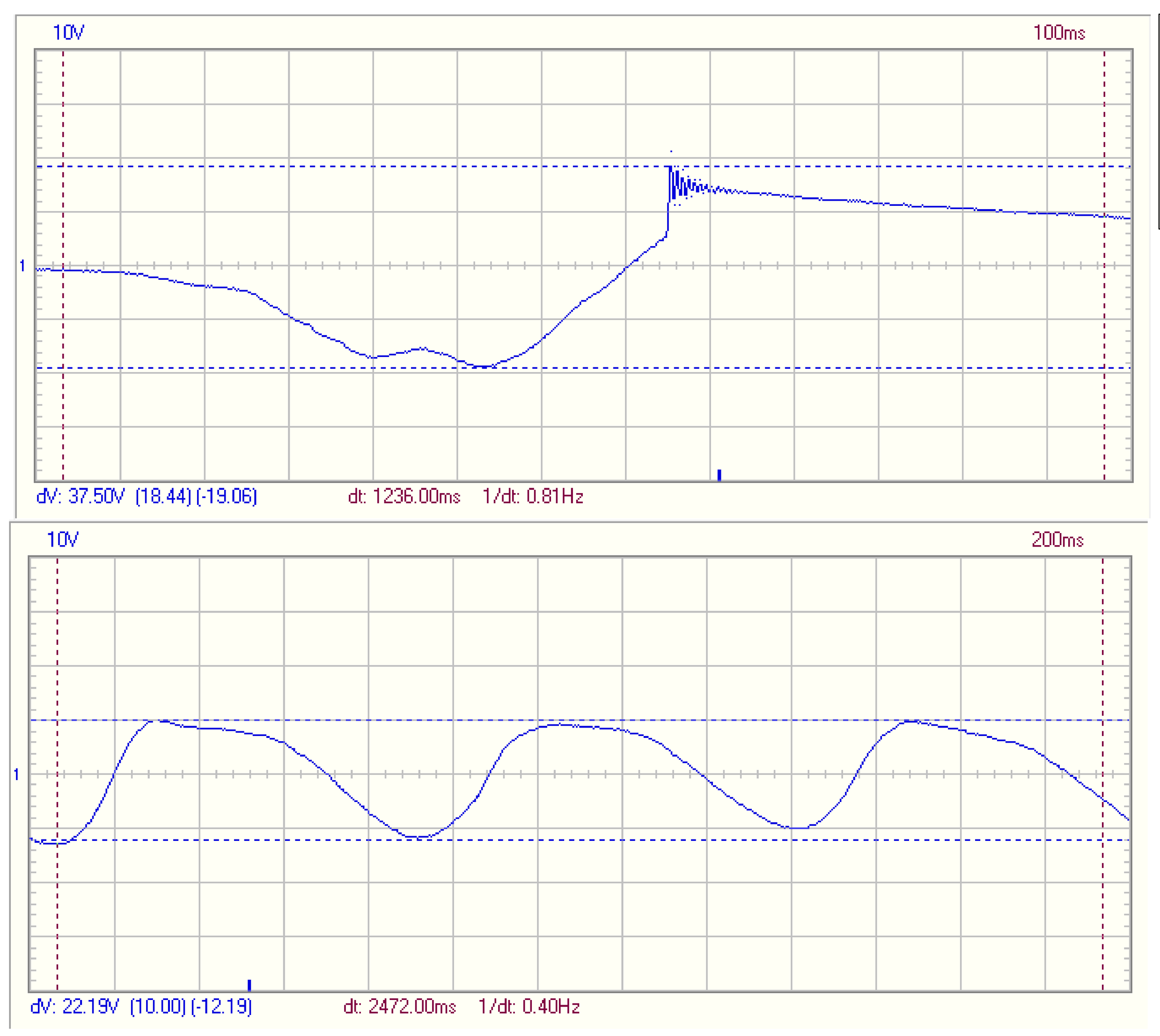

Fig 3
Oscilloscope reading of a single flick of the ACX strip (top) compared to a push and release (bottom)

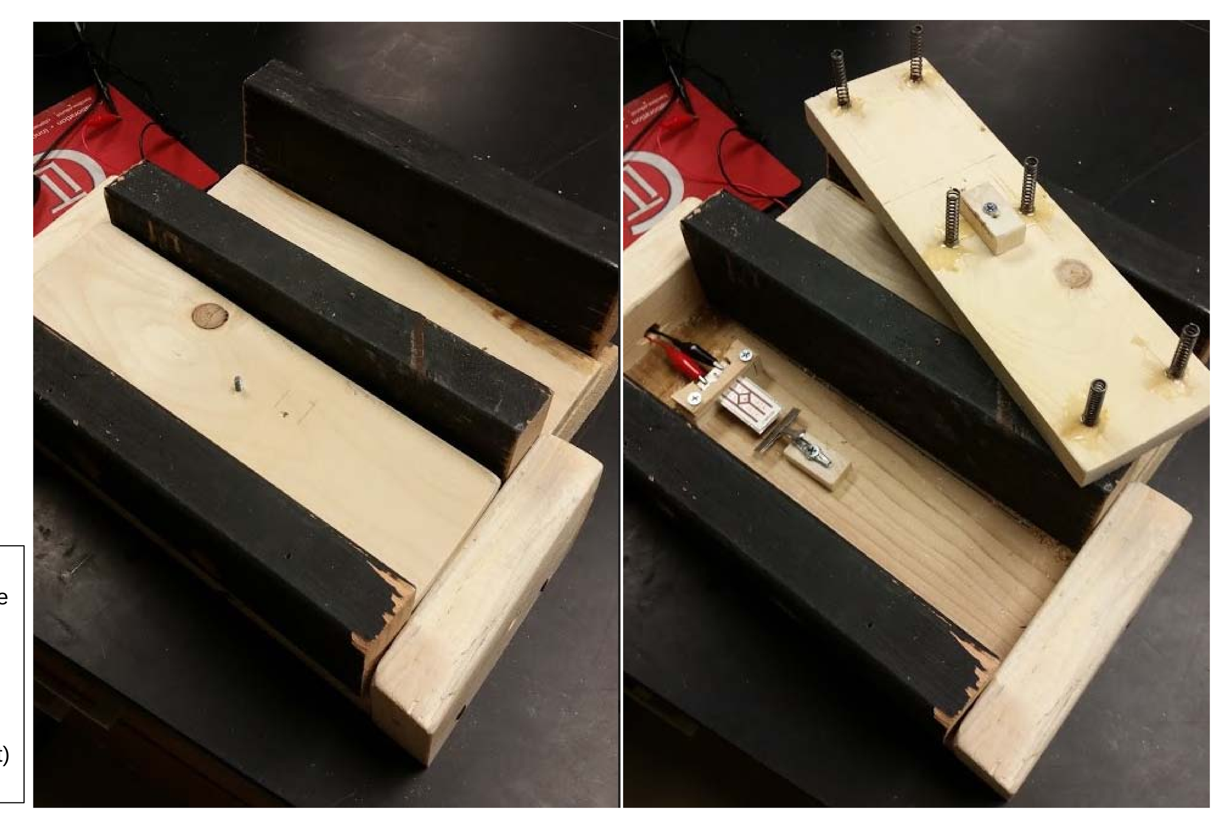

Fig 4
Frame with the panel in place (left) and with the inner mechanism and springs exposed (right)

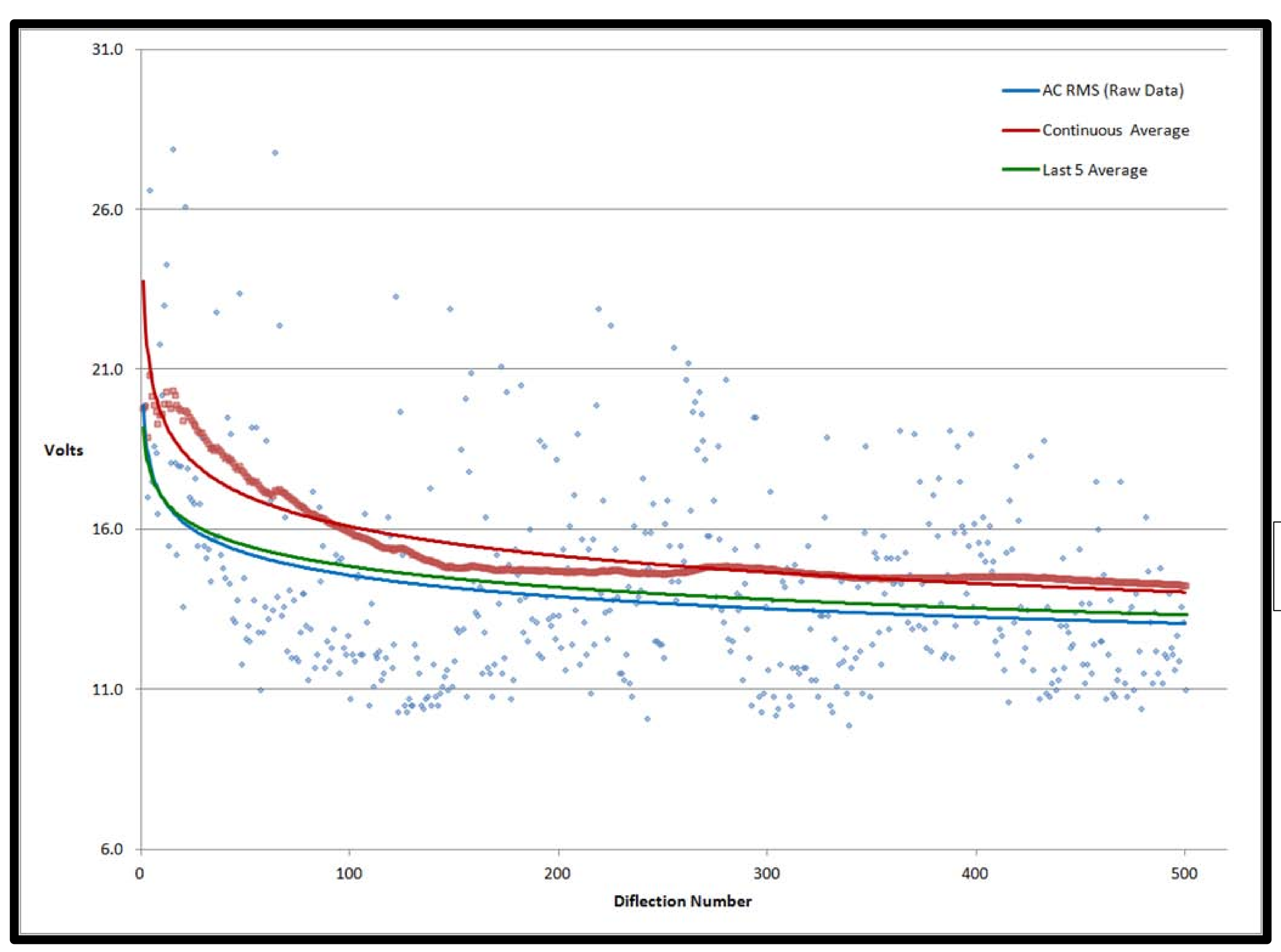

Fig 5
Consistency test data

Consistency Tests

This data was gathered using the final design pictured above. The blue data points are the raw data gathered with a best fit curve. The red points are a continuous average, meaning each point is an average of all earlier points of raw data. Finally the green curve is a best fit for the points that average the previous five raw data points. While the raw data varies greatly, one can see that the average slowly levels off, implying that this apparatus would be sustainable for long term use.

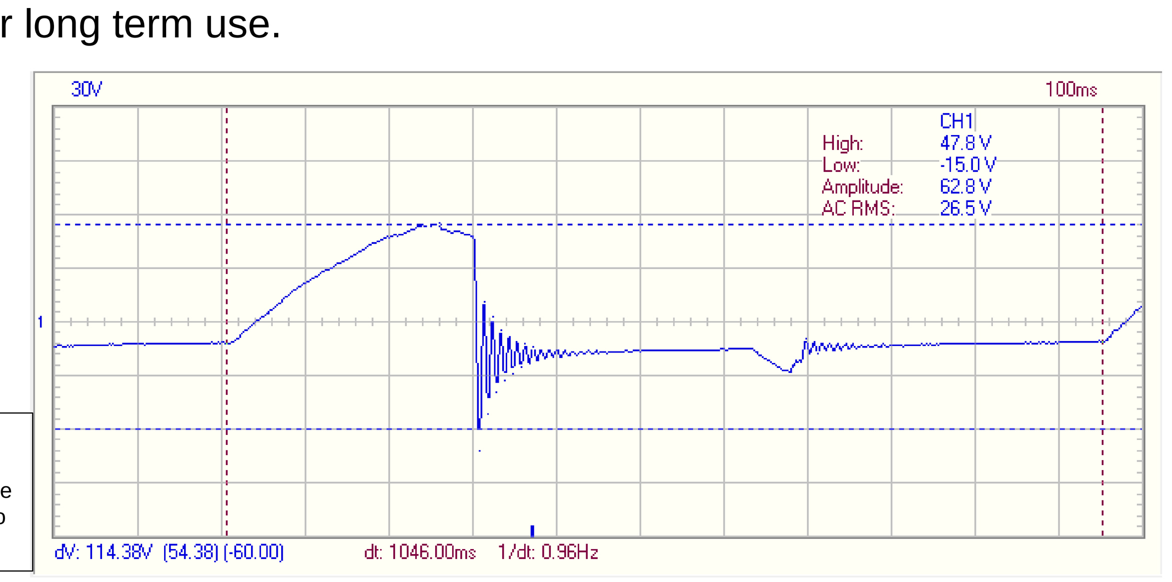

Fig 6
A sample waveform from the apparatus used to gather data.

Final Design

To improve our design we rearranged the flicking apparatus to give more consistent hits on the piezo element.

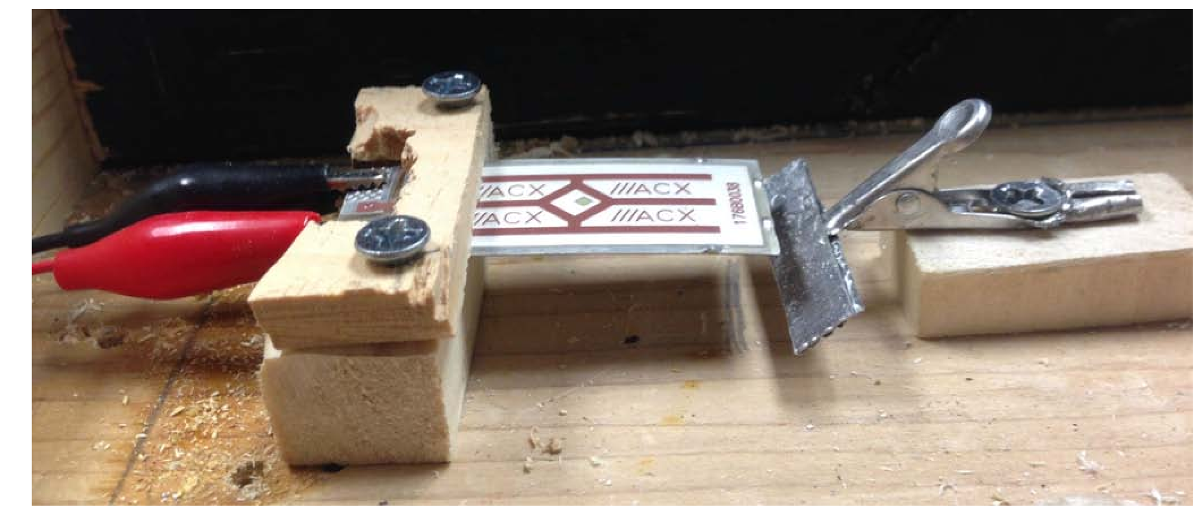

Fig 7
Final design of apparatus used

When the handle of the lever is pushed down, it lifts the edge of the piezo strip until they slip by one another. Then when the lever is released, the spring underneath it does the same process in the opposite direction. This allows for the piezo element to be "flicked" twice in one push of the lever.

Conclusions

With our research, we have found that the ACX strips are better for generating electricity from small constant stresses, and building a smaller, more durable apparatus in the above format is optimal for generating renewable energy. However, the waveform generated is too volatile (as seen below) to incorporate into an electrical circuit that is trickle charging a battery (The battery could then be used to power nearby electronics). We would suggest purchasing a linear energy harvesting module from Advanced Linear Devices. This product would smooth out this complex waveform into something with a workable voltage and current for such a purpose. While we are doubtful that piezoelectric materials could be the sole power source for simple electronics, they could greatly extend the life of battery-powered ones.

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