Team 23: Los Alamos National Laboratory

Desktop "High Striker" Piezoelectric Test Fixture

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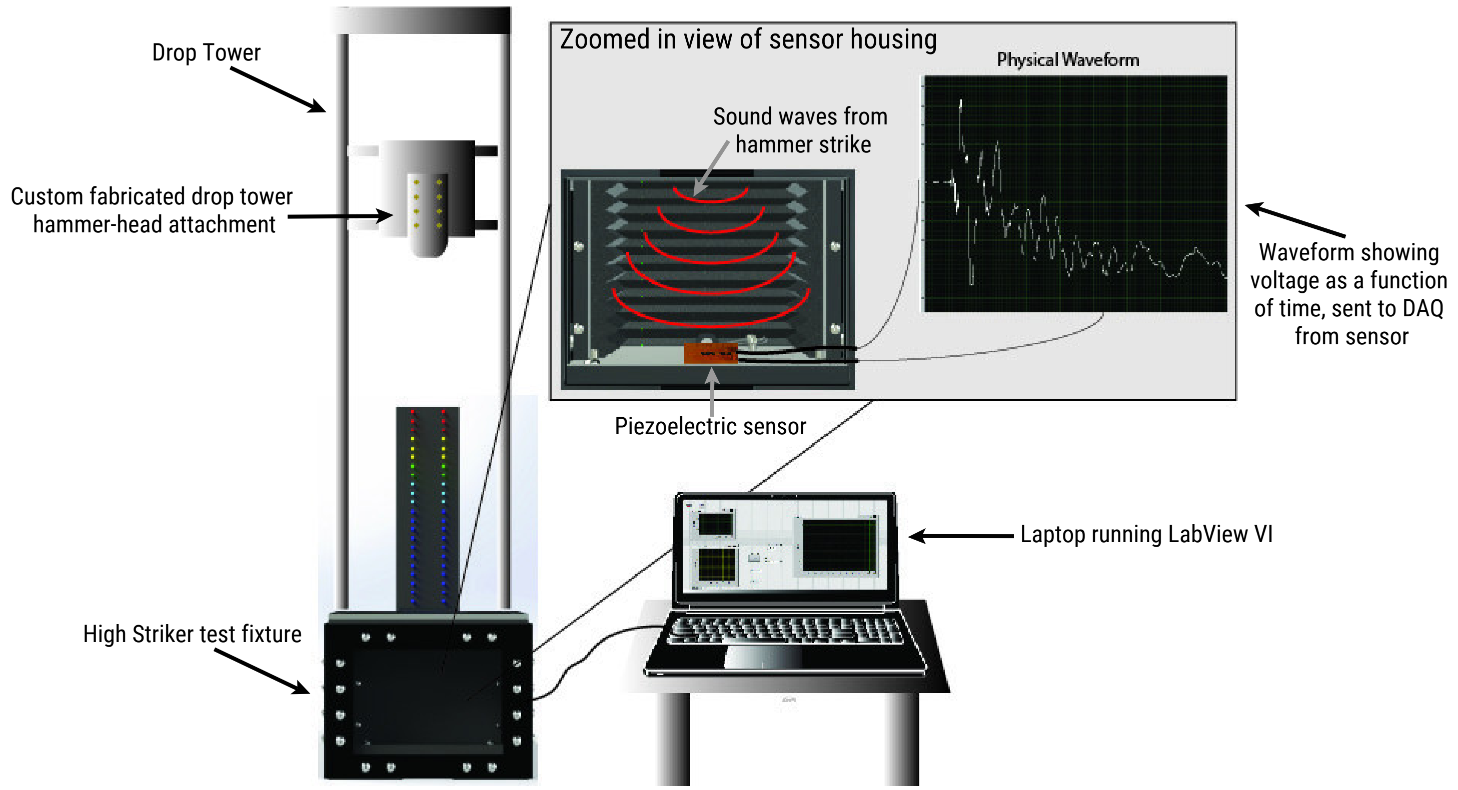

Figure 1: Overall assembly of High Striker fixture, along with drop tower. Zoomed in view of sound box interior with waveform data gathered from a strike to the test fixture.

Project Overview

Engineers and researchers at the Los Alamos National Laboratory (LANL) need to understand how the PVF2-11-.125-EK piezoelectric sensor from Dynasen Inc. works, specifically the relationship between the sensor's output to the provided input. Piezoelectric materials output a voltage when strained. This could be from a device physically striking the material, a pressure wave impacting it, or many other sources of strain.

To properly use this piezoelectric sensor, the characteristics must be understood. The test fixture described throughout this paper has been designed to characterize the specified sensor when struck by high speed, high impact forces. As outlined in the project description, the text fixture must also weigh less than 50 lbs and fit within a 2' by 2' size constraint. It should also be able to withstand an expected life cycle of 100 strikes. The final requirement laid out by LANL was that there needed to be a fun, aesthetic component for visual purposes at the university's public Expo.

The fixture consists of an extruded aluminum frame which houses two containments. The first containment is a sound chamber that houses the sensor. The sensor is placed on the bottom of the chamber, with a steel plate as the lid. The plate is struck to create a sound wave within the box to actuate the sensor. The next containment houses the electrical components, including the DAQ and the controls for the aesthetic lights and sound.

To test the fixture and the sensors, the force delivered to the strike plate needed to be consistent and known. This was accomplished using a vertical drop tower. Using the tower tested the integrity of the fixture and provided the repeatable strikes needed to build the trend-line required by LANL.

Figure 2: Early stage test fixture. A ball bearing is dropped from a constant height onto the metal plate below.

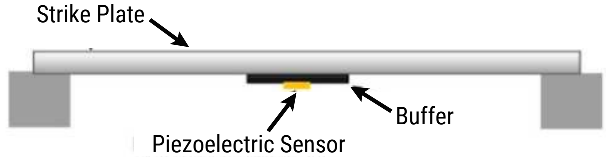

Figure 3: Direct hit method with sensor attached to underside of strike plate

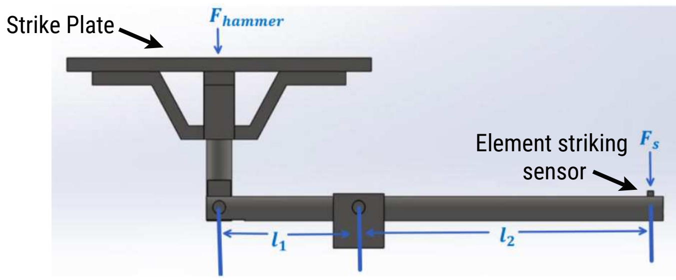

Figure 4: Direct hit method where force is directly applied to sensor element.

Design Motivations and Iterations

In order to characterize the response of the piezoelectric sensor, a “High Striker” style test fixture was made. The fixture is used to produce an overall trend-line that relates the hammer strike force input to the voltage output of the sensor. At the onset of the project, three main ideas of actuating the sensor were considered. The first was a direct hit method, where the force of the strike would be directly applied to the thin film sensor. This can be seen in Figure 4 above.This idea was not pursued due to the fragility of the sensors and the likelihood of sensor degradation over time. The second method considered was another direct hit method, but in this case, the sensor would be attached directly to the underside of the strike plate. This can be seen in Figure 3 above. This option was viable, but it was decided through early stage testing, shown in Figure 2, that this method still posed a risk to the sensor and its integrity.

The chosen actuation method is using pressure waves through air onto the fixed piezo element. Please refer to Figure 1 on page 2 for a visual. The pressure waves are created by striking a stainless steel strike plate that is on top of the insulated sound box with a high impact force. The sensor is placed on the bottom of the interior of the box, and the box is lined with sound absorbent foam to reduce sound wave bouncing. The output voltage registered by the sensor is relayed to a NI USB-6211 data acquisition device (DAQ) and then to LabView, where the virtual instrument (VI) will store the data and create a trend-line. The strike plate is supported by an extruded aluminum frame that distributes the forces onto the table that the fixture is on.

Another requirement outlined by LANL was for the test fixture to emulate the `High Striker' strongman carnival game. Since this device would be presented at a campus-wide, public Expo, the test fixture was designed to be interactive. It features a "fun" aspect where feedback will be given to the user directly using lights and sounds. Similar to the traditional ‘High Striker’ carnival game there is a vertical panel of lights accompanied by audio to reflect the calculated force of the user’s hammer strike. Guests at Expo could strike our test fixture with a hammer and get live feedback as to how much force they applied through the hammer strike.

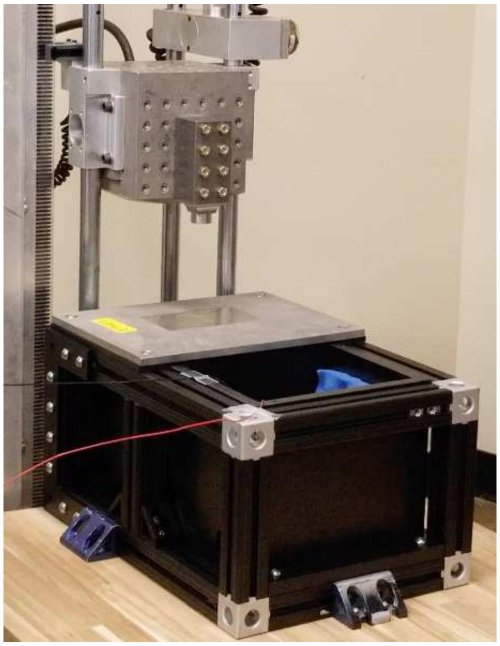

Figure 5: High Striker test fixture under the drop tower

Testing Summary

The testing of the High Striker was split into four parts. The first part was centered around prototype testing to see what the best way to conduct and gather data in the future would be. The second was to test the final fixture for failure. The third was to test the type of data gathered and its meaning. While the final step combined everything together and showed the comprehensive data as the piezoelectric sensor registered the strikes from the drop tower.

To properly test the system, an understanding of the piezoelectric sensor and the type of strikes it could take needed to be gathered. The piezoelectric sensor was tested in several different environments, such as a direct hit method and the sound propagation method. Data was gathered using the prototype drop fixture shown in Figure 2 on page 5, and it was determined that the sound propagation method allowed for a greater longevity of the piezo.

To ensure the fixture could not only withstand the lifecycle of 100 strikes but also not deform to the point that data was corrupted, the system had to go through rigorous testing. By imparting a strike with a drop tower, the system was able to be repeatably tested at several heights. These consistent strikes allowed observation and measurements of failure to be taken and gathered reliably. The drop tower also ensured that data would be gathered in a measurable and definable way. By having constant weights and heights to compare the output voltage to, the data could be graphed and analyzed for inconsistency as well as trends that define the piezo system at impact forces.

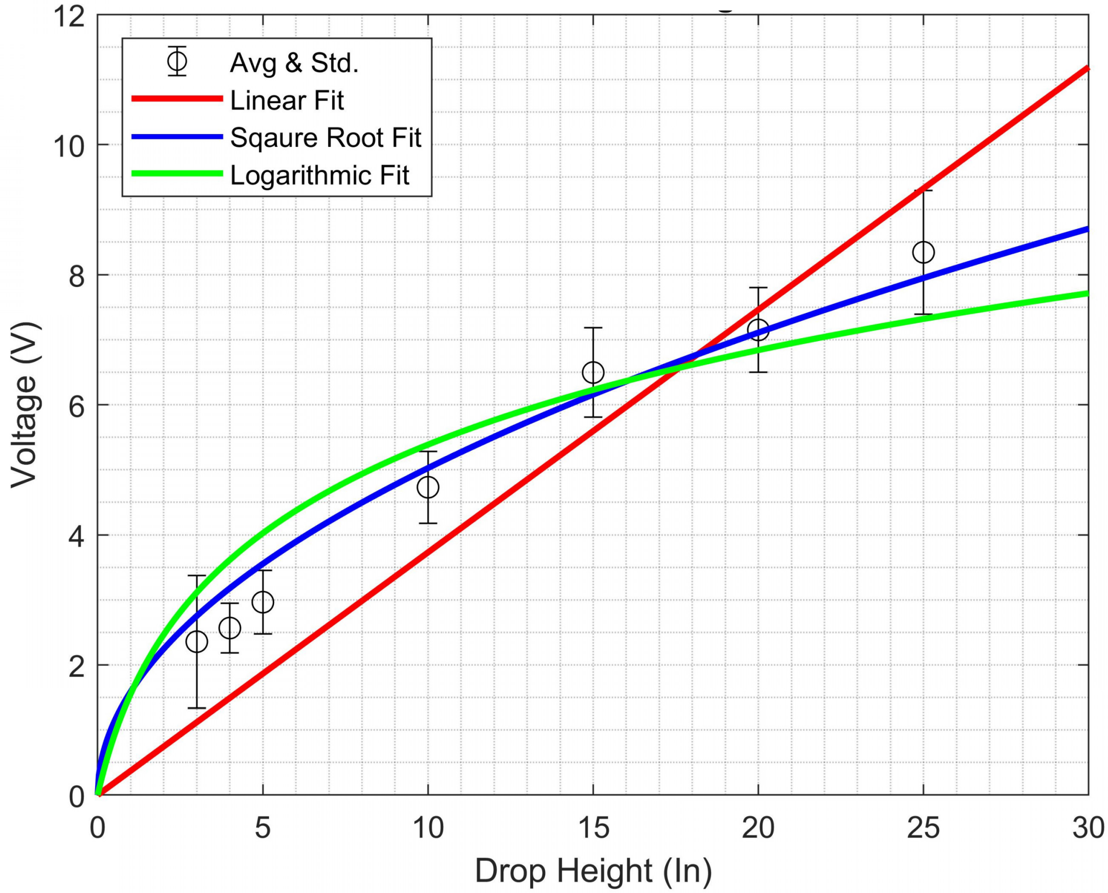

Figure 6: Peak voltage recorded by piezoelectric sensor vs. drop height of the tower attachment with three possible trend lines.

Data Analysis

As shown in Figure 6, analysis of the data showed a positive correlation between strike force and peak voltage output by the sensor, but the increase in voltage is marginally lower as strike force increases. This could possibly be attributed to reaching the usable range of the sensor, as drops above 25 inches gave a large spread in voltage, and thus they were omitted. The standard deviation from the average at all drop heights plotted was relatively large due to time constraints allowing for less than ten data points at each height, which gave volatile statistical measures. The dataset was approximated with the model function $f(x)=\sqrt{x}$, which gives a concave shape similar to the data. Additionally, the residuals for a square root fit showed no trend, as opposed to a linear, logarithmic, or quadratic fit.

This data does not necessarily represent the behavior of the sensor alone, due to the other variables that are being affected by the drop tower. These include deformation of the strike plate, vibrations on the table, and force distributions on the fixture itself. Although the data gathered was consistent and repeatable, it is not known if these results will be repeatable if the sensor is placed in a different testing setup.

Outlook and Conclusion

Due to the COVID-19 pandemic, the amount of data collected was much lower than anticipated. Prior to the closure of the University of Colorado facilities, all but one piece of the high striker were manufactured. That piece was not critical, and due to the cancellation of the Expo, not necessary for the project success. The fixture was able to be assembled and underwent one day of drop tower testing.

In an ideal situation with unlimited time, budget, and lack of a global pandemic, more data would have been collected, which would lessen the deviation of our current data and allow for a more precise voltage readout. A voltage de-amplifier would be added to reduce the chance of voltage clipping and ensure that higher drops on the tower would land within the 10V range of the DAQ. The strike plate would have been manufactured from a higher grade steel to reduce the chance of deformation and sustain higher impact forces.

Overall, Team 23 is very satisfied with the state of the High Striker project. The fixture meets the weight and size requirements outlined by LANL, and succeeds in actuating the piezoelectric sensor through a hammer strike and sound propagation. Based on the small amount of preliminary data, a definitive characterization of the sensor cannot be reported. However, the scientists at LANL have a clearer path to further investigate the properties of this piezoelectric sensor based on the early results as well as the design process taken to acquire those results.

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Further Reading and Contact Information

For further information on the Dynasen PVF2-11-.125-EK sensor, refer to ***this link***.

To contact the team, please send emails to the Logistics Manager at *emily.page@colorado.edu*