MASS SPRING DAMPER PROJECT

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Introduction

L3Harris developed a large, heavy dampener using wire rope isolators. The original system needed to be redesigned due its high manufacturing costs, and large volumetric size and weight (Figure. 1).

Our team was tasked with testing the feasibility of the flex circuit dampening system, developing a design parameters program, and producing a flex circuit system prototype.

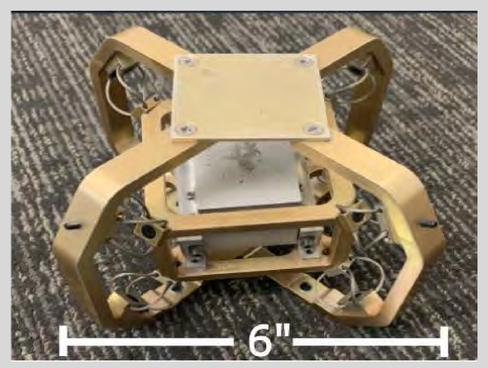

Figure 1. Original L3Harris dampening system.

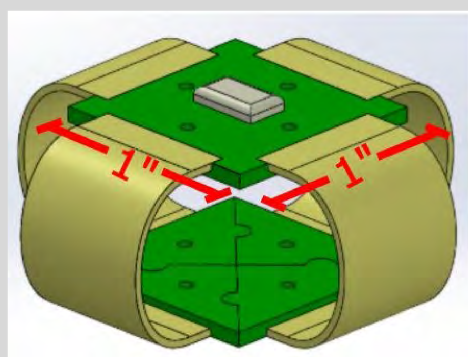

Figure 2. Flex circuit dampening system CAD model.

Methods and Materials

The fabricated prototype was based on a finite element model, optimization code using MATLAB®, and material testing.

Fabricated Prototypes

We constructed and built three different taped flex prototypes, that were a 3 times scale model as shown if Figure 3. The taped prototypes consisted of a 25%, 43%, and 60% copper to dielectric flex circuits.

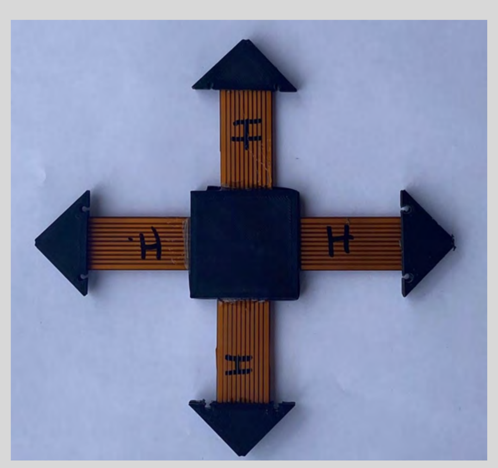

Figure 3. Fabricated prototype made with PLA, Copper, and Kapton tape.

Manufactured Prototypes

Figure 4. Manufactured prototype.

We had eight different manufactured prototypes that featured varying flex circuit properties. Mainly, the copper to dielectric percentage was varied (see Table 1) to obtain differing spring constant values in the flex circuits. For brevity's, we will focus on Prototype G, shown in Figure 4.

Results

Assumptions

The flex circuits in our system were assumed to act as massless springs. After weighing the parts we determined that a massless assumption will not hold for the system. The flex circuits being used must be less than 10 times the mass of the top board.

To simplify our design calculations we assumed 1 degree of freedom motion for the system. Preliminary test data from the utilized shaker table demonstrates evidence of off-axis rocking.

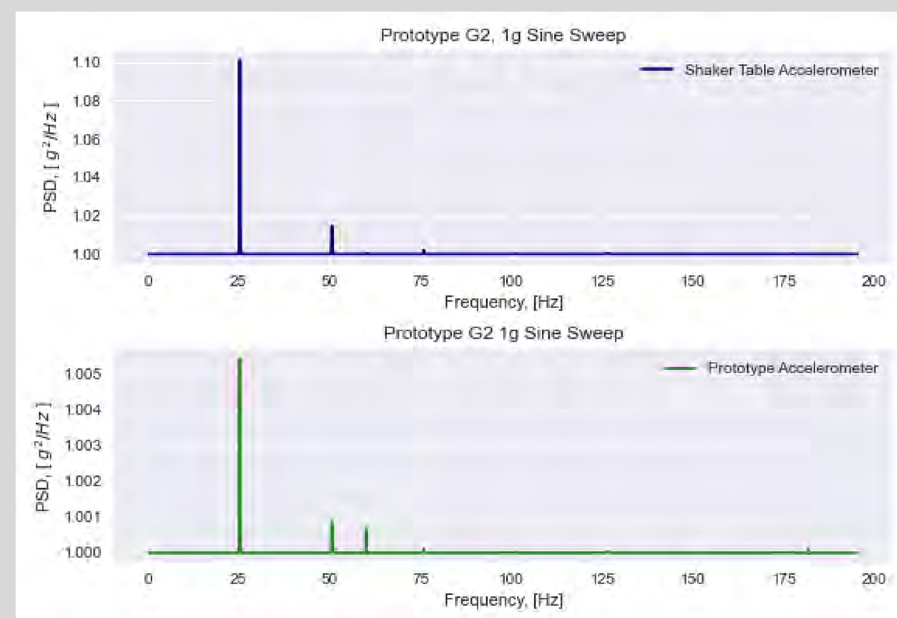

Figure 6. 1g sine sweep test on Prototype G.

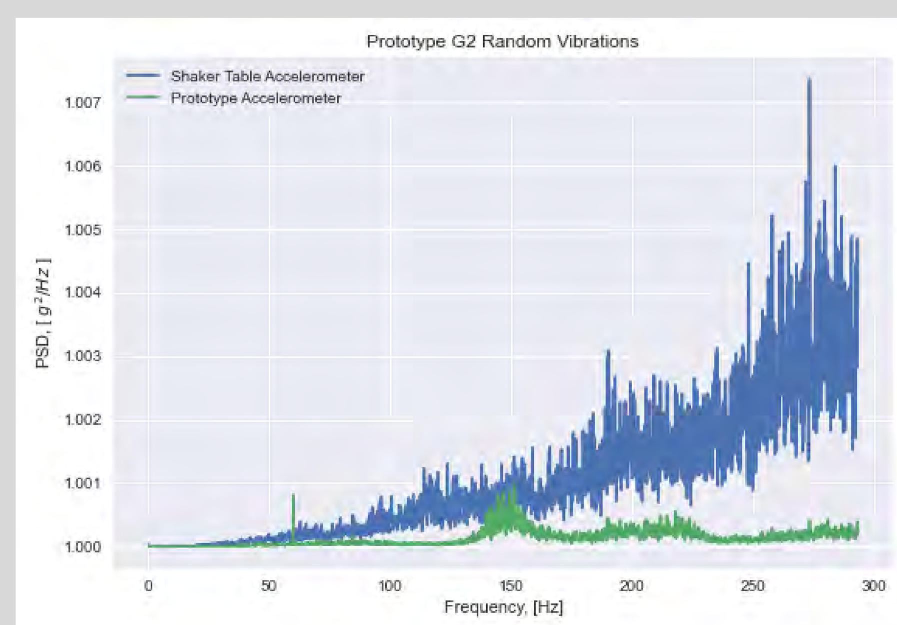

Figure 7. Random Vibration test of Prototype G. Peaks at around 60 and 150 Hz.

Tensile Testing

A tensile test was conducted over a range of prototype specimens (varying Cu content from 20-60% Cu) to see how well the rule of mixtures predicted modulus holds true for these tests.

Repeating each of the five specimens, shown in Figure 9, three times over to get a statistical average, we see that modulus increases as copper content increases (E being the highest, at 60% Cu). From this data, we conclude that the rule of mixtures is within an acceptable error for these specimens, having a percent difference range between 4% and 20%.

Power Spectral Density (PSD) Results

Using Prototype Specimen G (Table 1), a 1g sine sweep was performed that predicted there are natural frequencies at about 60 Hz and 180 Hz as can be seen by the peaks in Figures 6.

In the random vibration test graph seen in Figure 7, you can see that there are two vibration amplitude spikes which are at around 60 Hz and 150 Hz.

Table 1. Properties and dimensions of the manufactured prototypes.

Full Prototype Specimen	% Copper	Width (in)	Length (in)
A	12.33%	.5	1.571
B	18.49%	.5	1.571
C	24.66%	.5	1.571
D	30.82%	.5	1.571
E	38.36%	.5	1.571
F	18.49%	.75	1.571
G	24.66%	.75	1.571
H	12.33%	.5	1.178

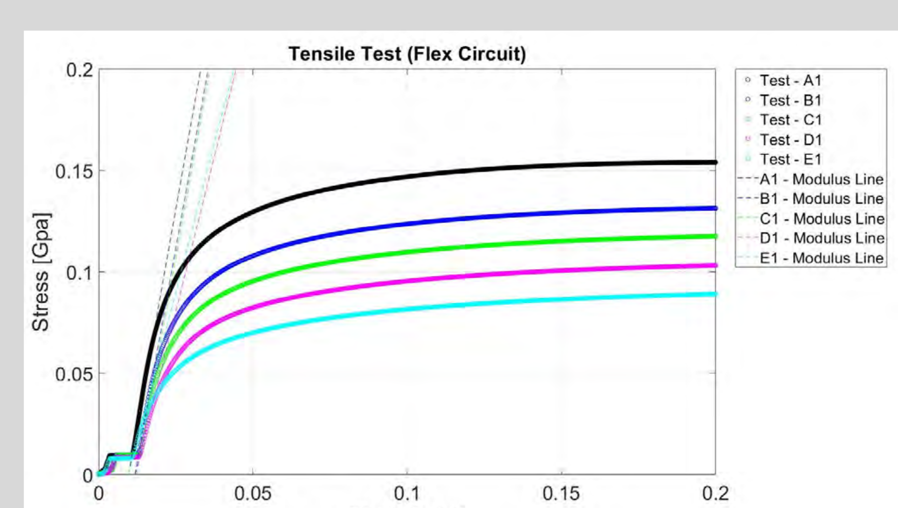

Figure 9. Tensile test data.

Conclusion

Predicted Results

The main result gathered from the tests showed reasonably well that the flex circuits can be used for damping. Varying the copper content within the flex circuits will alter the stiffness of the flex circuit. However, more testing is required to confirm the validity of the results.

Limitations

The shaker table was originally designed by L3 to test active vibration cancelation. We repurposed the test equipment to meet the needs of this project, shown in Figure 10.

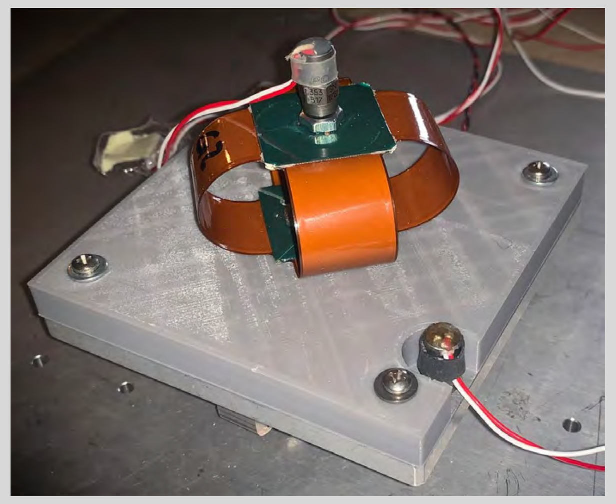

Figure 10. Prototype mounted to shaker table test fixture.

Learning to use the m+p Analyzer software to interface with the DAQ was difficult and time consuming. The first data gathered with the system from the pilot test was too low in resolution, making the results inadequate.

Future Research

Due to time constraints, a limited quantity of high resolution tests were conducted. With that said, additional testing should be done to verify results.

Performing an impact test will confirm the location of the natural frequencies, which will build confidence in the data.

Compression tests should be conducted to determine a valid relationship between the copper weight and stiffness. This relationship will influence the transfer functions.

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