Aer E 322 Aerospace Structures Laboratory – Lab Report 2023

Lab 1 – Practice Experiment and Data Analysis

Section 5, Group 5
Ethan Pickard, Isaac Pollard, Joseph Spewock, Lucas Tavares
09/08/2023

Introduction

To gain experience with data collection and analysis, our group worked on a pre-assembled structure that simulates a wing in an in-flight situation. We induced vibration to a beam and later caused disturbance. It is important to practice our lab skills as a first assignment so we can minimize the probability of making mistakes in the future.

Our group got our hands on the PASCO tool kit, which includes sensors, electronics, software, and Lego like building structures that we will be using throughout the semester. For our future experiments, we will simulate aircraft structures such as airframe, wings and landing gear and test them using the tools provided by the PASCO kit. Thus, we will be applying the concept of "rapid design, prototyping, and learning" by designing, constructing, testing, and analyzing small-scale models of aircraft parts.

A previous reading and study of how to process and analyze the data using MATLAB was conducted by our group members. Additionally, we saw a video on how to use the PASCO tool kit sensors, wave driver and software to successfully conduct the testing.

Objectives

The main objective of this lab is to gain familiarity with how to take data in an environment where there are multiple moving parts. In addition to this the lab also gives groups the opportunity to use MATLAB to do data analysis.

Hypothesis

Our hypothesis is that as there were more disturbances added into the experiment the data will be more difficult to manipulate and curve fit to make it look smooth. Whereas if there are no or less disturbances it will be easier to curve fit.

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Work Assignments

Work assignments																
Section	5	Group	5													
Lab 1	Lab work				Report writing											
Name	Data Record	Exp Setup	Exp Work	Clean up	Introduction	Objectives	Hypothesis	Variables	Materials	Apparatus	Procedures	Data	Analysis	Conclusion	References	Appendix
Ethan	☐	☑	☑	☑	☐	☐	☐	☐	☑	☑	☑	☐	☑	☐	☐	☐
Isaac	☑	☑	☐	☑	☐	☐	☐	☐	☐	☐	☐	☑	☑	☐	☐	☑
Joseph	☐	☑	☑	☑	☐	☑	☑	☐	☐	☐	☐	☐	☑	☐	☐	☑
Lucas	☑	☑	☐	☑	☑	☐	☐	☐	☐	☐	☐	☐	☑	☑	☐	☐

Materials, Apparatus, and Procedures

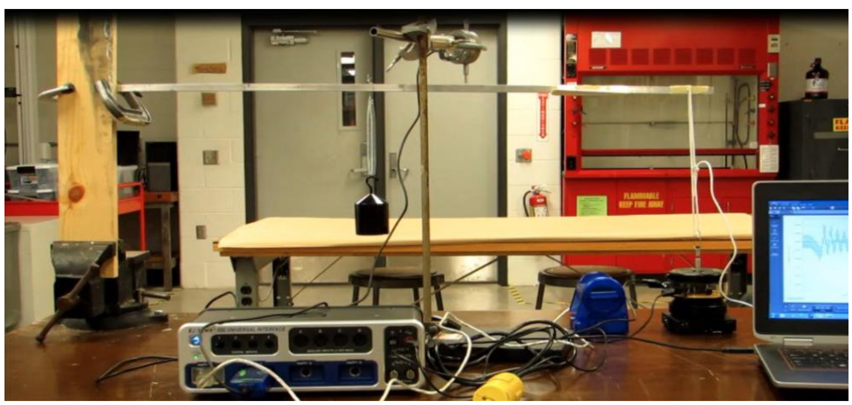

Figure 1 Lab setup

This lab was set up to mimic an aircraft wing structure with two different sources of loading. As shown in Figure 1, there was an elevated cantilever aluminum beam which is used to represent the aircraft wing. The two sources of loads were the PASCO mechanical wave driver, positioned at the end of the beam, and a spring-loaded weight in the middle of the beam. The loading on the beam is used to simulate different forces on the wing during flight.

The whole point of this experiment was to dynamically monitor the vertical movements of the beam vs. time, so two PASCO sensors were used to measure this data. The first being a non-contact motion sensor that was positioned directly under the beam. The second sensor was a round point-tip "needle" displacement sensor that was held up by a stand and facing downwards touching the top of the beam. The two sensors and the mechanical wave driver were all plugged into a command center which was controlled by the PASCO Capstone software on a computer.

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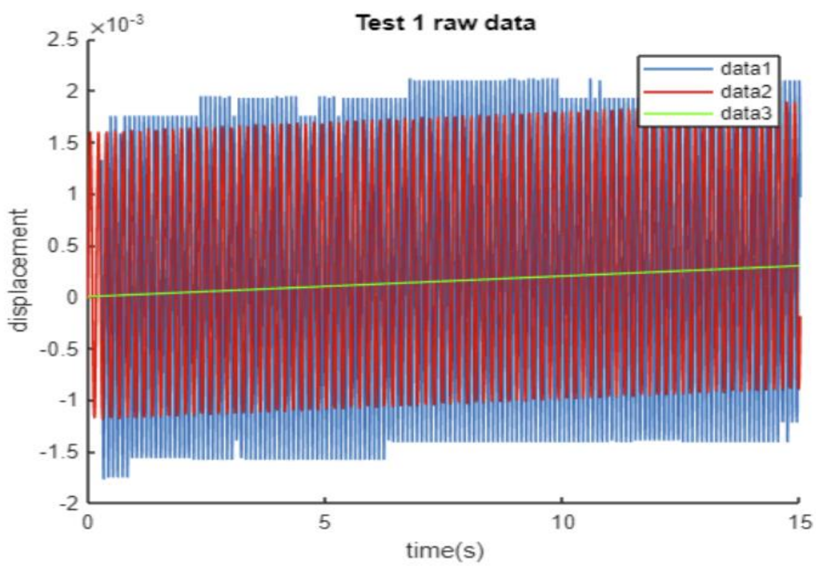
Before any tests could be ran, the PASCO Capstone software needed to be set up in a way that it could measure displacement and position, both plotted against time. Once this was done the mechanical wave driver needed to be set up. This involved setting the waveform type as sine, the frequency to 10 Hz, and the amplitude to 10 V.

Once all the components of the lab were set up, test one could be performed. Test one only involved loading from the mechanical driver for 15 seconds. This was followed by test two which didn't require the point-tip displacement sensor any longer. Test two was like the first, but as soon as the mechanical driver was activated, a group member pulled the spring-loaded weight directly down and released it. Pulling down on the spring-loaded weight resulted in the weight oscillating for the remainder of the test. Test three followed the same procedures as test two, but another group member randomly disturbed the beam throughout the test. This allowed for a third load to be measured on the beam.

Finally, once all three tests were run, the data had to be downloaded as a csv file and saved to a USB flash drive so the data could be analyzed in MATLAB.

Data



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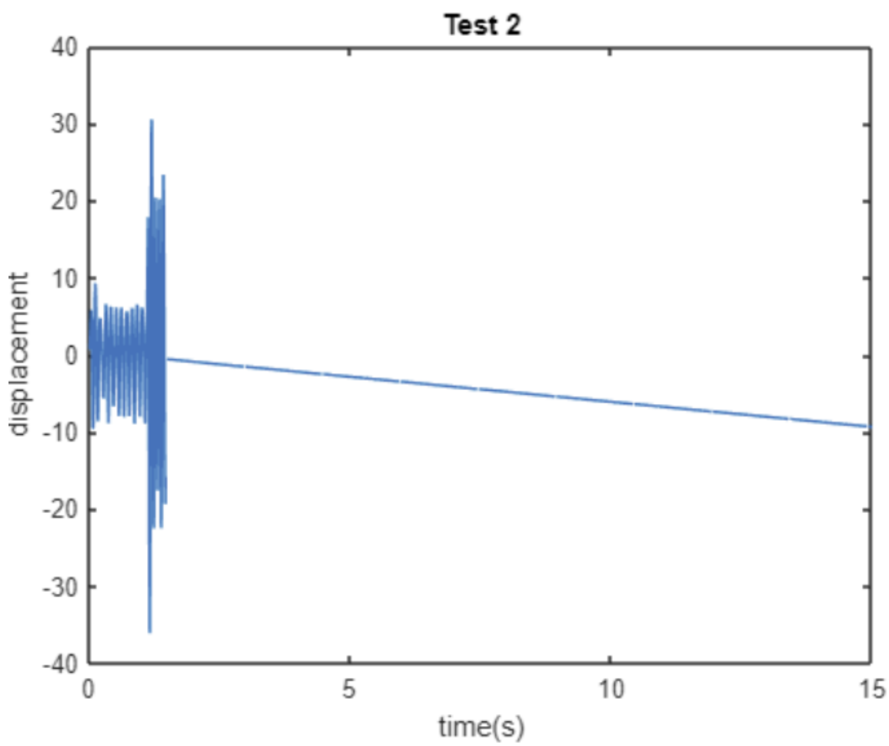
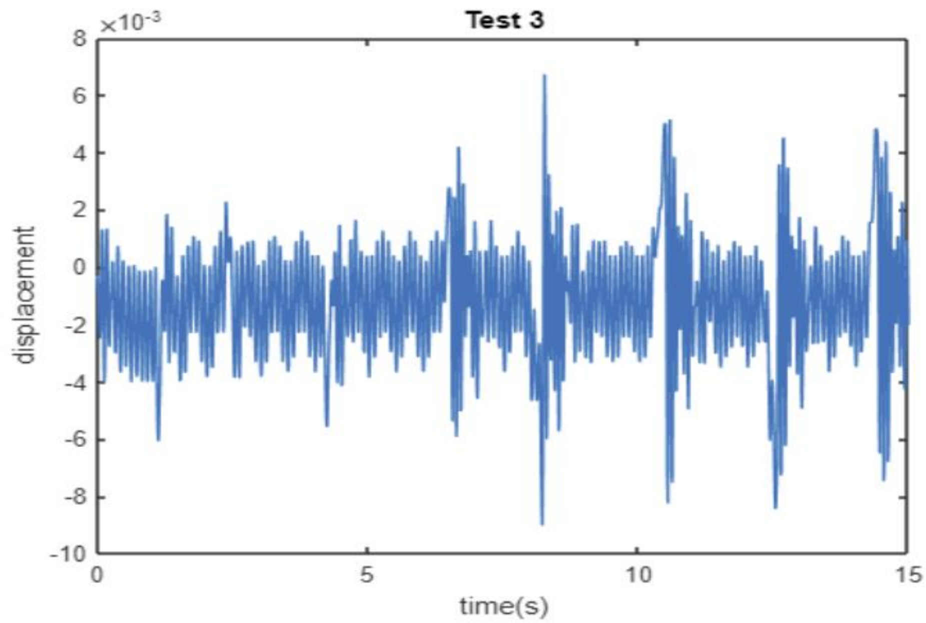
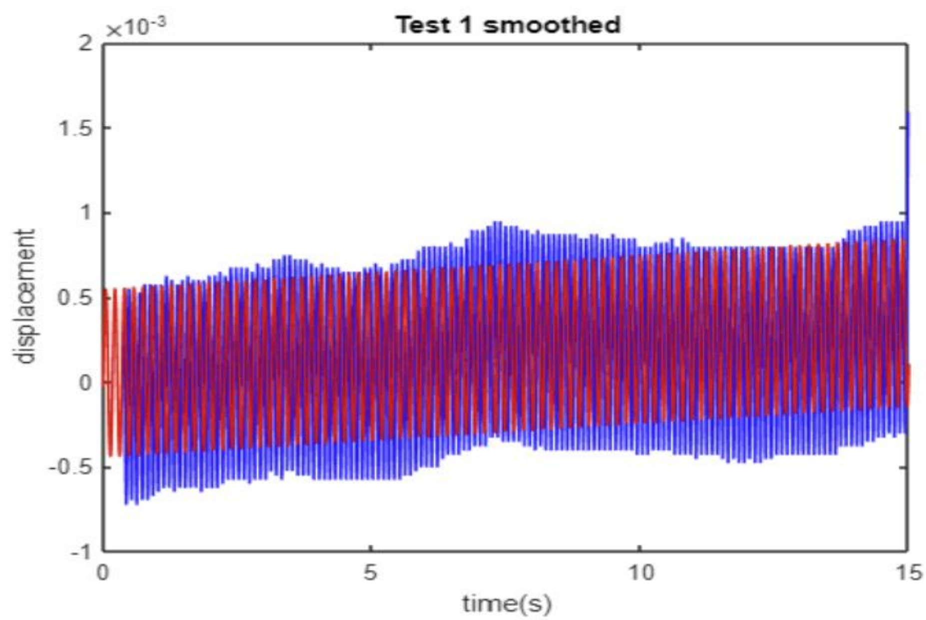
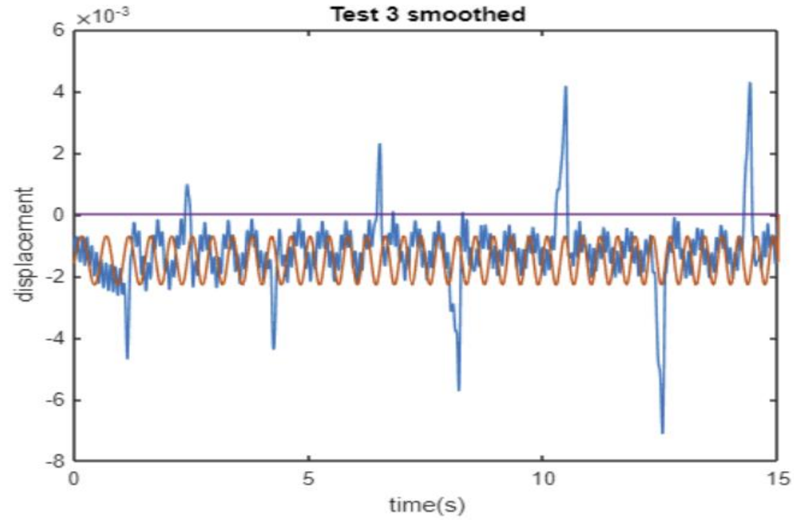


It can be seen here that for test 2, which included the weight into the test, that there was human error that made the data "corrupt" and should be a case where data is discarded.


Test 3
×10-3
displacement
time(s)
8
6
4
2
0
-2
-4
-6
-8
-10
0
5
10
15


Test 1 smoothed
×10-3
displacement
time(s)
2
1.5
1
0.5
0
-0.5
-1
0
5
10
15



Analysis

1. In the first set of data after the smoothing we can confidently identify three noises in the run that are spaced out evenly in the data. They are very slight so it was also hypothesized that it could be normal, but since the frequency stayed constant across the test, we came to the conclusion that it would be considered small noises. We also believe that this would be a good model for steady level flight of an aircraft wing. We say this because the displacement in test one stays very constant and exhibits little outside noise which is what would be expected of an aircraft at steady level flight.

   In the second set of data, we can confirm nothing as the entirety of the data itself is inconclusive and should not be used to formulate any opinions or conclusions because of this.

   In the third set of data, it is much easier to see where the noises and disturbances are. Meaning we can come to the simple conclusion that there are eight disturbances in the data. It is our belief that the disturbances seen are the time when the beam was being tapped by one of our group members, which makes sense because we tapped the beam eight times, thus bringing validity to this argument. This third test would be a good model for a flight that experiences sudden and unexpected turbulence or crosswind. We believe that the tapping on the beam and the weight bobbing up and down are good models for it.

2. In test one results we can infer the frequency to be about ten hertz. Granted this is much simpler to do since we already knew the original frequency. It can be obtained directly from the data sets, since the test only ran for fifteen seconds but resulted in one thousand and five hundred data points it is obvious that the frequency was ten hertz. Obtaining it directly from the graph would be possible but you would need to count every single minimum and maximum in the data. This does answer the question why the displacement needle was removed, as if it had not been removed it would not have been able to directly read the frequency of as the added weight disturbance would have thrown its value way off. This reasoning can be applied in the third test as well as there were even greater disturbances that was acting on the beam.
3. The smoothing of the data can be viewed in the data section and will be labeled as the smoothed data of a specific set. The type of curve that we used for our line of best fit was a sine curve that we used for both graphs. We used this as it was the line that could correctly oscillate around the position, in addition it starts at zero whereas cosine starts at one. Some factors that we believe could have caused the data to deviate from the prediction would be outliers and if the beam was bumped too hard or the weight was pulled down too far. The lines of best fit for tests one and three were fairly accurate but we came to the conclusion that the line for test one could have a higher amplitude to better represent the data.

Sources of Error

We as a group believe that our error from test two came from some type of malfunction in the acoustic reader. We are unsure why this would have happened as it was plugged into the machine, and we followed the instructions of the lab.

Conclusion

We successfully simulated a wing in-flight by inducing vibration and disturbances to a beam fixed at one end. Those situations can be compared to turbulence, bumps, and vibration caused by engines and systems that affect the aircraft's wings. Our data shows how the wing can be structurally stable under specific vibrations, as well as modeling how an aircraft wing would perform under these conditions. More importantly, however, we gained valuable knowledge about the basics of how to process and plot data. Along with analyzing what that data means and its validity in an experimental environment.

Appendices

```
rawDataT1 = readmatrix("Sec 5 Gp 5 Test 1.csv");
rawDataT2 = readmatrix("Sec 5 Gp 5 Test 2 - Sec 5 Gp 5 Test 2.csv");
rawDataT3 = readmatrix("Sec 5 Gp 5 Test 3.csv");
%DisplacementDataT1 = smoothdata(rawDataT1);
%plot(rawDataT1(30:end,1),rawDataT1(30:end,2),');


fit_x = [0:.01:15];
fit_yT1R = .0014*sin(36*fit_x - .16) + .0002 + .00002*fit_x;
fit_yT1 = .0005*sin(36*fit_x - .16) + .00005 + .00002*fit_x;
fit_yT3 = zeros(1501);
for i = 1:1500
    fit_yT3(i) = .0008*sin(12*(fit_x(i))^1.1 - .1) - .0015;
end


trend_line_y1 = .00002*fit_x;


hold on
plot(rawDataT1(30:end,1),rawDataT1(30:end,2));
title("Test 1 raw data");
xlabel("time(s)");
ylabel("displacement");
plot(fit_x,fit_yT1R, 'r');
plot(fit_x,trend_line_y1, 'g');
legend()
hold off
%R1 = rescale(rawDataT1(:,5),-.05, .05);


scatter(rawDataT1(:,1),rawDataT1(:,5),'g');
title("Test 1 raw data for displacement needle");
xlabel("time(s)");
ylabel("displacement");
```

```
plot(rawDataT2(:,1),rawDataT2(:,4));
title("Test 2");
xlabel("time(s)");
ylabel("displacement");


plot(rawDataT3(:,1),rawDataT3(:,2));
title("Test 3");
xlabel("time(s)");
ylabel("displacement");


DispNeedle = rmoutliers(rawDataT1(:,5));
T1RunningAverage = movmean(rawDataT1,7);
T2RunningAverage = movmean(rawDataT2,3);
T3RunningAverage = movmean(rawDataT3,8);


plot(T1RunningAverage(40:end,1),T1RunningAverage(40:end,2),'b');
hold on
title("Test 1 smoothed");
xlabel("time(s)");
ylabel("displacement");
plot(fit_x,fit_yT1, 'r');
hold off


% scatter(rawDataT1(:,1),DispNeedle,'g');
% title("Test 1 displacement needle smoothed");
% xlabel("time(s)");
% ylabel("displacement");


plot(T2RunningAverage(:,1),T2RunningAverage(:,2));
title("Test 2 smoothed");
xlabel("time(s)");
ylabel("displacement");


plot(T3RunningAverage(:,1),T3RunningAverage(:,2));
hold on
title("Test 3 smoothed");
```

```
xlabel("time(s)");
ylabel("displacement");
plot(fit_x,fit_yT3);
hold off
```