Lab 1 Practice Experiment and Data Analysis

Objectives

(1) Learn how to take measurements from a structure in a dynamic environment, and analyze/process the data,

(2) Get familiar with a structure model building kit and understand the "rapid design, prototyping and learning" concept.

Introduction

One essential skill of an aircraft structural engineer is to be able to configure a measurement setup on a structure and analyze and process the data measured from this setup. In week 1 lecture [1] you have learned the basic concepts of taking measurements, identifying accuracy levels and source of errors, and processing data. In this lab, you will work on a pre-assembled structure which qualitatively simulates an aircraft wing structure in an in-flight situation. This lab allows you to practice all the knowledge and techniques you learned from the lecture in a quick and concise manner.

This lab also introduces another important renovation of this course: the "rapid design, prototyping and learning" concept. Throughout this course we will be seeking for ways that allow you to rapidly go through the cycle of design, construction, testing and analysis, and in the same short timeframe also gain a good quality of learning experience. All these are made possible by using a set of tool kits manufactured by PASCO [2]. These tool kits consist of a large number of "Lego"-like building blocks, sensors and electronics for college-level model construction. With these tool kits, you can quickly construct a small-scale of structural model to simulate an airframe, a landing gear, wing skins and substrate, etc. with minimal turnaround time. These tool kits are further equipped with vibration generators and many different sensors to measure load distribution, motions, and displacements of the structure. By using a user friendly software from the vendor, you can then easily perform static and/or vibration analysis on these measured data in both time and frequency domains. It would be otherwise difficult to perform this kind of structure building and analysis cost effectively and efficiently.

Work to be done

1. Prelab

Watch the two lab demo videos related to this lab. They can be accessed from Canvas under *Lab Assignments and Demo Videos* module. *Practice experiment and data analysis demo video* shows you what this lab is about and what you will do during the lab. *PASCO tool kits demo video* explains each component of the PASCO tool kits available to you in this course. Pay particular attention to the key devices such as the 850 command center, wave driver, sonic motion sensor and the point-tip "needle" displacement sensor that you will be using in this lab. *PASCO manual,example.zip* in the *Misc* module in Canvas should contain most the answers to the questions you may have. You may also want to visit PASCO web site [2-3]. For more lengthy tutorials, try a recent webinar [4].

After you have done these preparations, answer all the questions given in the prelab sheet which can be downloaded from Canvas under *Prelab* module.

2. In lab

Prior to the lab session, you and your group members have been pre-assigned in Canvas to one of the five workbenches to work on the lab. Your section TA may supplement with last-minute instructions and other related information – please pay attention. Each workbench is equipped with a full set of PASCO kits plus a laptop computer. You can always access this lab assignment online from Canvas.

The "flight simulator" construct for this lab, shown in Fig. 1, has already been pre-assembled for you on the workbench. You can see, with some imagination, that the elevated cantilever aluminum beam mimics an aircraft wing structure with two different sources of loads: the PASCO mechanical wave driver at the end of the beam and a spring-loaded weight in the middle. These two loadings simulate typical forces applied to the wing in flight, and can also be viewed as the sources of errors. As you have seen in the demo videos, there are two PASCO sensors attached to the beam: a non-contact motion sensor (placed on the bench and facing upward) and a round point-tip "needle" displacement sensor (held by the stand and pointing downward). The key work of this practice experiment is to dynamically monitor the vertical displacements of the beam vs. time at the two sensor locations.

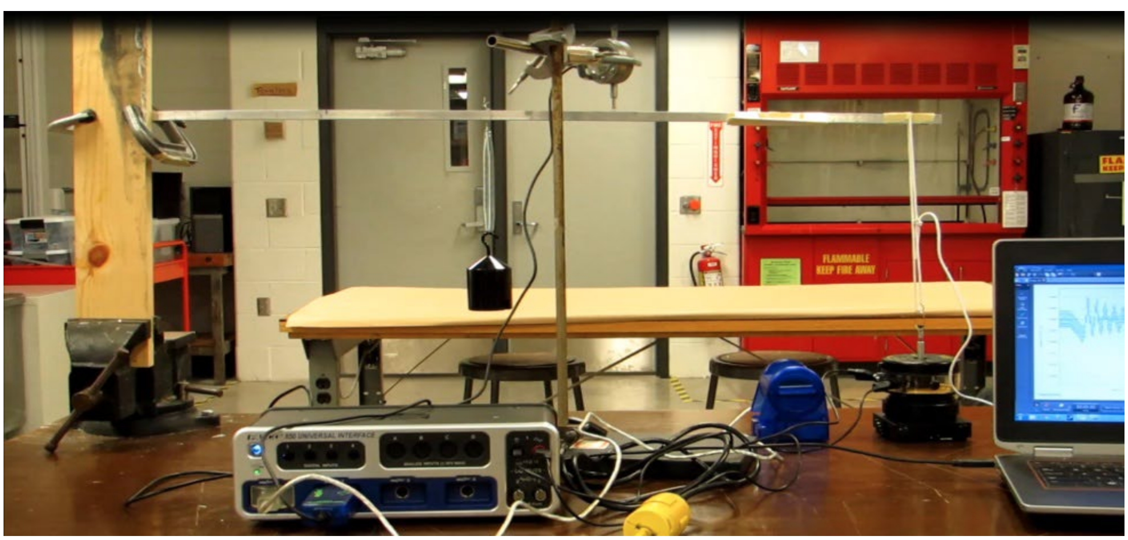

Figure 1: Laboratory Setup

If you have glimpsed through the manuals for the two sensors, you should know that the motion sensor measures the change of distance between the motion sensor and a reflector (i.e. the flat foam attached to the beam facing down toward the motion sensor) by tracking the time-of-flight of the bouncing sonic pulses it emits. The point-tip displacement sensor uses the conventional spring-dial mechanism to measure the movement of the point tip. Note that there is about 15cm dead zone you should set to separate the motion sensor from the reflector in order to obtain accurate measurements.

Your group need to work together to perform three rounds of measurements. To run the tests, first run the Pasco Capstone software by double-clicking its icon on the left of desktop. Open the Hardware Setup by clicking its icon on the left of software screen to ensure both motion and displacement sensors are recognized and activated. Then set up the screen to display two graphs by selecting the corresponding icon from the on-screen template. Click on the axis labels to set x-axis parameters to Time for both graphs, and the y-axis parameters to Displacement for displacement sensor and to Position for the motion sensor (Fig. 2).

Figure 2: Display of two graphs

To setup the wave driver, click on the Signal Generation icon on the left. Click input frequency tab and set the waveform type to sine, sweep to off, amplitude to 10V, frequency to 10Hz and toggle Auto on (Fig. 3). Click the Recording Condition tag on the bottom row of the Capstone screen to open the property dialog. Select Stop condition. Set the Condition Type to Time based and Record Test to 15 seconds (Fig. 4). On the same bottom row of screen, select motion sensor and set the sampling frequency to 100Hz and zero its readout by clicking the button to the right. Likewise select the displacement sensor and set 5Hz for the sampling rate. On the displacement sensor itself, zero the readout by pushing the On/O button.

Figure 3: Signal generator setup

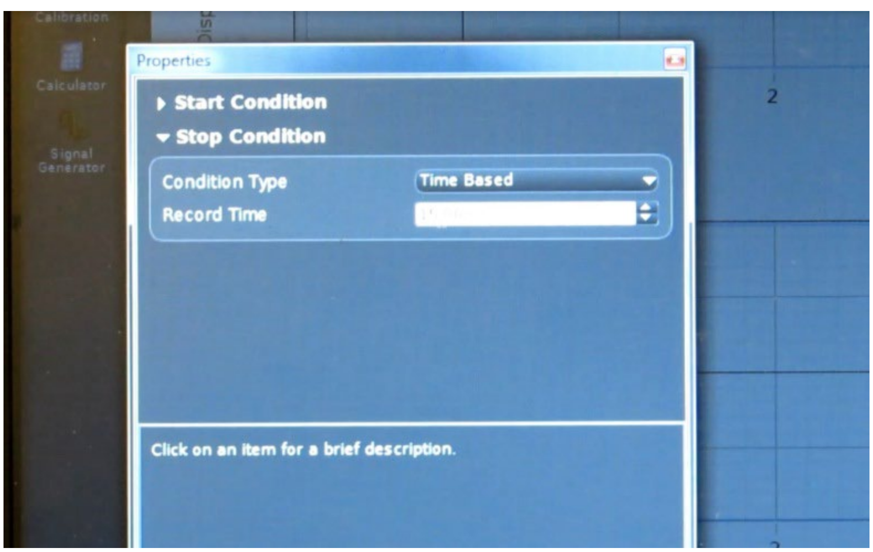

Figure 4: Test duration setup

Before testing you also need to set both the motion and displacement sensors to record at least five significant digits. To set the motion sensor, click the Data Summary icon on the left column of the screen ➔ Motion Sensor ➔ Position (m) ➔ select the gear ➔ Numerical Format ➔ change Number Style to Significant Figures and set Number of Significant Figures to 5. Do the same for the displacement sensor. Please note that these settings were not covered in the video.

In the first test, the input (i.e. external force/disturbance) only comes from the mechanical wave driver. You need to ensure the point tip of the displacement sensor is in firm contact and half depressed on top of the beam, and the gold grid face of the motion sensor is directly below and parallel to the foam surface it will reflect against. Check if there is at least 15cm between the sensor face and the foam. Make sure there is proper tension in the rope tied between the beam and the connector tip in the wave driver axle, and the connector tip is firmly seated inside the axle socket of the wave driver. Zero the reading of the displacement senor once again. Finally, click the record button in the bottom row of the Capstone screen and let the test run for its duration.

For test two, the point-tip displacement sensor will no longer be used; just set it aside for the remainder of the lab period. You then add the second input by attaching the mass-spring system to the beam. You will run this second test similar to the first, but as soon as the test begins, a group member will pull the mass straight down and release it, allowing it to oscillate for the remainder of the test.

For test three, you will repeat the same procedures as in test two that a group member will pull and release the mass immediately after the test begins. In addition, another group member will randomly disturb the beam throughout the test as the third input. As shown in the video, quickly pushing down or up on the end of the beam will suffice for disturbing it.

Follow the video and TA's instructions to save all the data to your own memory stick, etc. or upload to a cloud storage for later After Lab work and lab report writing. *This is very important: if you forget to do so, your group's data will be lost after the lab laptop is turned off!*

3. After Lab

Analyze the data obtained from the three rounds of tests using the same methods learned in lecture. Include all work done here in your lab report under the Analysis section. *Please note that this lab is designed to stimulate your creative reasoning and to encourage you exploring all possible solutions to the questions posted here, some of which can be open-ended and have no definite right or wrong answers!*

1. (35%) How many types of "noises/interferences" can you identify in the displacement data of the beam? Can you match them with what you would expect from an aircraft wing under in-flight conditions? **Hints: think about the high frequency internal vibration from, e.g. engines, the sudden storm turbulences, the more gentle air flow fluctuations, etc.** What other possible sources of error you can think of?

2. (15%) In test one results, can you read off the frequency of the vibration (generated by the wave driver) from both graphs which in turn recorded from the two sensors? **Hint: remember what frequency was set for the wave driver?** Does your finding explain why was the point-tip displacement sensor removed after first test? What terminologies would you use to describe this? **The clue is on page 5 of the lecture notes.**

3. (50%) Smooth the data using the running average filter in single or multiple passes and then fit a curve or line to the data as you have learned from lecture. What kind of curve or line should you use and why? **Hint: remember that both sensors were recorded the beam displacements at the same locations, and this beam is a part of wing structure in a steady-state in-inflight condition (before it encounters the external disturbances). The key word here is "steady-state"!** What factors caused the data to deviate from the predicted curve? Plot the fitted line or curve on top of the raw and the smoothed data, respectively. Show the numerical values of fitting parameters for each. Also evaluate the goodness of fit based on your best judgment.

4. Report

Lab report in pdf format is due as a group to Canvas. Standard report structure (as described in the report instruction and sample report, both available in Canvas) should be followed and include all other regular components not covered in Section 3. *After Lab* above. As mentioned, include all After Lab work (in exact three subsections as listed above) in the Analysis section of the report. Your grading will consist of the scores from the Analysis section (i.e. After Lab work) and the rest sections of the report. No cover letter is needed but extra photos, drawings, charts and tables are welcome.

References

[1] Week 1 lecture notes: https://thermal.cnde.iastate.edu/aere322/notes.wsgi
[2] http://www.pasco.com/engineering/index.cfm
[3] https://www.pasco.com/prodMulti/pasco-capstone-software/index.cfm
[4] "Getting Started with PASCO Capstone" at http://www.youtube.com/watch?v=rsqj-LqV1pw&feature=youtu.be