Lab 10 Structure Model Building

Objectives

Design and construct a structure model using pre-made building kits to realize the “rapid design, prototyping and learning” concept. Test and analyze the structure’s response subjected to static and/or dynamic loading, and relate the results to theories.

Introduction

One important change in curriculum of this course is the addition of vibration/dynamic analysis. If you recall, in Week 1 lecture you have been exposed to vibrational events from two video demos. One revealed the surface vibration pattern on the so-called “Chladni plate”, and the other demonstrated resonance phenomenon in forced vibration of a vertical beam model. To continue the quest, in Week 13&14 lectures you will learn the basic theories of vibration, structural dynamics and fast Fourier transform (FFT).

Another important renovation of this course is the introduction of “rapid design, prototyping and learning” concept. In this lab we are 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. This is made possible by using a set of tool kits manufactured by PASCO [3]. 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 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 driver to generate dynamic loadings 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

Since Week 1 you have been provided the access to a large zip file [2] which contains all needed documents for this lab. You should download it and review these documents. The Capstone software is the commanding center for the structure model you will build in this lab. To get started with this software, play the short video “Capstone-Software-Introduction.mp4” available in Canvas [2]. For lengthier tutorials, try a recent webinar [4]. “Pasco Capstone user guide.pdf” should contain all the answers to the questions you may have later. To be familiar with the PASCO tool kits commonly used in this lab, watch the demo video "PASCO tool kits" also available in Canvas [2]. After you have studied the above and have reviewed this lab manual, you can then complete the prelab assignment and submit to Canvas as usual.

2. In lab

In this lab you are tasked to design and construct a structure model using (but not limited to) PASCO building tool kits. You then test and analyze the structure's behavior under static and/or dynamic loading. Given the scope and efforts to be made, please note that this lab will be most heavily weighted among all labs in this course!

For ideas of building the structure model, you can start with the two demos shown during Week 1 lecture, i.e. the Chladni plate and the resonance beam. "Advanced-Structures-Set-Manual-ME-6992B.pdf" in [2] has some worked structures, in addition to the basic construction techniques. You can also browse PASCO web site [3] and other internet sources for more information. Other possibilities include free vibration of a spring system, forced vibration of a damped system (adding a pendulum as the damper), testing of impact loading by, e.g. throwing a utility cart wheel (mimicking a landing gear) onto the forced platform, etc. Remember this is a flight structure lab – your model should be more relevant to an aircraft than to a bridge or ship. You can choose to build a very basic truss section under static load or a complicated aircraft-like structure subjected to vibration/dynamic loading. Also, you are not bounded by only using PASCO products: why not make your own plastic or aluminum wing skin and attach it to a PASCO frame?!

You should not just work on the construction pieces in designing your model. Instead you should get yourself familiar with all the sensors we have and see how they can be used and fitted with your design. Each sensor has its pros and cons, and size limitation as well. Below are some pointers:

<u>Load cell</u>: Be aware of load cell's physical size, which may dictate your model's size (in order to fit the load cells in). Also, before using them, look into the calibration setting in Capstone and make sure they are balanced.

<u>Wave driver</u>: this is probably the most used in vibration experiment. You need to know that its amplitude diminishes with increase of frequency. At lower frequency, you may need to set to lower voltage (3-8v) and increase to higher 10-15v at higher frequency. For most of your design, frequency range of 5-100 Hz should be good enough. When connecting it to your model, never make direct connection. Instead use flexible interfaces such as elastic string (we have a few rolls of it) or rubber band. Please remember to turn the mechanical switch under the wave diver to *unlock* position before use.

<u>Motion sensor</u>: this is popular with vibration model since it is non-contact, and you have made use of it in Lab 1. Be aware it has a 30cm dead zone of sensing (i.e. don't place

the motion sensor within 30cm to your model). Also, your model needs to have a sufficient planar surface NORMAL to the sensor surface. This would ensure a good reception of the reflected sound pulses. You may need to try-and-error with different sampling rate, as it may not sample fast enough if your model vibrates too fast.

Displacement sensor: this is a good alternative to motion sensor, and you too have used it in Lab 1. If your vibration frequency is fairly low, this should work quite reliably.

You may want to use multiple sensors together to ensure capturing the main features of your experiment. For example, in doing impact loading with the two-axis forced platform, attach additional motion sensor should increase the chance of catching most bounces of the model. You may also want to consider analyzing your signals in frequency domain. For this, be sure to study the Week 13 & 14 lecture notes and gain experience with the spectral analysis of e.g. the beat phenomenon. Actually, in the vertical resonance beam demo, a second chart was used to take data in frequency domain with FFT. That clearly indicated two resonance frequency groups. This demo file is readily available from Canvas for you to use as a template.

3. After Lab

The lab report is the nominal place to present your work on model construction. This should include the standard sections such as objectives, hypotheses, experiment procedures, data/results, analyses, discussions and conclusion remarks, plus descriptions of your model. You can supplement your presentation in any form and using any media allowed. The simplest would be just the usual viewgraphs and pictures in the lab report. We do, however, encourage you to make a 3-5 minutes video to enhance your presentation, particularly if your project involves dynamic events. The whole lab will be graded based on the following criteria:

1. Creativity (15%): Is your project “one of a kind” and “out of box”?
2. Complexity (10%): What level of complexity your project achieves? How difficult to build your model, to take the measurements and to analyze the data?
3. Relevance to aircraft structures (10%): Modeling of an aircraft wing will certainly weigh much more than that of a bridge!
4. Results, analysis and theoretical support (40%): Does your project have clear objectives and hypotheses? Do you have sufficient data/results to support them? Is your analysis sound and in-line with related theory?
5. Report/presentation (25%): Does your report meet all nominal requirements of lab report for this class? Does the report writing and organization clearly present all data/results? Up to 10% extra will be rewarded for additional efforts such as making video presentation.

You should have noticed a high 40% of the report is attributed to analysis and theoretical support. This means, after you have spent all those time in building your masterpiece and taking the best data possible, you should also make equal efforts to analyze the data and to report your findings. Given the complexity of the tool kits, we understand that it is not possible to quantify your analysis to decimal-place accuracy. However, you should have no problem to provide qualitative estimates in many aspects. For example, if your experiment involves vibration, you need to first determine which category it is in (a free vibration or a forced vibration)? Resonance occurs? How much is the damping effect (underdamped, critically damped, or overdamped)? What is your signal strength comparing with the background noise (these two comprise the so-called signal-to-noise ratio as you learned in NDE lectures)? Does the sensor sample fast enough (you may want to review the terms "sampling frequency" and "Nyquist frequency" which are covered in Weeks 1, 13 & 14 lecture notes)? Furthermore, you should be able to put some of the knowledge you learned in EM 324 and AerE 321 in good use here. Stress and strain analysis of frame structure by stiffness method and impact loading by energy method are just two examples of possible applications. You can find PASCO material properties from "PASCO beam model info.pdf" in class Canvas site.

Lastly, a suggestion is in order about choosing the processing tool. Capstone software provides pretty good functionalities for displaying and processing of the data (see [4] for a good coverage). But, as you did in Lab 1, you can always export the data out to Microsoft Excel or even to MATLAB and python if you wish to run the extra mile!

4. Report

A full report is due to class Canvas site (all sections). As mentioned above, standard report structure should be followed and include all other regular components not covered in 3. After Lab above - extra photos, drawings, charts and tables are almost always welcome. If your group will submit additional data/files, you can personally deliver the data/files or send them via e-mail to both TA and the instructor. For data/files too big to e-mail (such as videos), please let us know clearly where and how to retrieve them. You should also request a "Read Receipt" in your e-mails to ensure a safe delivery.

References

[1] Weeks 13 & 14 lecture notes

[2] "PASCO manual,example.zip" and "Capstone-Software-Introduction.mp4" in Misc module of Canvas and demo video "PASCO tool kit" in Lab Assignments and Demo Videos module of canvas.

[3] http://www.pasco.com/engineering/index.cfm

[4] "Getting Started with PASCO Capstone" at http://www.youtube.com/watch?v=rsqj-LqV1pw&feature=youtu.be