Vibration Measurements Part 1
Sine Sweep Test of a Cantilever Beam

Objectives:

The objects of this experiment are to:

1. Find the first natural frequency of a cantilever beam using both theoretical and experimental techniques and to estimate the first mode's damping.
2. Find the second natural frequency of a cantilever beam by locating its 180° phase shift.

Introduction:

Every physical bony has an infinite number of resonant or natural frequencies. The body will vibrate with a different vibration envelope for each of these resonant frequencies. We refer to the vibration envelope as the mode of vibration, hence we refer to the resonant frequencies as modal frequencies. You can see the vibration envelope of a meter stick by holding it horizontally by its end and moving it rapidly up and down. The first mode will look like a wedge with the apex at your hand. When the meter stick reaches the edge of the vibration envelope, it must come to a stop so it can reverse its direction. Your eye can see the stick when it briefly stops moving, but when it passes through the midpoint it is going very fast and appears as a blur. If you shake the stick even faster you will see the second vibration mode. No one has been able to shake it fast enough to see the third mode

The first three vibration modes of a cantilever beam are shown in Figure 1. Notice that each mode adds one vibration node to the mode shape. The natural (or resonant or modal) frequency associated with each of these vibration envelopes s greater than that associated with the previous envelopes. That is $\omega_{n1} < \omega_{n2} < \omega_{n3} < ...$ Notice that while driving frequencies are harmonic and increase by integer multiples the modal, frequencies do not necessarily exhibit this characteristic.

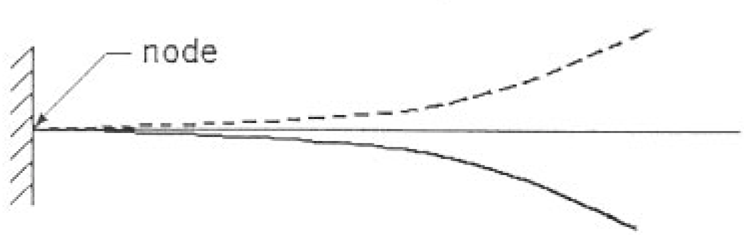

Figure 1a: Typical First Mode Vibration Envelope

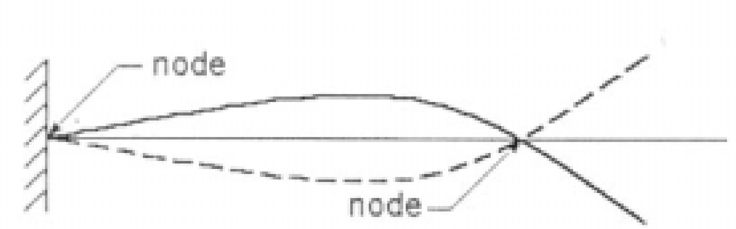

Figure 1b: Typical Second Mode Vibration Envelope

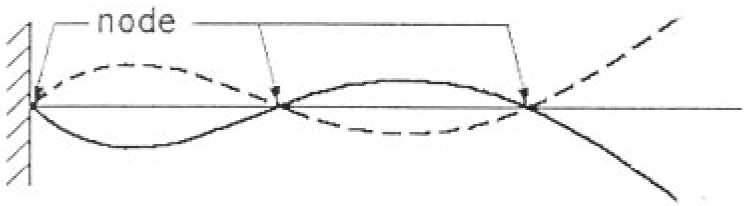

Figure 1c: Typical Third Mode Vibration Envelope

Use any vibration textbook to find the first natural frequency of a cantilever beam with distributed mass. We obtain this frequency experimentally using an electromechanical shake table, accelerometers and an oscilloscope or a spectrum analyzer. We will use the sine sweep method.

Procedure:

1. Measure the beams length, width and thickness. Use the ruler graduations to measure the length and a vernier caliber to measure the width and thickness. Measure the thickness carefully since the calculations are very sensitive to errors in this measurement. Calculate the beam's mass assuming that it is made of 6061 T6 aluminum (167 1b/ft^3).

2. Set up the shake table and the instrumentation according to Figure 2.

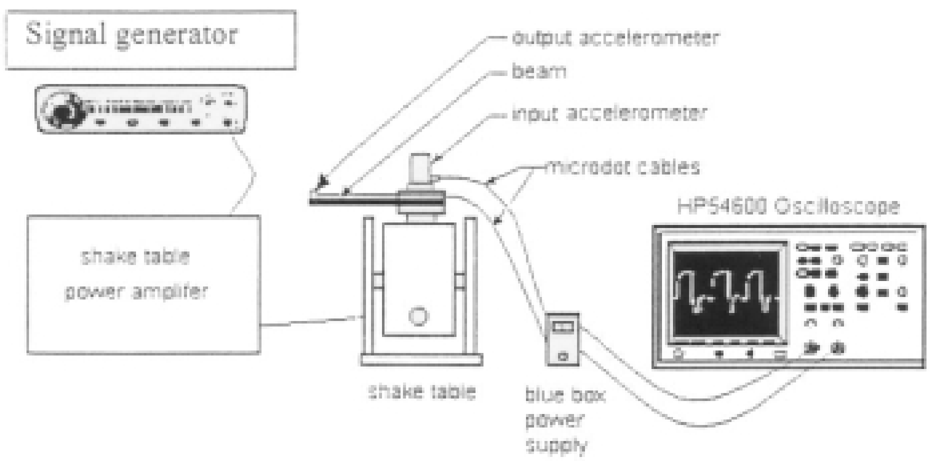

Figure 2: Experimental Setup & Wiring Diagram for the Sine Sweep Test

3. If they are not already attached, you should attach one accelerometer on top of the beam at the shake table's center (the input accelerometer) and a second one on the beam's end (the output accelerometer).

4. Carefully connect a micro-dot cable to each accelerometer and to the PCB power supply and coupler blue box. Be sure you have the blue box power turned on when checking.

5. Use BNC cables to connect each of the channels used on the blue box to an oscilloscope.

6. Check to see if the accelerometers are working, by tapping them lightly with your finger. If you do not see any wiggle on the oscilloscope screen then something is wrong. Check the wiring, the blue box battery, the oscilloscope, etc., or call your instructor

7. Attach a cable from the output terminal on the function generator to the power amplifier's input. This cable is always attached to the power amplifier, so all you need do is attach it to the function generator, but do make sure the table number on the lead is the same as that on your shake table If using the function generator set the following controls.

   Frequency. 100 HZ
   DC offset: off (very important) !!!!
   Sweep rate: off
   Sweep width. Off

   Turn on the function generator, the power amplifier and the instrumentation. Use the amplitude control of the function generator to adjust the shake table amplitude. It will be necessary for you to adjust this each time you change the frequency so as to maintain a low output amplitude near the natural frequency. <u>PLEASE KEEP THE TABLE AMPLITUDE LOW (barely visible if visible at all) TO AVOID BLOWN FUSES. Do not allow the beam to vibrate any longer than necessary at the natural frequency.</u>

8. Your goal is to obtain the ratio of the amplitude of the end of the beam (output amplitude) divided by the amplitude of the shake table (input amplitude). In addition, you should obtain the phase relationship between the output and input signals (remember there is a 180 degree phase shift that occurs at resonance). Start at about 130% of the computed ω_n and take about 20 data points down to 70% of ω_n. It may be difficult to get data right at the natural frequency because the input amplitude goes almost to zero. Be sure that the oscilloscope signals appear to be sine waves; you may have to adjust the function generator's output to maintain sine waves at all times. You should tabulate frequency, input amplitude, output amplitude, and the phase between output and input. Making a rough graph as you take data will help you avoid bad data.

9. Plot the phase angle and the output over input amplitude ratio vs. frequency. As you go through the natural frequency the output should go from being in phase with the input to being 180 degrees out of phase with the input. This gives you a rough check on the location of the natural frequency. In addition, the amplitude ratio should be a maximum at the natural frequency.

10. Estimate the first mode's damping ratio using the approximation,

$$\zeta \cong \frac{1}{2*(\text{Peak Amplitude Ratio})}$$

11. Use the phase change (but now from in phase to out of phase) to locate the second modal frequency. Increase the driving frequency until the output and input signals are in phase again. Try to locate this frequency within ±5%. State your range of uncertainty with your

answer. If you change the frequency too rapidly you will confuse the oscilloscope, but if you change it too slowly you will never get there. Choose a rate that is “just right”.

12. Hold the frequency constant, at any frequency not near the natural frequency and vary the amplitude of the input signal. Find the phase and amplitude ratio for about five different input signal levels. What happens to the phase and the amplitude ratio under these conditions? What is the meaning of this result? Hint: see objective 3.

13. Remove the aluminum beam and replace it with the plastic beam and repeat this experiment.