Modal Analysis Experiment

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Special Topics in Mechanical Engineering

Textbook 2 – Chapter 10 - Section 8 (10.8)

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What is Modal Analysis Experiment?

- For a continuous structure, like a beam, *Experimental modal analysis*, also known as *modal analysis* or *modal testing* is an experimental method used to determine
    1. Natural Frequencies
    2. Mode Shapes
    3. Damping ratios

- Modal testing is based on two basic ideas:
    1. When a structure, machine, or any system is excited, its response exhibits a sharp peak at resonance when the forcing frequency is equal to its natural frequency when damping is not large.
    2. The phase of the response changes by 180° as the forcing frequency crosses the natural frequency of the structure or machine, and the phase will be 90° at resonance.

Equipment used in modal analysis experiment

- The measurement of vibration requires the following hardware:

1. An **exciter** (like a hammer) or source of vibration to apply a known input force to the structure or machine.
2. A **transducer** to convert the physical motion of the structure or machine into an electrical signal, i.e., accelerometer.
3. A **signal conditioning** amplifier (Data acquisition system DAQ) to make the transducer characteristics compatible with the input electronics of the digital data acquisition system.
4. An **analyzer** to perform the tasks of signal processing and modal analysis using suitable software.

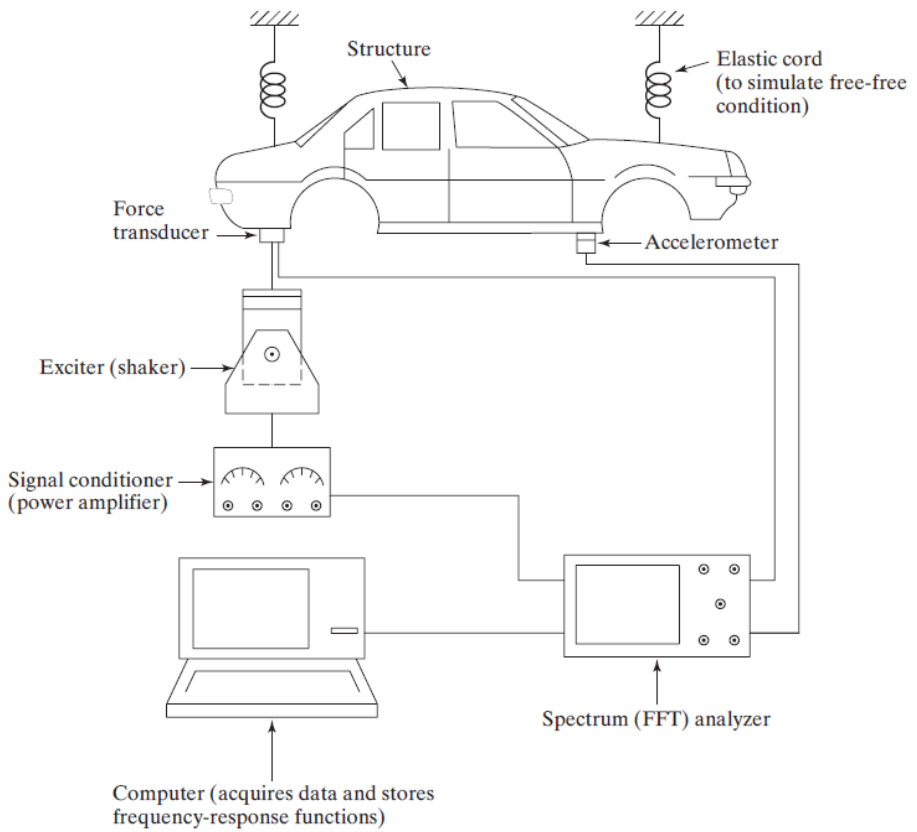
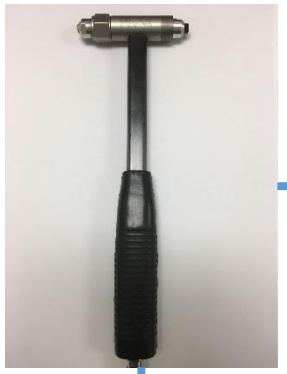


FIGURE 10.27 Experimental modal analysis.

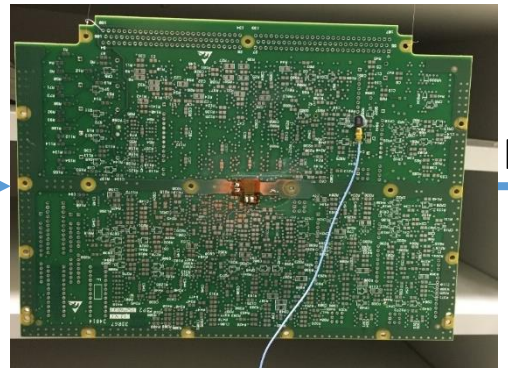
Experiment

Impact hammer



Excitation

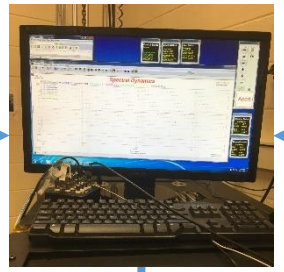
Test plate



Response

Accelerometer

Input signal



Output signal

DAQ System

Signal processing

Natural Frequencies
Mode Shapes
Damping ratios

PCB mesh grid

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

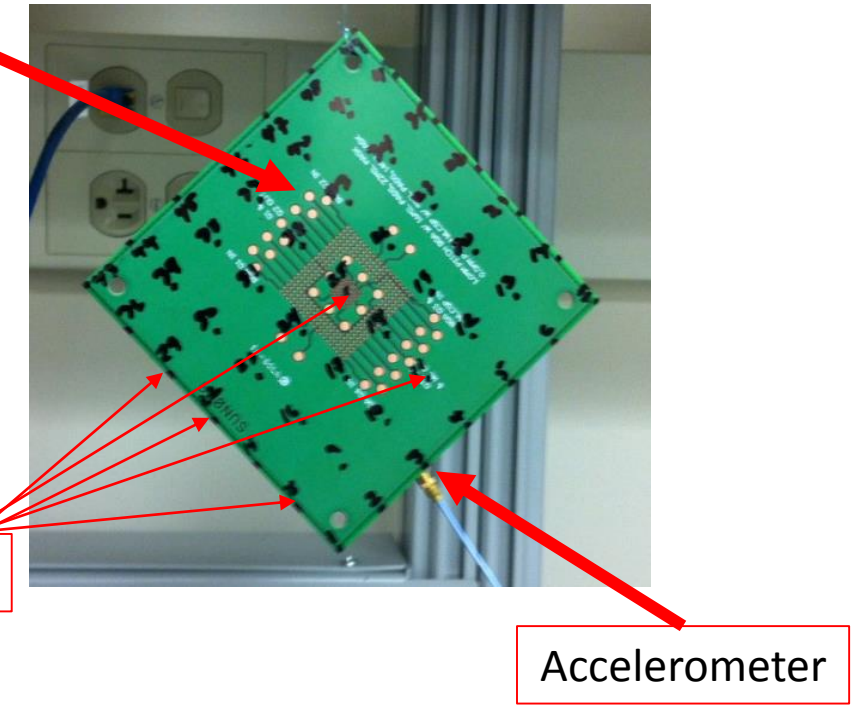
Procedure - 1

1. A gird point is specified on the structure. The impact hammer is then used to hit the structure at each grid point.

2. The accelerometer measures the structure acceleration after each hit.

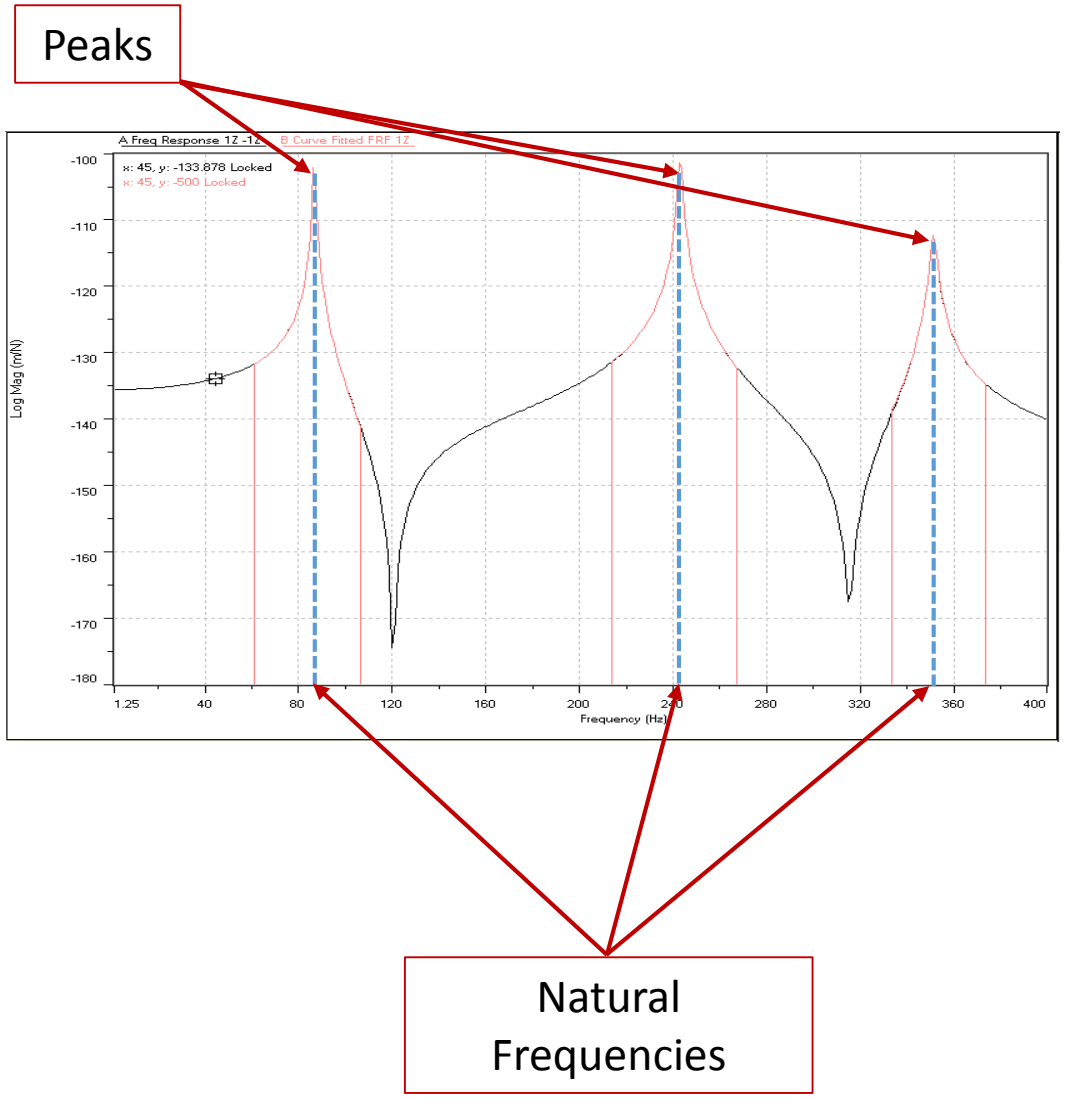
3. The transfer function between the accelerometer outputs (acceleration) to the hammer excitation (force) response is to be acquired Data Acquisition (DAQ) system.

4. Finally, the analyzer software is to be used to generate the modal characteristics of the tested configuration.

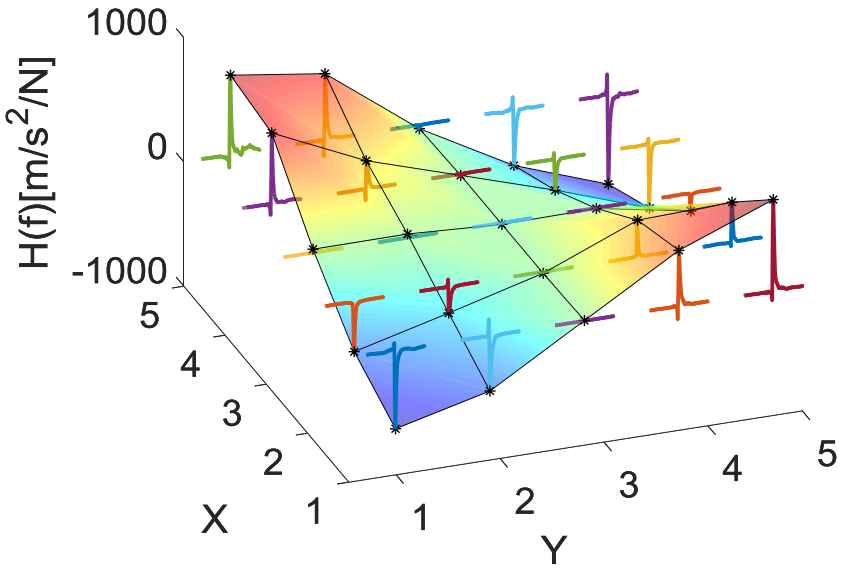


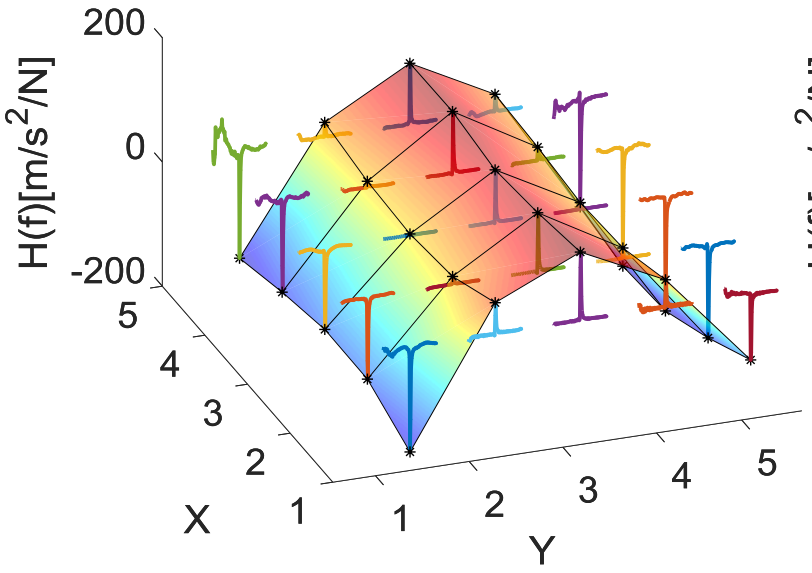
Procedure - 2

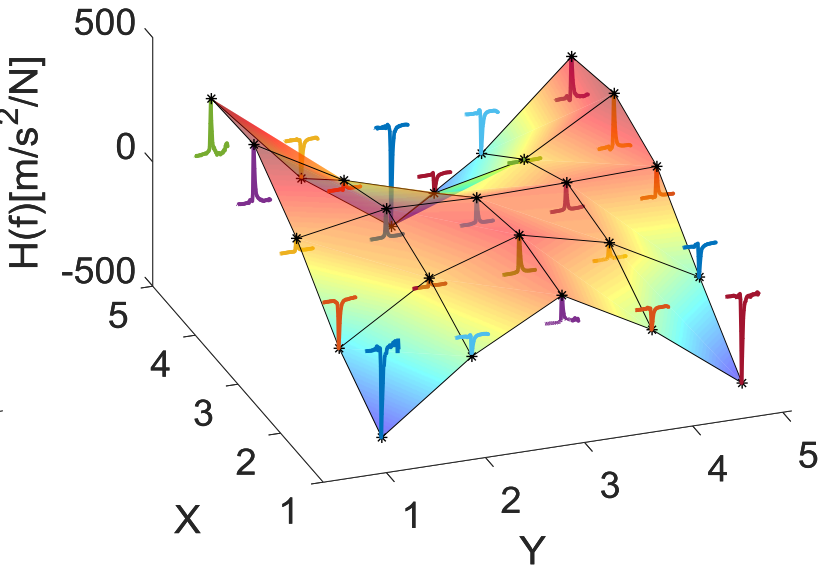
- For each hit point, a frequency response function (FRF) is generated using the analyzer software.
- From this function we can determine natural frequencies (peaks)
- The analyzer software uses least squares method to curve fit all hit points to obtain mode shapes.
- From those FRF's we can estimate damping ratio for each mode.



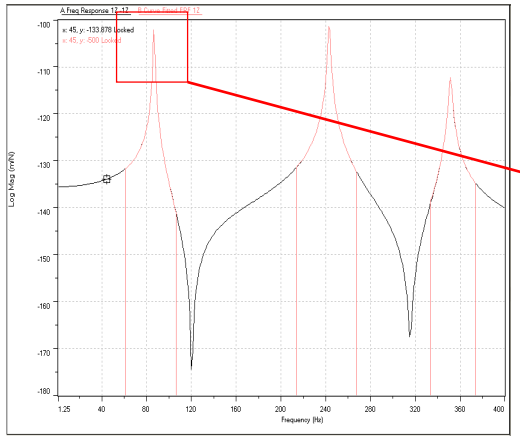
Mode Shape Curve fitting

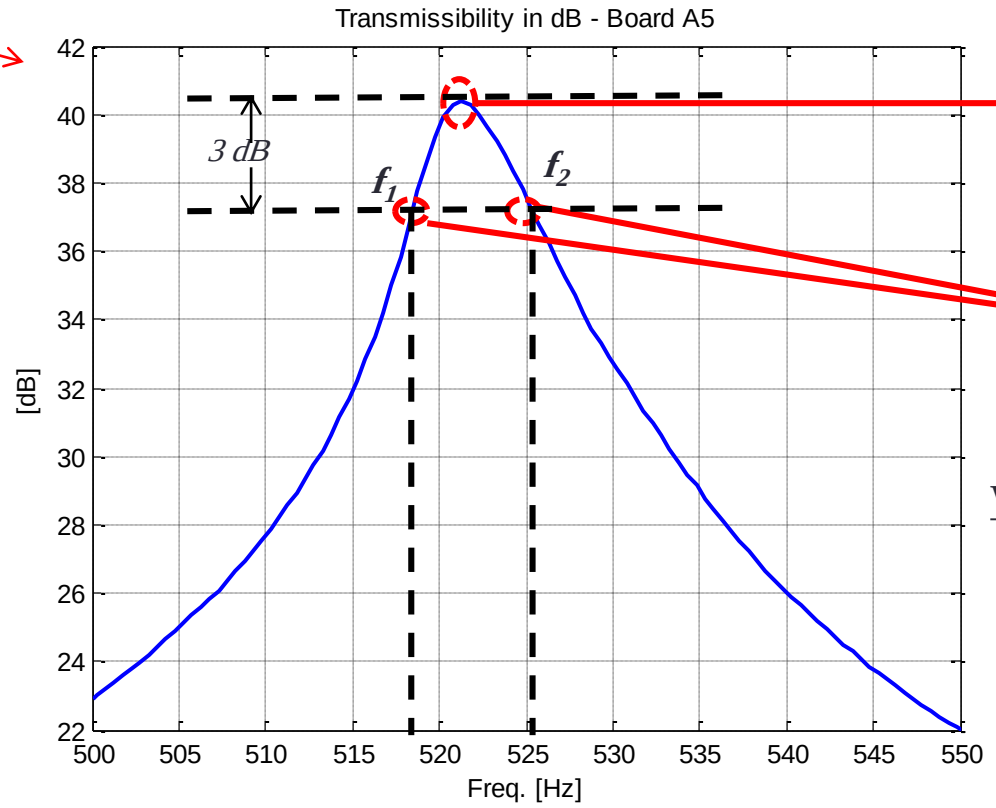






Damping: Half-Power Points Method





Frequency (f_n) = 521.3 Hz
40.3 dB

f_1=518.5 Hz
f_2=525.3 Hz
37.3 dB

We can obtain quality factor from:

$$Q = \frac{f_n}{f_2 - f_1} \longrightarrow \text{Q=76.7}$$

Now, damping ratio:

$$\zeta = \frac{1}{2Q} \longrightarrow \zeta = 0.65\%$$

Thank you!