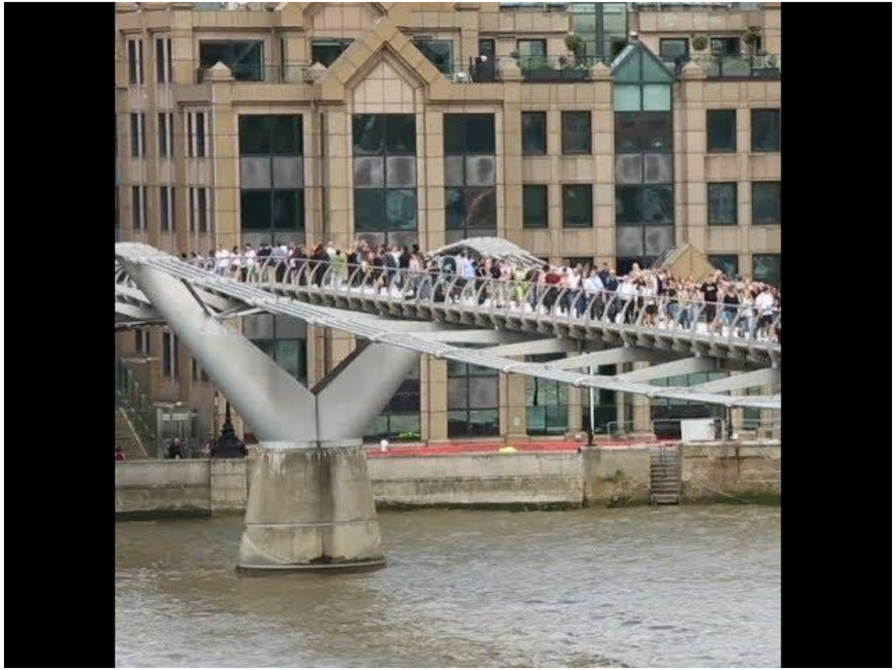
ME-372 : Heat transfer and Metrology lab

Vibration Measurement of Structure Using Accelerometer Sensor

Contents

Introduction

- Every structure has its
  - natural frequencies and
  - natural modes of vibration
- Modal analysis is → *method*
- Use?
  - resonant frequencies
  - mode shapes



People walking on the bridge

Introduction contd..

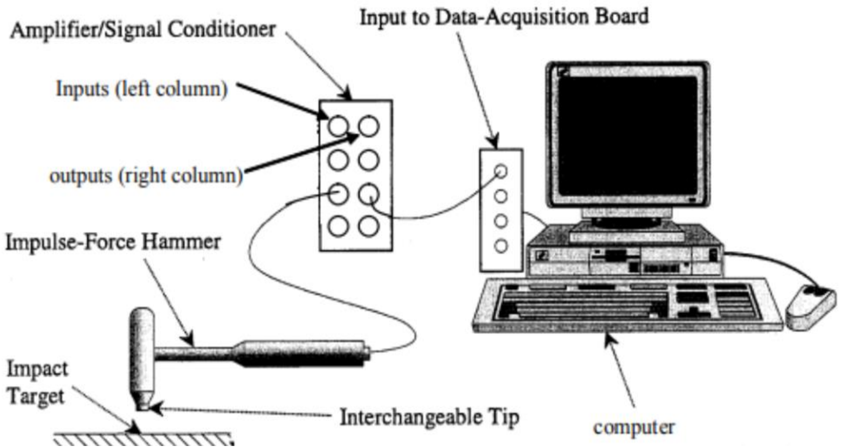
Objectives of experiment :-

- To measure :

  the vibration of a structure using accelerometer

  the impact forces applied using the impulse-force hammer

- To determine the frequency response functions for calculating the natural frequencies and modal parameters of a vibrating structure

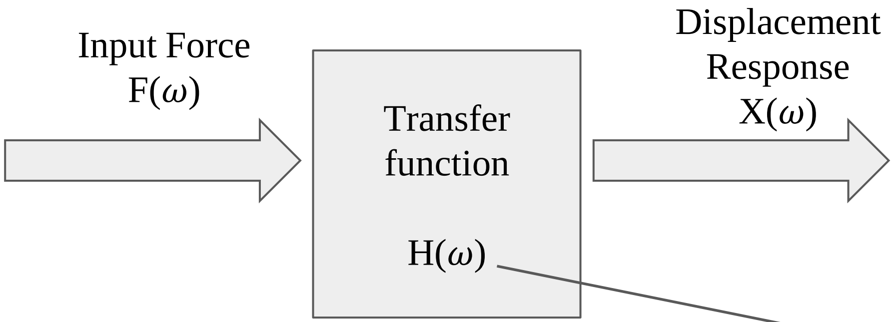


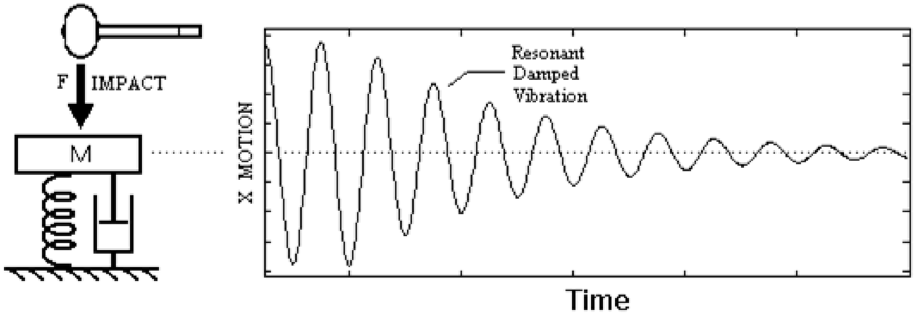
Principle:-

❖ To convert the vibration signals of excitation and responses measured on a complex structure into a set of modal parameters

Theory

Frequency Response Function Model





Vibration response of a SDOF system to a hammer impact force excitation process

Linear system

$F(\omega)$ = input force as a function of the angular frequency ω
$H(\omega)$ = transfer function
$X(\omega)$ = displacement response function

$$H(\omega) = \frac{X(\omega)}{F(\omega)}$$

- ❖ Each function is a complex function
- ❖ Represented in terms of magnitude and phase

Theory (Contd..)

<ins>Analytical Frequency Response Function</ins>

$$\sum F = m\ddot{x}$$

$$m\ddot{x} + c\dot{x} + kx = F$$

$$\ddot{x} + 2\zeta\omega_n\dot{x} + \omega_n^2 x = \omega_n^2\frac{F}{k}$$

$c/m = (2\zeta\omega_n)$

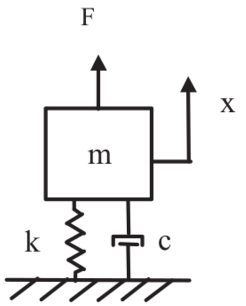
$k/m = (\omega^2{}_n)$

resulting transfer function is
called as receptance function

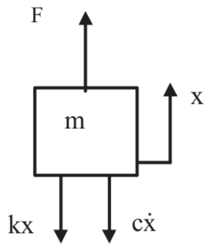
$$\frac{X(\omega)}{F(\omega)} = \frac{1}{k}\left(\frac{\omega_n^2}{\omega_n^2 - \omega^2 + j(2\zeta\omega\omega_n)}\right)$$

The **accelerance function** is

$$\frac{A(\omega)}{F(\omega)} = \frac{1}{k}\left(\frac{-\omega^2\omega_n^2}{\omega_n^2 - \omega^2 + j(2\zeta\omega\omega_n)}\right)$$



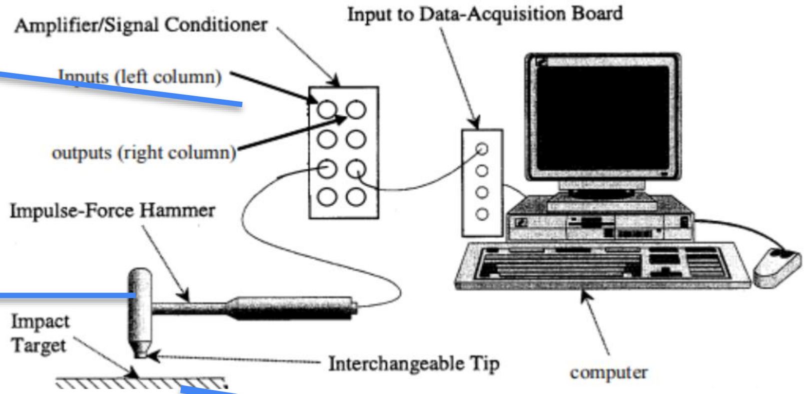
<ins>Single-degree-of-freedom system subjected to a force excitation</ins>



<ins>Free-body Diagram</ins>

Schematic of actual experimental setup & components:-

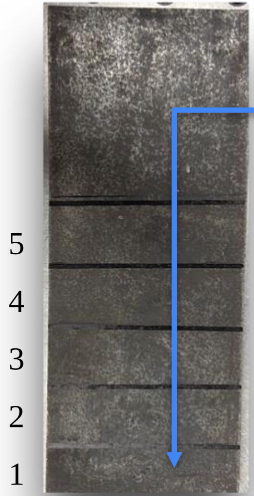
Amplifier/Signal Conditioner



<u>Schematic diagram of experimental setup</u>

Impulse-force hammer

Accelerometer sensor



Impact Target-Mild steel slab divided into 5 equal parts

Fitting of Figure 4 (from MATLAB):-

1	0.000000	-0.002088	0.000583
2	5.000000E-5	-0.002195	0.001217
3	0.000100	-0.001731	0.001249
4	0.000150	-0.003382	0.001618
5	0.000200	-0.001226	0.001346
6	0.000250	-0.001801	0.000613
7	0.000300	-0.001998	0.001029
8	0.000350	-0.000792	0.001327
9	0.000400	-0.002101	0.000866
10	0.000450	-0.000543	0.001225
11	0.000500	-0.002353	0.000831

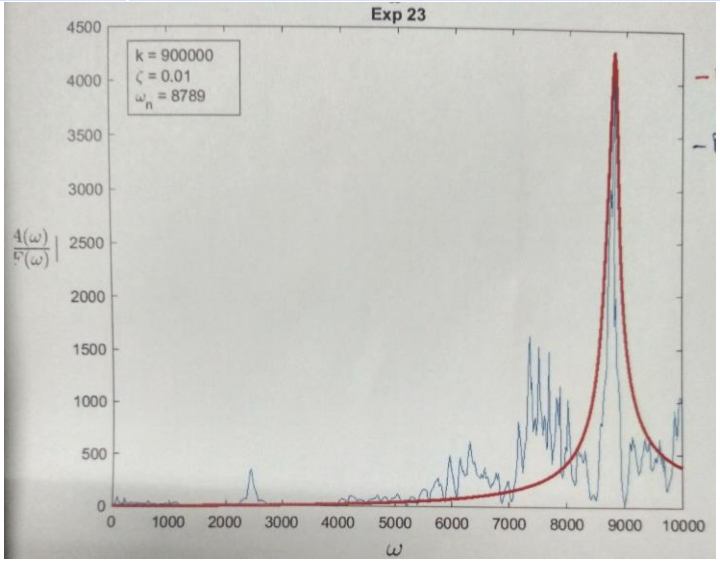
"11.lvm file screenshot"
Such set of data files will be shared
to the students

Accelerance function is

$$\frac{A(\omega)}{F\omega} = \frac{1}{k}\left(\frac{-\omega^2\omega_n^2}{\omega_n^2 - \omega^2 + j(2\zeta\omega\omega_n)}\right)$$

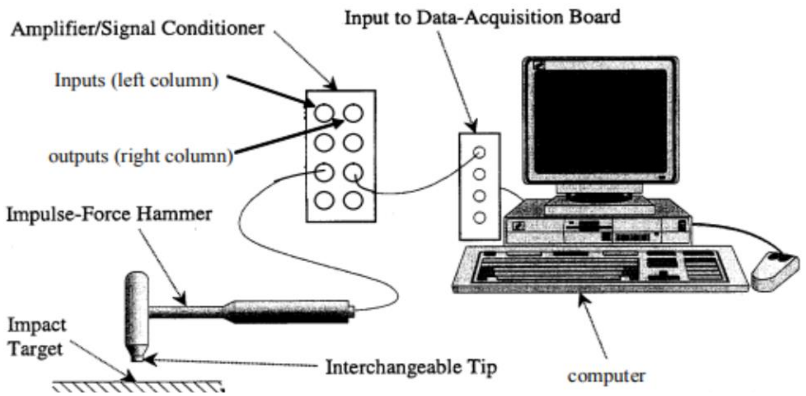
Knowns	Unknowns
$\frac{A(\omega)}{F(\omega)}$, ω	ω_n , ζ , k

Example plot:



Procedure:-

1. Make sure all the devices are working properly.
2. Divide the structure into 5 different nodes.
3. Each of which will be excited to completely understand the natural modes of vibration of the plate.
4. Identify the two nodes where you want to take the measurement using impulse hammer at one node and accelerometer at another node.
5. Place the accelerometer at the node where you want to measure the response.
6. Start the data acquisition using the run button at the computer Labview software panel.
7. Tap the impact hammer at the one of the selected node to excite the structure.
8. Save the data of acceleration and impact force which will be in **time domain**.
9. Repeat the process by selecting the different nodes on the structure.



Experimental setup

Precaution:-

To avoid affecting the test result, care must be taken to ensure that the test is not disturbed by any shock or vibration.

Results & Analysis (Report requirements):-

Question 1. *Plot* the frequency response function (FRF) for the data acquired for different nodes.

Question 2. Determine the *natural frequency* using these FRFs at different locations.

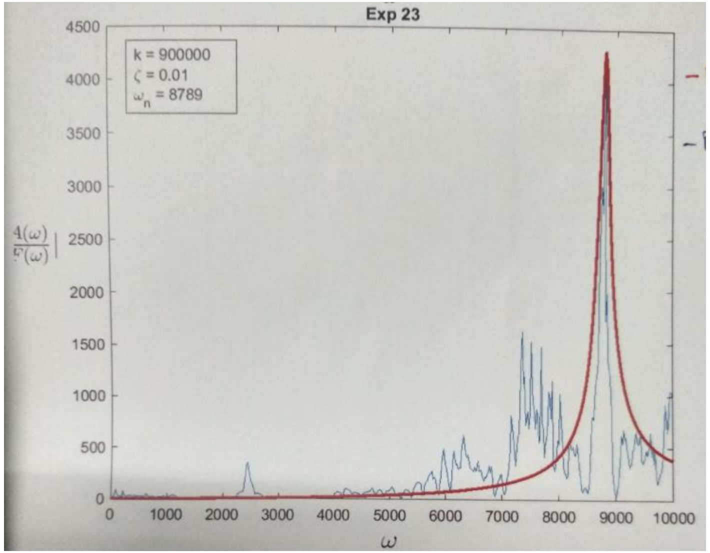
Question 3. Determine the *modal parameters* for different modes using curve fitting method.

Question 4. Write *conclusions* and some *potential sources of error*.

Remember to also attach:

- Introduction
- Objective
- Principle
- Theory
- Procedure & Precaution

Report Plots:



- Data *provided* to you will be:
  - MATLAB program(“FFT_FRF.m”)
  - 10 “**.lvm” files(coming from the LabView Software)
- Expected plots from *your side* will be:
  - ***10*** different fitted plots with (as shown in the side example plot)
    - ***legend*** containing the mention of
      - ζ
      - ω_n
      - k
    - *X and Y axis label*
    - Clear ***fitted plot in red color*** along with the data plot in the same graph
    - ***Title*** of the input file plot (e.g. mention “*Exp 23*” coming from the “23.lvm” file as shown)