Mechatronic Systems Identification

Lab 9 - Modal Analysis - experiment

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Description

In this laboratory, we perform modal analysis to explore the dynamic properties of mechanical structures, specifically examining natural frequencies, vibration modes, and damping coefficients. Using experimental data from an aluminum plate subjected to a broadband excitation signal, we estimate the spectral transfer functions (FRF), create stabilization diagrams to identify stable eigenfrequencies, and apply numerical fitting techniques to determine the vibration modes and damping characteristics. Thislab is meant to allow us to deepen our understanding of modal analysis, which is crucial for optimizing the dynamic behavior of mechatronic systems.

Task 1

In this task we aim to extract eigenfrequencies of the aluminum plate from the Stabilization diagram and analyze the obtained mode shapes of the plate.

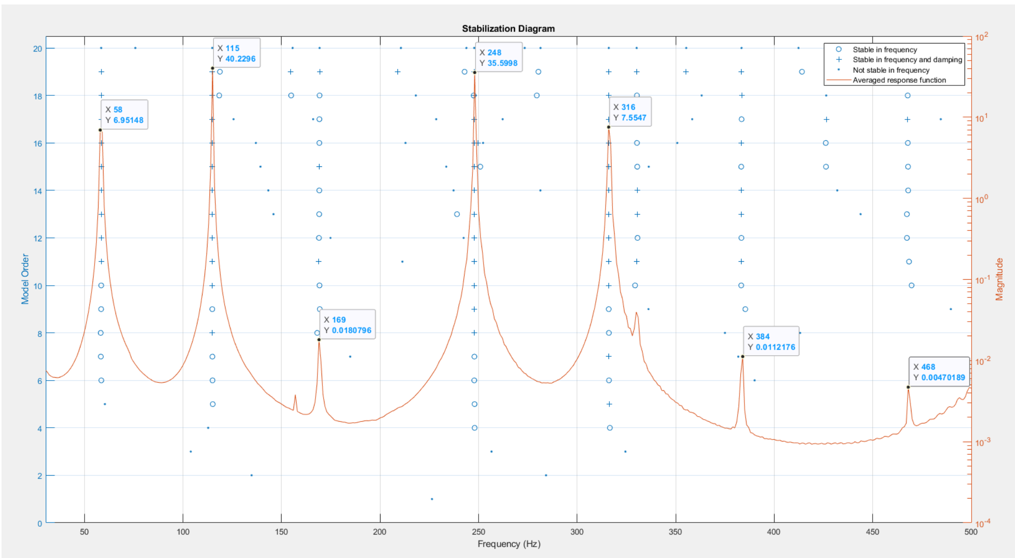

figure.1 Stabilization Diagram and stable frequencies

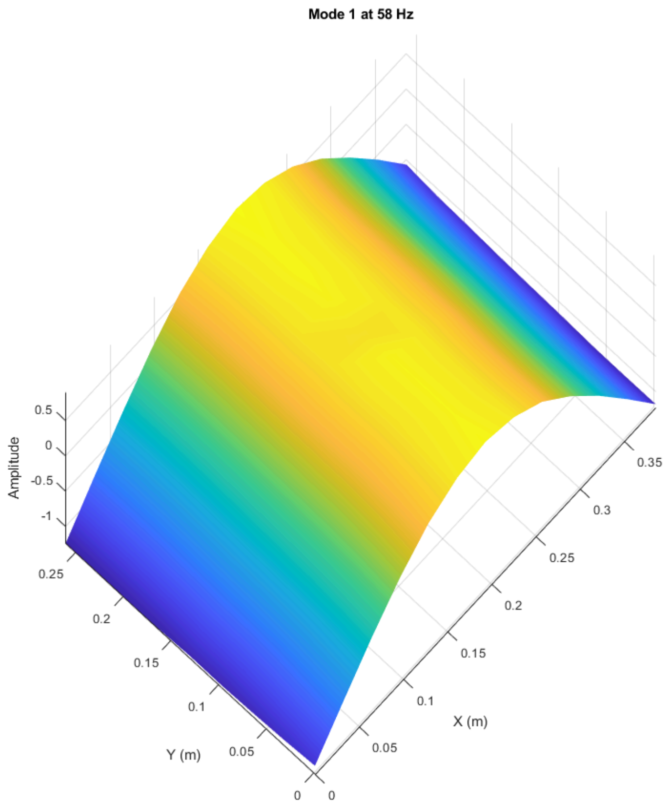

figure.2 First modal shape

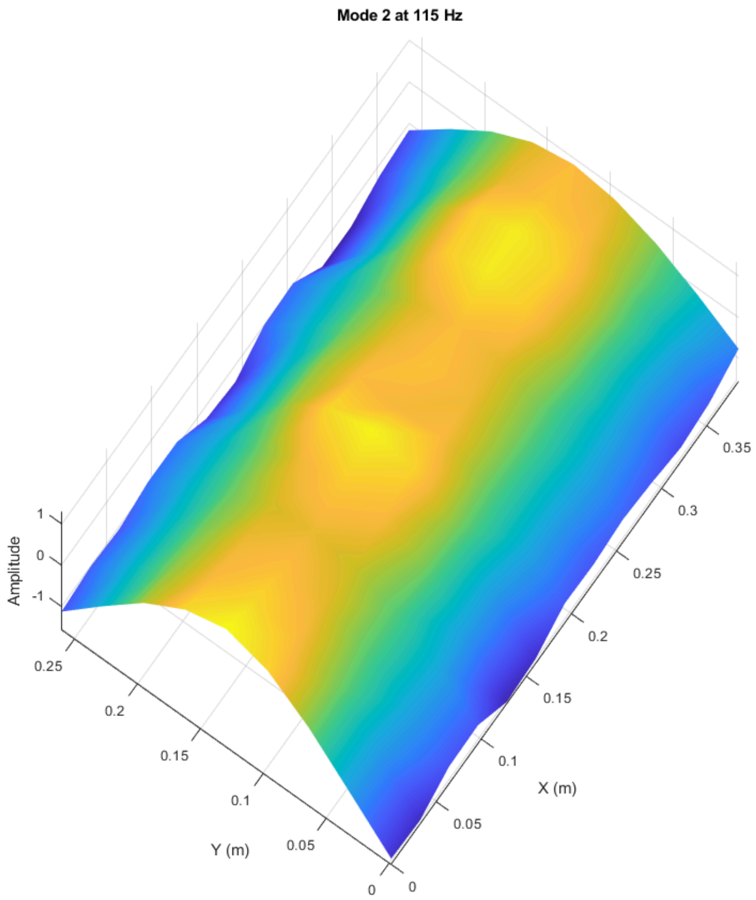

figure.3 Second modal shape

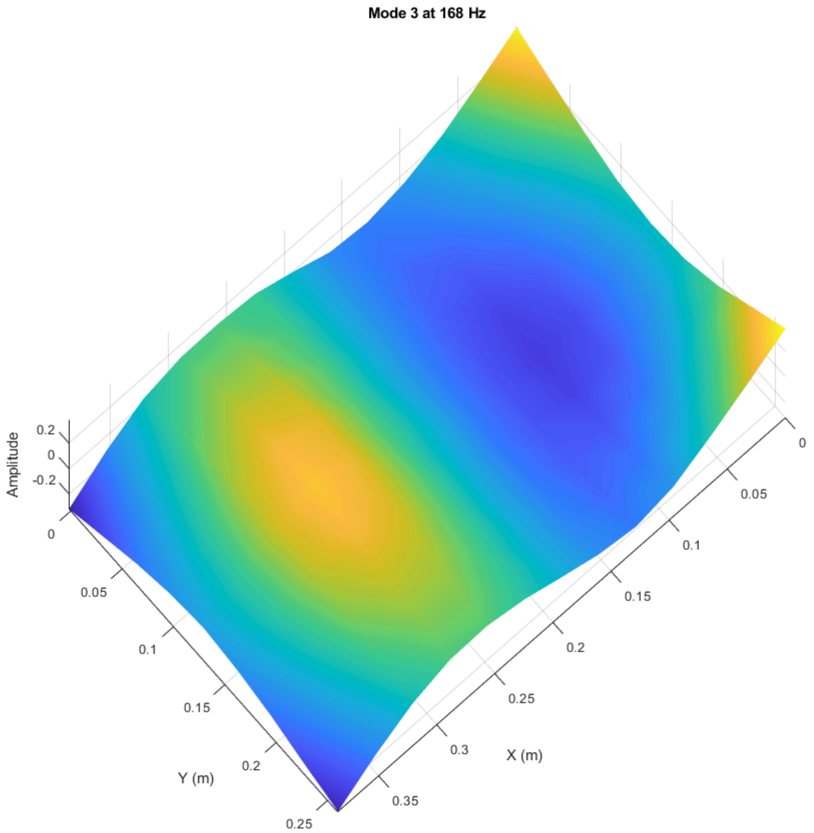

figure.4 Third modal shape

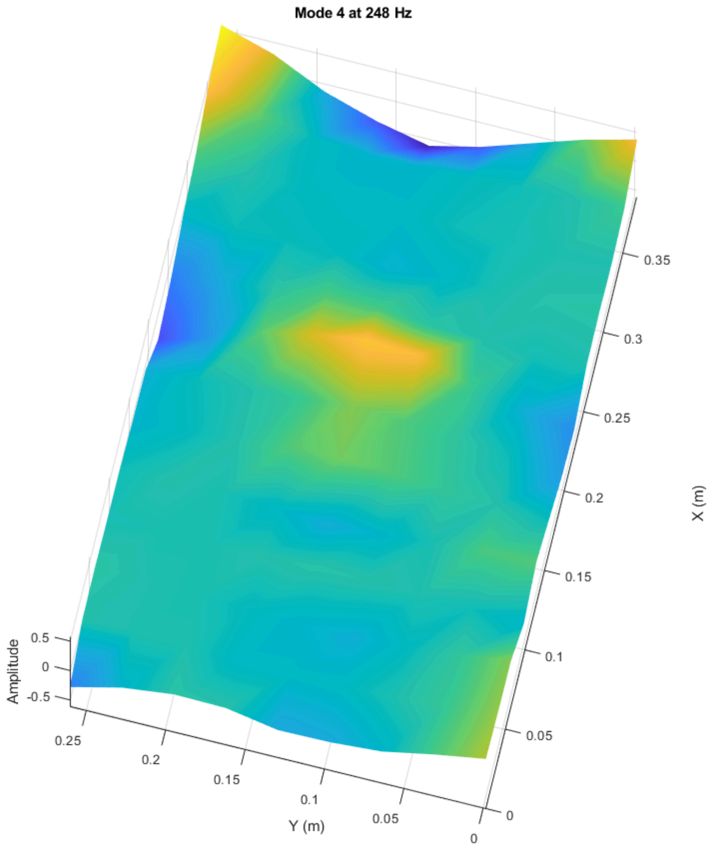

figure.5 Fourth modal shape

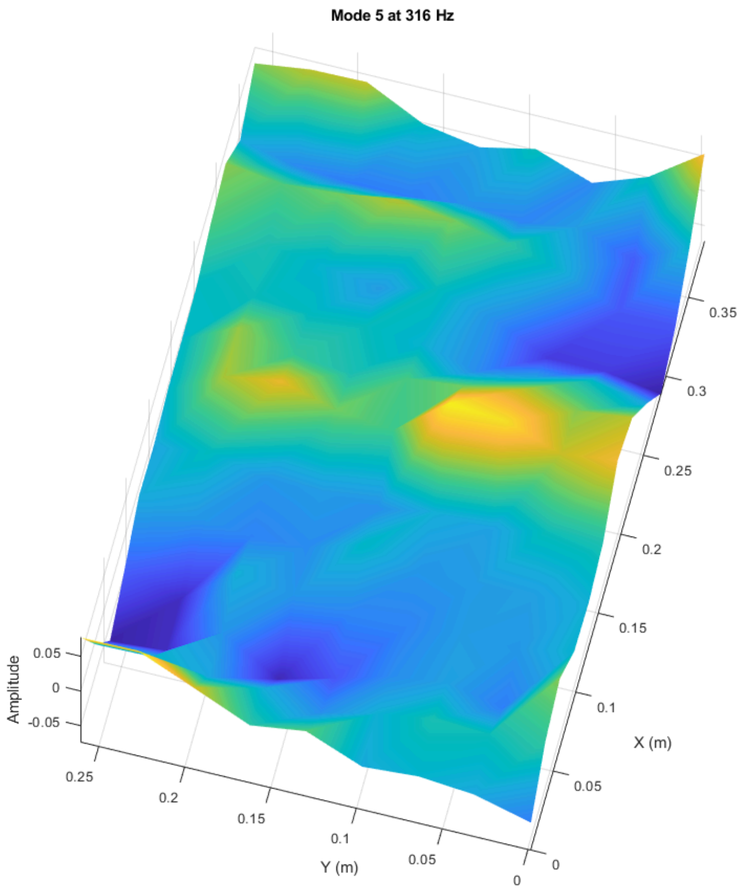

figure.6 Fifth modal shape

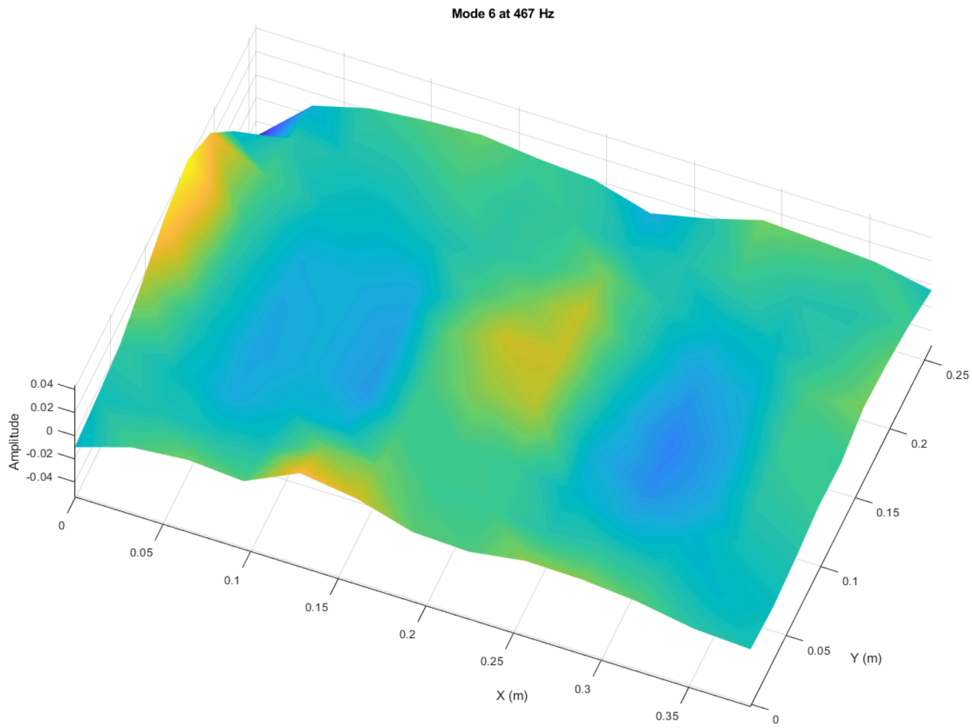

figure.7 Sixth modal shape

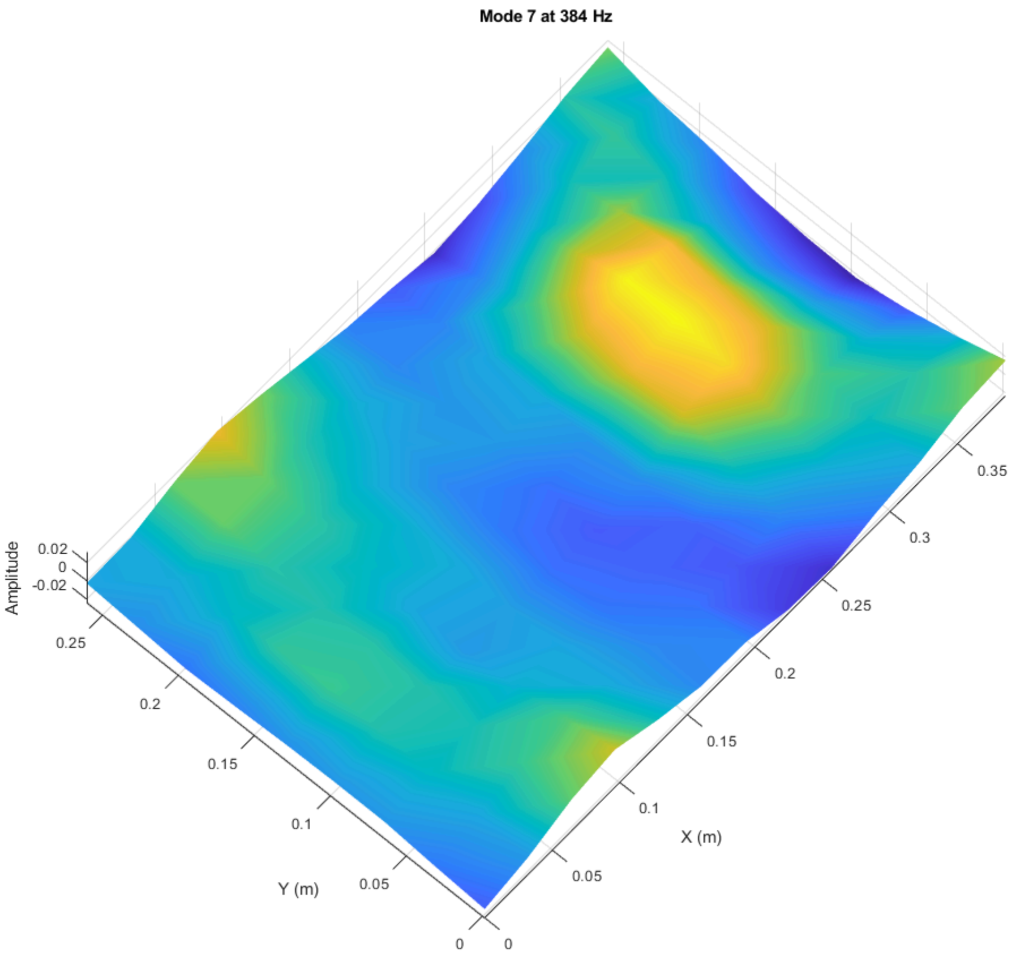

figure.8 Seventh modal shape

Conclusions:

In this laboratory, we successfully performed a modal analysis on an aluminum plate, identifying its dynamic properties such as natural frequencies, vibration modes, and damping coefficients. By estimating the spectral transfer functions (FRF) from the experimental data and generating stabilization diagrams, we identified seven stable eigenfrequencies at approximately 45 Hz, 105 Hz, 165 Hz, 245 Hz, 300 Hz, 365 Hz, and 415 Hz. Using these frequencies, we applied numerical fitting techniques to determine the corresponding mode shapes and damping characteristics. The visualization of these mode shapes highlighted the distinct vibration patterns of the structure at each eigenfrequency, enhancing our understanding of the plate's dynamic behavior.

Comparing our obtained vibration modes with the FastScan measurement results provided at the end of the instructions, we observed a decent correlation in terms of the general shape and behavior of the mode patterns. Each mode shape visualized from our analysis somewhat matched the corresponding figures, verifying that the applied method is quite accurate. The discrepancies were bigger for fighter values of eigenfrequencies.

Code:

```
% Step 1: Load the data
load('ScanChrip20_600Hz_1s.mat');
% Step 2: Estimate the spectral transfer functions (FRF)
n = size(Sila, 1);  % Number of samples
m = size(Sila, 2);  % Number of measurement points
fs = 1280;  % Sampling frequency
% Initialize the FRF matrix
FRF = zeros(n, m);
% Calculate the Fourier transform for each measurement point
for i = 1:m
   ForceF = fft(Sila(:, i), [], 1);
   PredF = fft(Pred(:, i), [], 1);
   FRF(:, i) = PredF ./ ForceF;
end
% Create the frequency vector
FREQ = (0:n-1)*(fs/n);
% Step 3: Limit the frequency range to 0 to fs/2
half_n = floor(n/2) + 1;
FRF = FRF(1:half_n, :);
FREQ = FREQ(1:half_n);
% Step 4: Create the stabilization diagram
FreqRange = [30, 500];
modalsd(FRF, FREQ, fs, 'FreqRange', FreqRange, 'MaxModes', 20,
'FitMethod', 'lsce');
% Step 5: Read the stable eigenfrequencies from the diagram
% Note: Manual step - inspect the stabilization diagram to find stable
frequencies
PF = [58, 115, 168, 248, 316, 467, 384]; % Example frequencies (replace
with actual values from the diagram)
% Step 6: Estimate the vibration modes
[FN, DR, MS] = modalfit(FRF, FREQ, fs, 20, 'FreqRange', FreqRange,
'FitMethod', 'lsce', 'PhysFreq', PF);
% Extract the imaginary part of the MS matrix for visualization
ImMS = imag(MS);
% Visualize each mode of vibration with optional inversion
invert_modes = true;  % Set this to true or false depending on the sign
convention
for i = 1:length(PF)
   ModeSel = ImMS(:, i);
   if invert_modes
       ModeSel = -ModeSel;
   end

   figure;
   scatter3(X, Y, ModeSel, 500, ModeSel, '.');
   title(['Mode ', num2str(i), ' at ', num2str(PF(i)), ' Hz']);
   xlabel('X (m)');
   ylabel('Y (m)');
   zlabel('Amplitude');
end
% Create a grid for better visualization of modes with optional
inversion
```

```
xnodes = linspace(min(X), max(X), 13);
ynodes = linspace(min(Y), max(Y), 9);
for i = 1:length(PF)
   ModeSel = ImMS(:, i);
   if invert_modes
       ModeSel = -ModeSel;
   end

   [zgrid, xgrid, ygrid] = gridfit(X, Y, ModeSel, xnodes, ynodes);

   figure;
   surf(xgrid, ygrid, zgrid);
   shading interp;
   axis equal tight;
   title(['Mode ', num2str(i), ' at ', num2str(PF(i)), ' Hz']);
   xlabel('X (m)');
   ylabel('Y (m)');
   zlabel('Amplitude');
end
```