Bauhaus-Universität Weimar

Experimental Structural Dynamics
Final Presentation

Free-Free Beam

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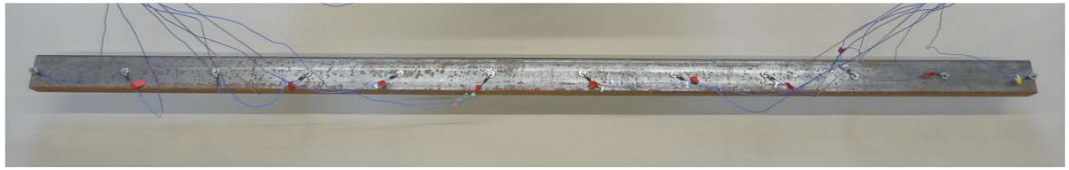
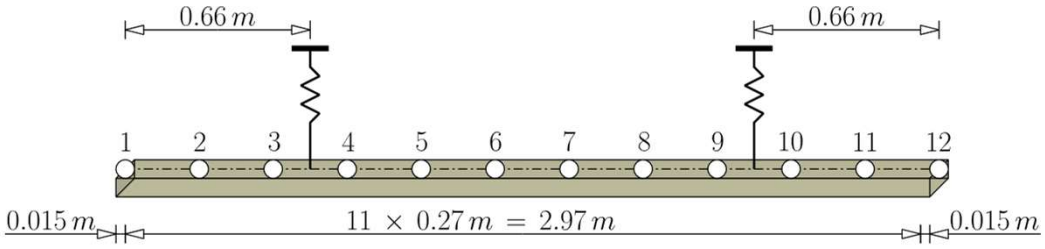
The Structure

Steel Beam with hollow section



Steel beam during the test



Scheme with position of the sensors and springs

Dimensions: 100mm x 60mm x 3mm

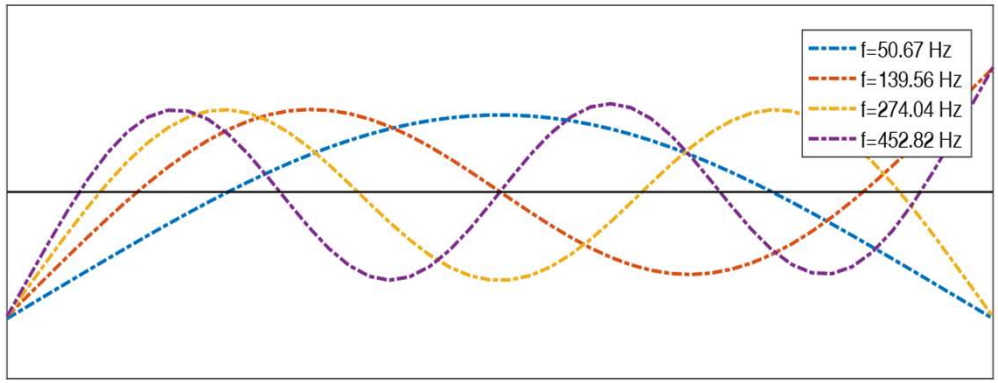
Modal Parameters

- The system was considered a free-free beam to obtain the modal parameters.
- The analytical solution was obtained in MATLAB and the FEM Software ANSYS for the first four non-zero frequencies.

Mode	Frequency		
	Analytical solution [Hz]	ANSYS [Hz]	Difference [%]
1	50.67	49.19	2.92
2	139.56	133.88	4.07
3	274.04	257.00	6.22
4	452.82	411.64	9.09

Modal Parameters

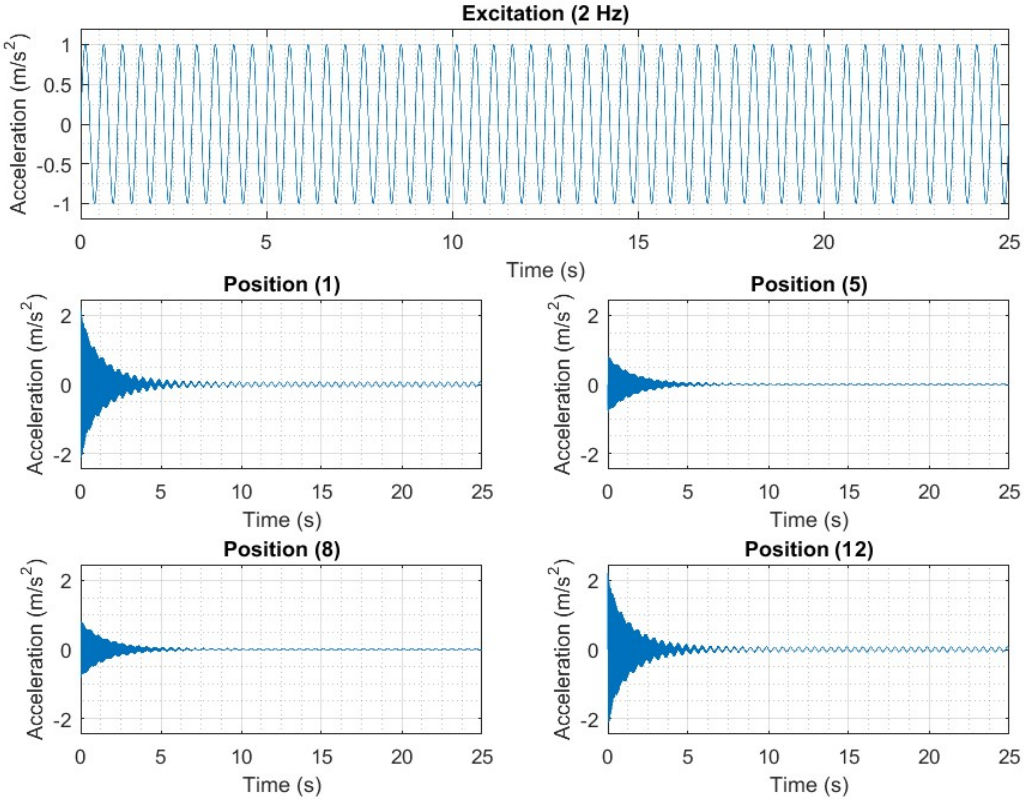
- Mode shapes for the four modes from MATLAB.



Mode shapes to respective frequencies in MATLAB

Numerical Solution With MATLAB

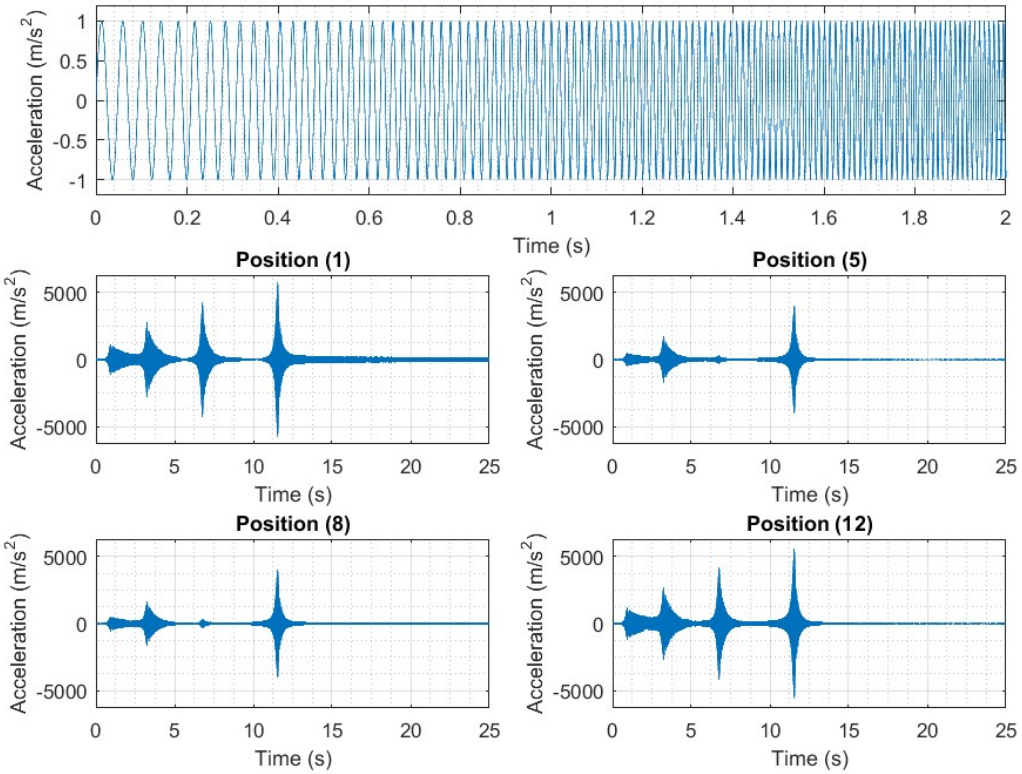
- Central difference method with modal superposition.
- Only the first 4 modes participate in the response.
- Harmonic excitation with an amplitude of 10 N and frequency of 2 Hz.



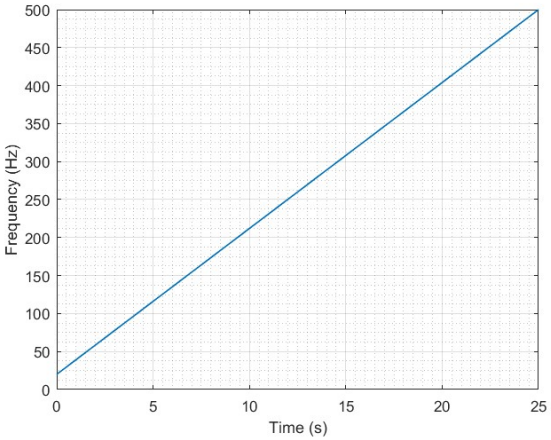
Response from MATLAB

Numerical Solution With MATLAB

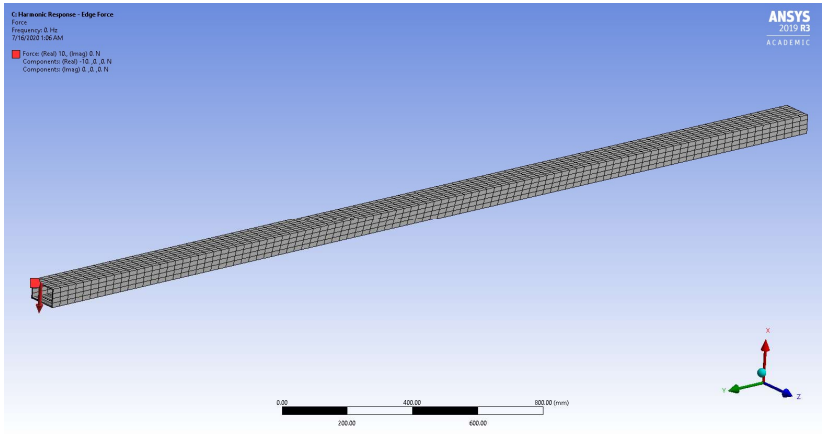
- Harmonic excitation with an amplitude of 10 N.
- Increasing frequency from 20 Hz to 500 Hz in order to stimulate the natural frequencies of the beam.



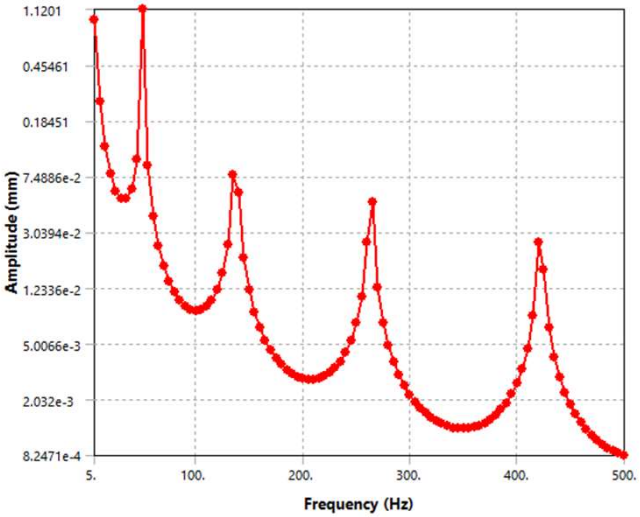
System response



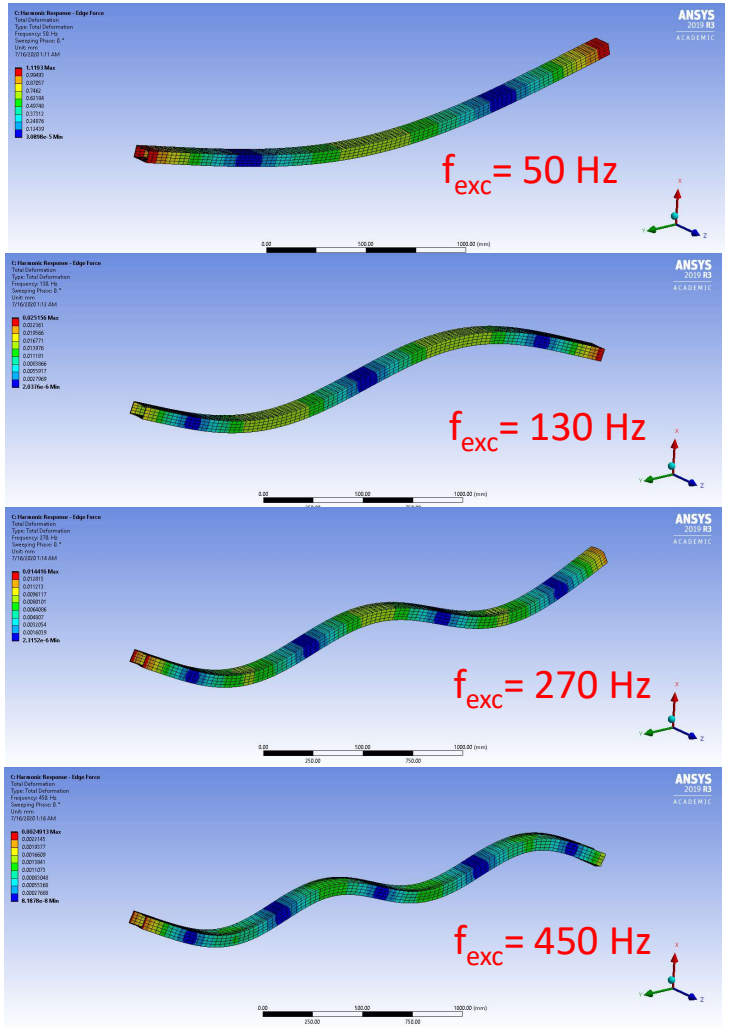
Numerical Simulation With ANSYS



Beam model



System response



Deformrd shapes

Computing Damping Ratio

- Theoretical damping ratio: 0.2%.
- Fitting curve:

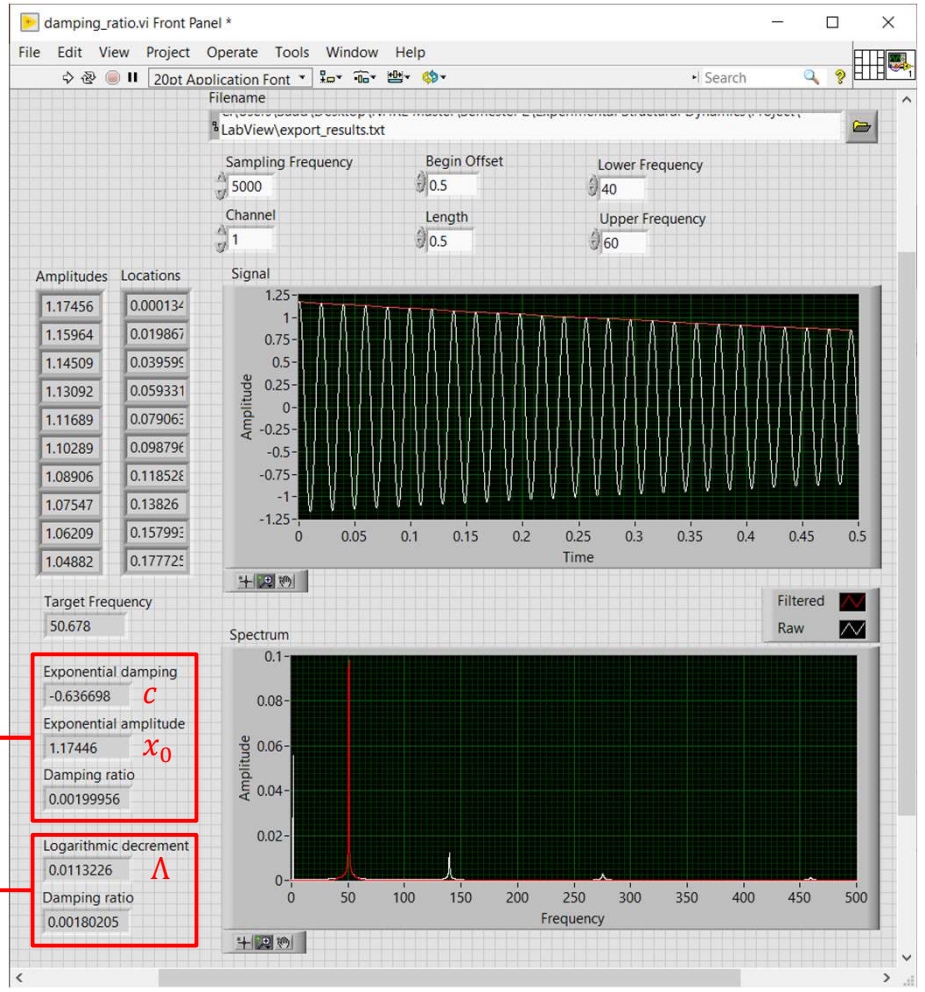
$$x(t) = x_0 e^{ct} = x_0 e^{-\zeta\omega}$$

$$\Rightarrow \zeta = -\frac{c}{\omega}$$

- Logarithmic decrement:

$$\Lambda = \frac{1}{n}\ln\left(\frac{x(t_1)}{x(t_1 + nT)}\right) = 2\pi\zeta$$

$$\Rightarrow \zeta = \frac{\Lambda}{2\pi}$$

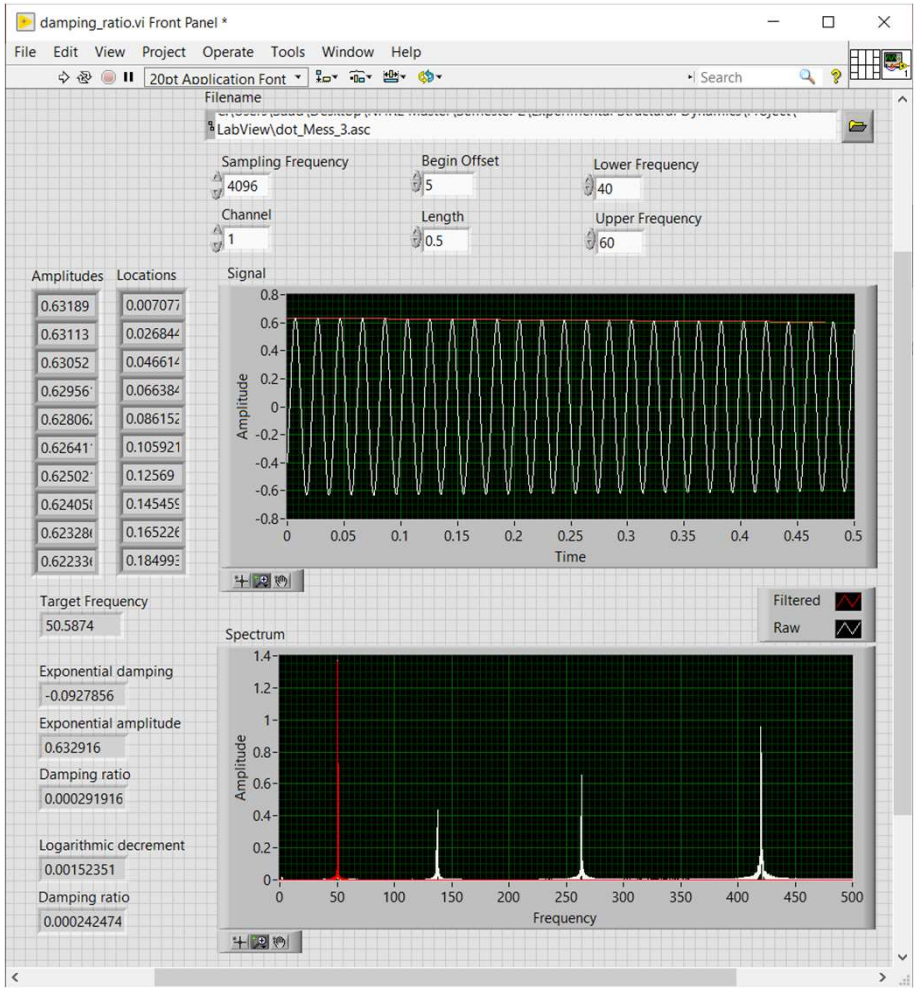


VI from LabVIEW to obtain the damping ratio

Computing Damping Ratio

Experimental results:

Frequency (Hz)	Damping (%)
50.59	0.03
137.66	0.04
263.58	0.05
420.34	0.04

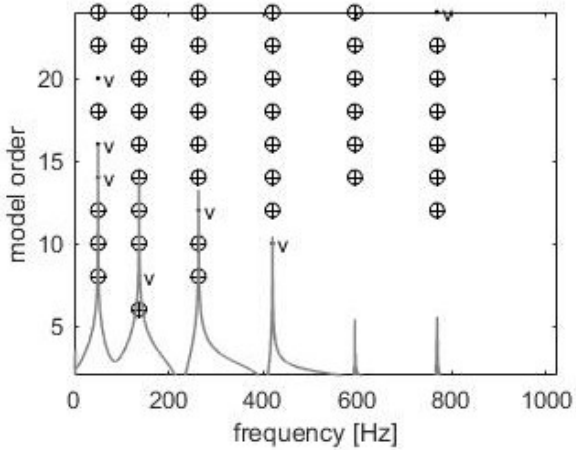


VI from LabVIEW to obtain the damping ratio

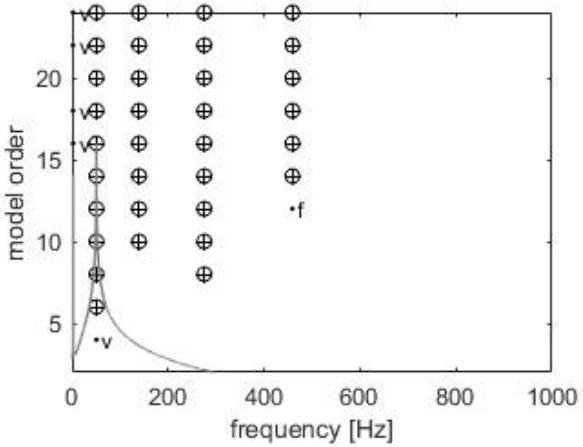
Modal Analysis with MACEC

- Toolbox for Modal Analysis in MATLAB.
- From measured or simulated data are obtained the modal parameters (Eigenfrequencies, mode shapes and damping ratios).
- The simulated data was obtained from the MATLAB script.

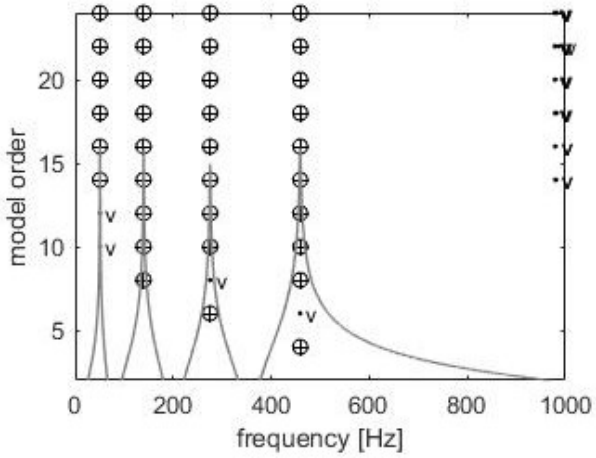
Modal Analysis with MACEC



Stabilization Plot – Measured data

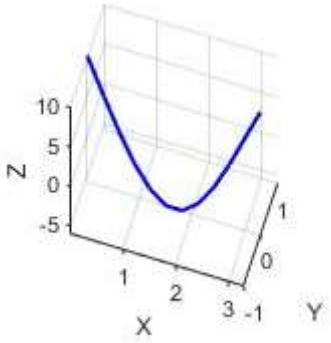


Stabilization Plot – Simulated Data 1

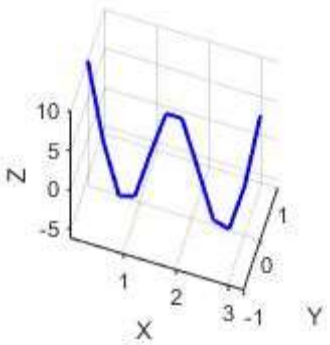


Stabilization Plot – Simulated data 2

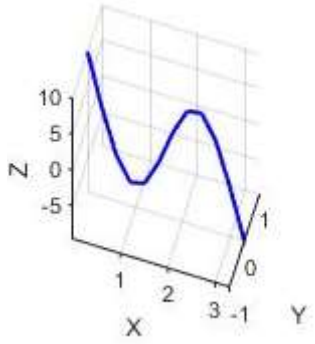
Modal Analysis with MACEC



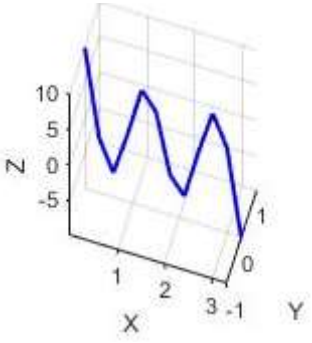
f_1 50,58Hz



f_3 263,58Hz



f_2 137,66Hz



f_4 420,34Hz

Mode Shapes of Measured Data

	Meas1	Sim1	Sim2	
f_1	50,58754	50,67857	50,6800	[Hz]
f_2	137,6646	139,7417	139,7417	[Hz]
f_3	263,5844	275,4126	275,4128	[Hz]
f_4	420,3425	459,1655	459,1653	[Hz]
ζ_1	0.046204	0.19997	0.18429	[%]
ζ_2	0.04129	0.19975	0.19519	[%]
ζ_3	0.043045	0.19904	0.19665	[%]
ζ_4	0.042651	0.19729	0.19585	[%]
Meas1	Measured data			
Sim1	Simulated data with a excitation of 2Hz			
Sim2	Simulated data with a linear excitation from 20Hz to 500Hz			

Conclusions

- The natural frequencies obtained from the analytical solution and the processed simulated data in MACEC are very similar.
- The damping ratio stablished in the simulated data matches with the obtained in the modal analysis in MACEC with a value of 0.2%
- The measured data natural frequencies are relatively smaller from the other analyses, and the difference increases with higher modes.

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Thank you for your attention!

Participants of this project

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