



Structural Dynamics Open-Ended Project

REPORT 2019

[Steady-state vibration response of a fixed-free beam subjected to base excitation ____ A numerical investigation using MATLAB]

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Introduction:

This work presents some of the consequences of doing a sine-sweep base-excitation test to determine the modal parameters i.e. Natural frequency (f_n) & amplification factor(Q). of a fixed-free beam using FRF-curve-fit¹ which is an extension to half-power bandwidth method.

In this work:

1-Natural bending mode frequencies of a 100mm x 20mm x 5mm Aluminum beam was determined via FEA on MATLAB.

2-Sine sweep base acceleration data (accelerometer data) was generated in MATLAB.

3-Response acceleration (accelerometer data) of the system (arbitrarily assumed system) under base excitation was generated in MATLAB

4-Frequency Response Function (FRF) was generated using the base excitation and response accelerations.

5-Using FRF-Curve-fitting the modal parameters (f_n & Q) are estimated.

FEA of beam:

A rectangular Aluminum beam of dimensions **100mm x 20mm x 5mm** is considered for the analysis

A dummy point mass (accelerometer mass) of **20 gram** is placed 80mm to the right of the fixed end to incorporate the effect of mass of accelerometer on natural frequency.


For the Aluminum beam density is assumed to be **2700kg/m³** and elastic modulus is assumed to be **70GPa**.

¹ FRF curve fit MATLAB GUI---by Tom Irvine (www.vibrationdata.com)

beam_FEA.m ver 2.0 by Tom Irvine This script calculates the bending natural frequencies of a beam.

Select Left Rotation

Free
Pinned
Fixed



Select Right Rotation

Free
Pinned
Fixed

Enter Uniform Nonstructural Mass

0 kg

Select Units

English
metric

Enter Length

0.1 meter

Point Masses

Location referenced to left end.

Number	meter	kg
0		
1	0.08	0.02
2		
3		

Select Number of Elements

1
2
4
8
16
32
64
128
256
512

Selection Cross Section

Rectangular
Pipe
Solid Cylinder
Other

Thickness (mm)

5

Width (mm)

20

Distance from Neutral Axis (inches)

0.0025

Select Material

Aluminum
Steel
Copper
G10
PVC
Other

Elastic Modulus (GPa)

70

Mass Density (kg/m³)

2700

Calculate Natural Frequencies

View Mode Shapes

Enter Damping

Transfer Functions

Select Mode Number

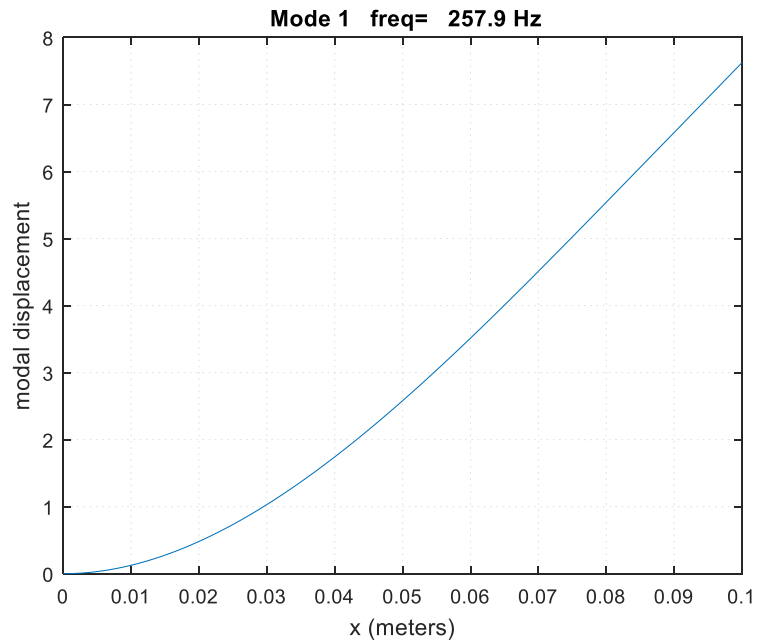
1
2
3
4

Return

1-Snapshot of FEA GUI

Mode #	Frequency (Hz)
1	257.882
2	2572.3
3	6490.8
4	11810

2 First 4 bending modes frequencies of the beam



3-Mode shape of first bending mode

Base excitation:

Base excitation dummy data can be generated in MATLAB to excite only the first bending mode at **257.9 Hz**.

It is decided to excite the beam from **100Hz** sweep-up to **500 Hz** in **200 seconds** at a constant acceleration magnitude of **6G**.

Under these conditions a dummy accelerometer data with a sampling rate of **8000samples/sec** was generated in MATLAB.

signal_sine_sweep

signal_sine_sweep.m ver 1.9 by Tom Irvine

Enter Data

Sweep Type

linear
log

Sweep Direction

up
down
up & down

Number of Coordinates

2
3
4
5

Coordinates

	Freq (Hz)	Accel (G)
1	100	6
2	500	6

Sample Rate (Hz)

5000

Select Time Option

Duration
Sweep Rate

Duration (sec)

200

Number of Octaves

2.32

Calculate Spectral Function

Yes
No

Save Signal to Matlab Workspace

Output Array Name

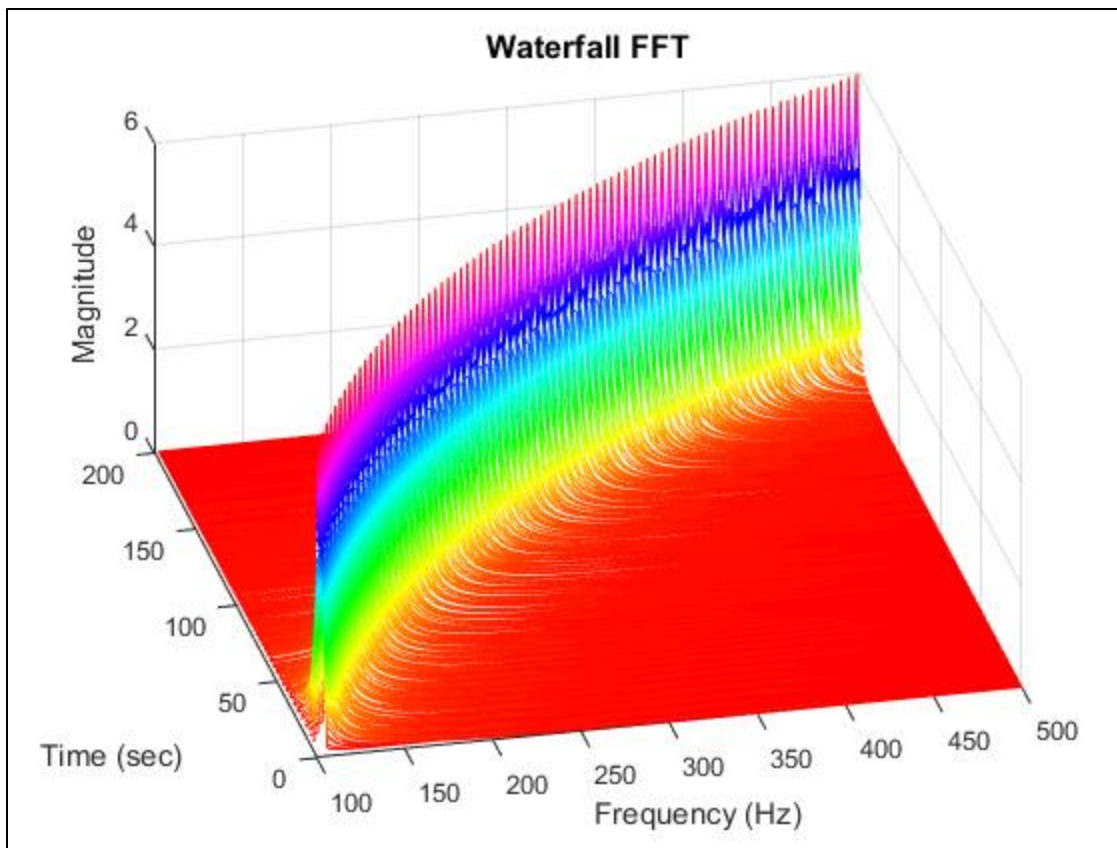
y

Save

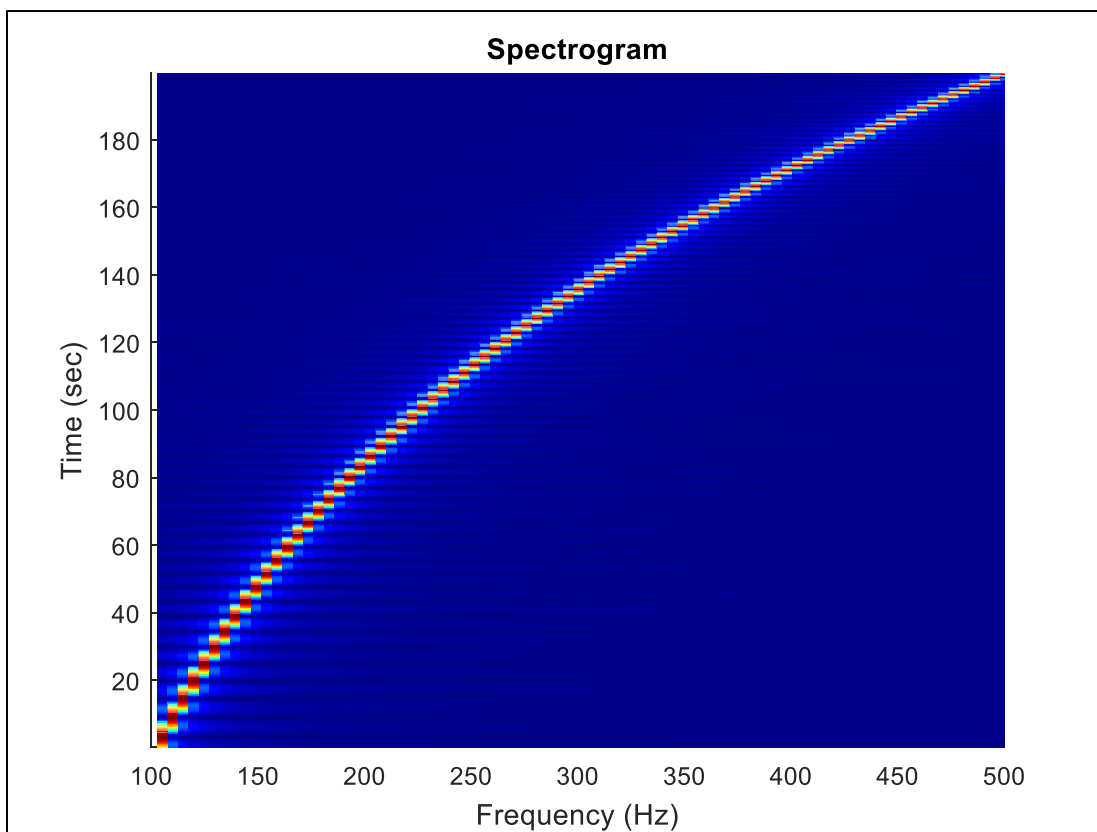
Calculate

Return

4-Snapshot of Signal generator GUI



**5-Waterfall
FFT of base
excitation
data**

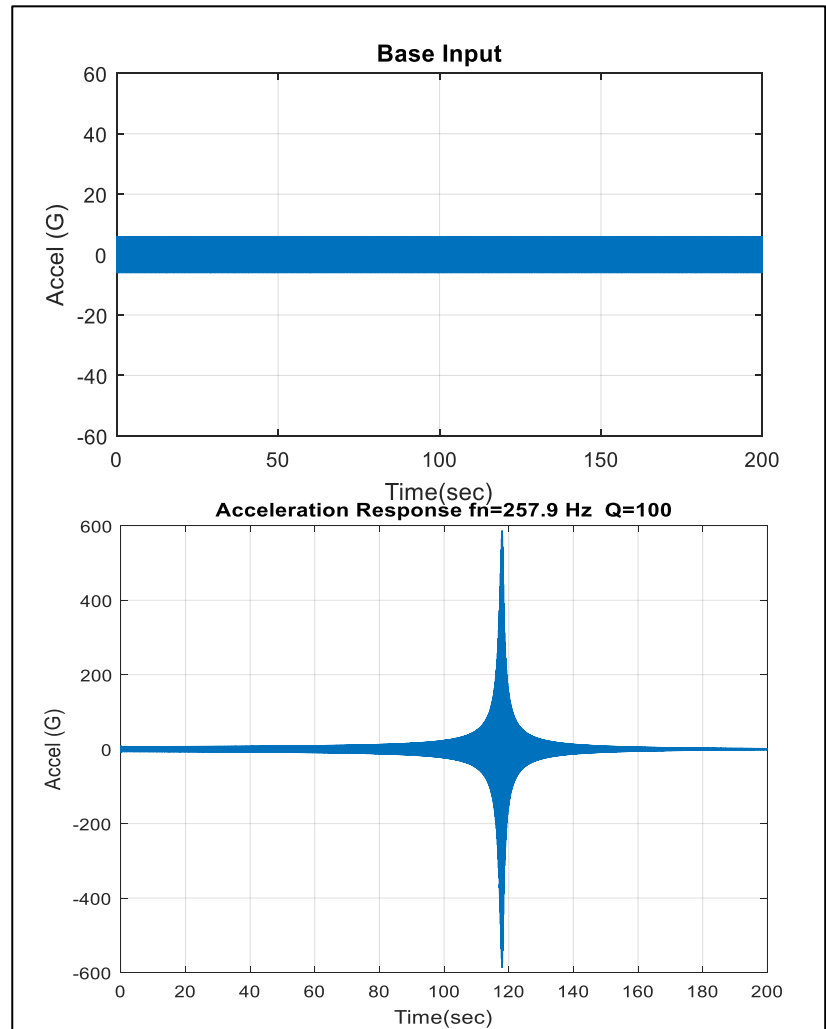


**6-
Spectrogram
of base
excitation
data**

Response:

FEA of the beam has revealed that the first bending mode occurs at **257.9Hz**. Also, the beam has very well separated modes in terms of frequency, so we can have an **equivalent Single DOF system** having a natural frequency of **257.9Hz** and an arbitrarily assumed damping **loss factor $\eta=0.01$** which corresponds to a **Quality factor $Q=100$** .

Under these conditions a SDOF response to base input was generated in MATLAB.



vibrationdata_s dof_base

vibrationdata_s dof_base.m ver 2.1 by Tom Irvine

This script calculates the response of an SDOF system to base excitation.
The input data must have two columns: time(sec) & base acceleration

Select Data Input Method
Array Preloaded in Matlab
External ASCII Text File

Input Array Name
Y

Select Amplitude
G, in/sec, in
G, m/sec, mm
m/sec², m/sec, mm

Calculate

Enter Natural Frequency (Hz)
257.9

Enter Q
10

Return

Results

Acceleration Response (G)
max= 59.85
min= 59.85
RMS= 13.29
crest factor= 4.5
kurtosis= 7.63

Relative Displacement (in)
max= 0.00883
min= 0.00883
RMS=0.001959

Save Output Time History to Matlab Workspace

Select Output
Acceleration Response
Relative Displacement

Output Array Name
X

Save

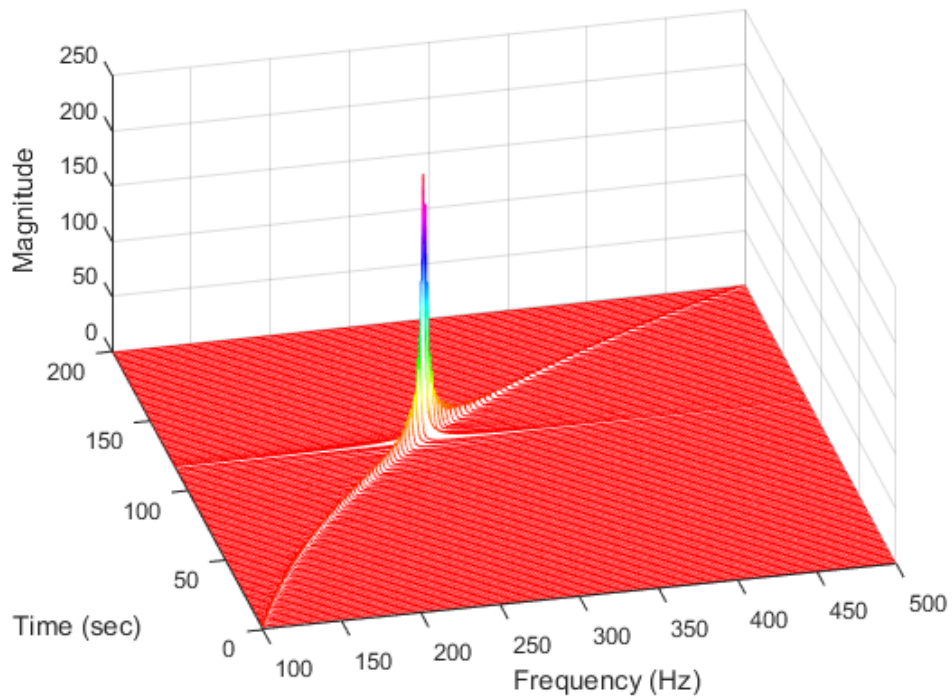
Statistics

PSD

Rainflow Fatigue

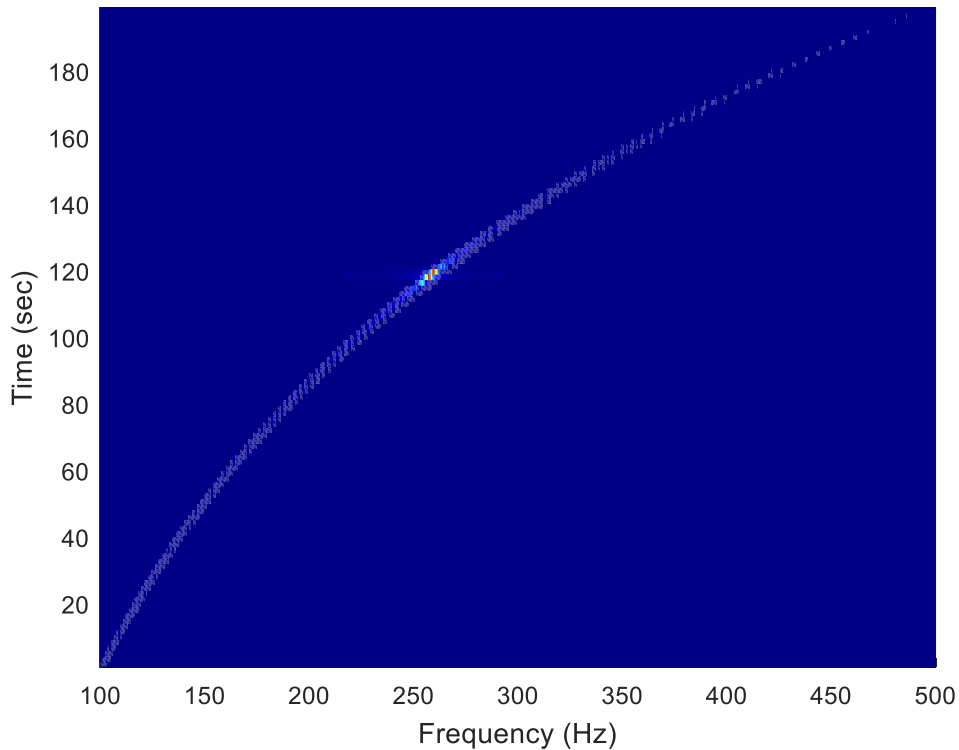
Steinberg Fatigue

Waterfall FFT



**Waterfall FFT of
Response Data**

Spectrogram



**Spectrogram
of Response
Data**

Frequency Response Function (FRF):

FRF of input and response accelerations is generated

modal_frf_ensemble_accel

modal_frf_ensemble_accel.m ver 1.6 by Tom Irvine

Recommended for shaker excitation.

Mean Removal

yes
no

Window

Rectangular
Hanning

Minimum Plot Freq (Hz)

200

Maximum Plot Freq (Hz)

500

Select Processing Option by Row Number

1
2
3
4
5
6
7
8
9
10
11
12

	No. of Segments	Samples/Segments	Time/Segment (sec)	df (Hz)	dof
1	1	1048576	131.0721	0.0076	2
2	3	524288	65.5360	0.0153	6
3	6	262144	32.7680	0.0305	12
4	12	131072	16.3840	0.0610	24
5	24	65536	8.1920	0.1221	48
6	48	32768	4.0960	0.2441	96
7	97	16384	2.0480	0.4883	194
8	195	8192	1.0240	0.9766	390
9	390	4096	0.5120	1.9531	780
10	781	2048	0.2560	3.9062	1562
11	1562	1024	0.1280	7.8125	3124
12	3125	512	0.0640	15.6250	6250

View Processing Options

Calculate FRF

Return

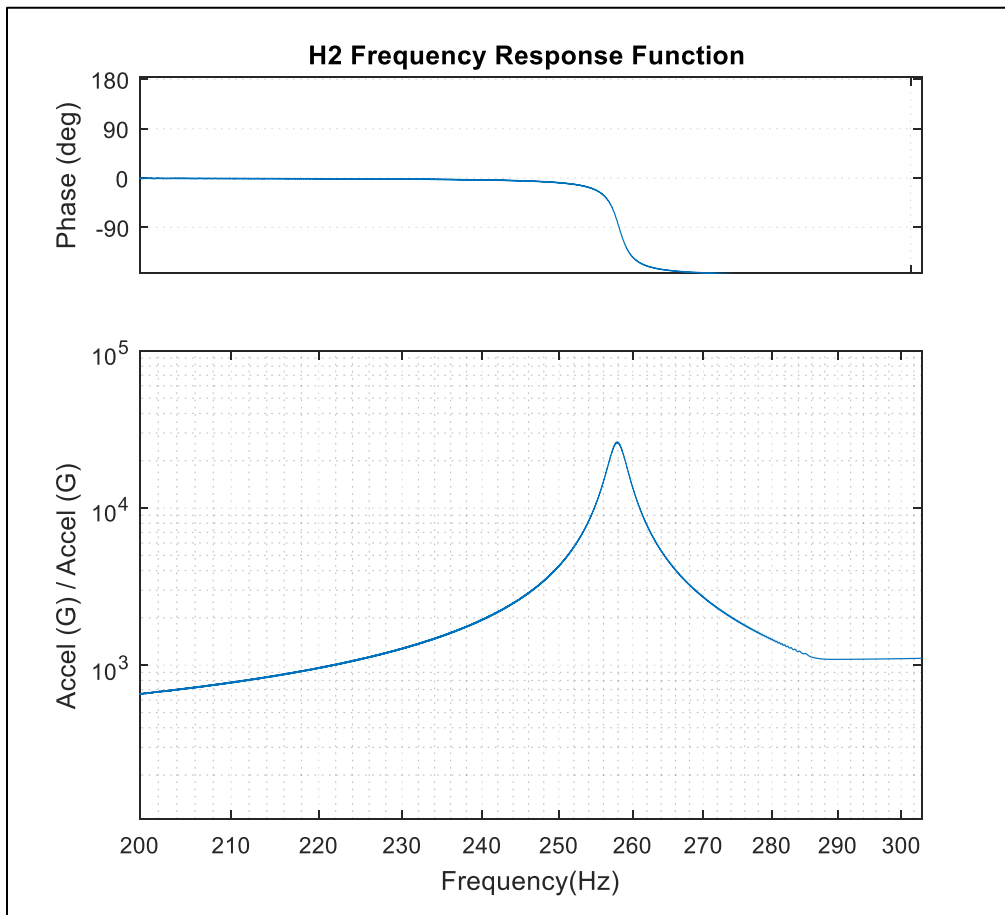
Save Data to Matlab Workspace

H1: Frequency & Magnitude
H1: Frequency & Magnitude & Phase
H1: Frequency & Complex
H2: Frequency & Magnitude
H2: Frequency & Magnitude & Phase
H2: Frequency & Complex
Coherence

Output Array Name

Frf

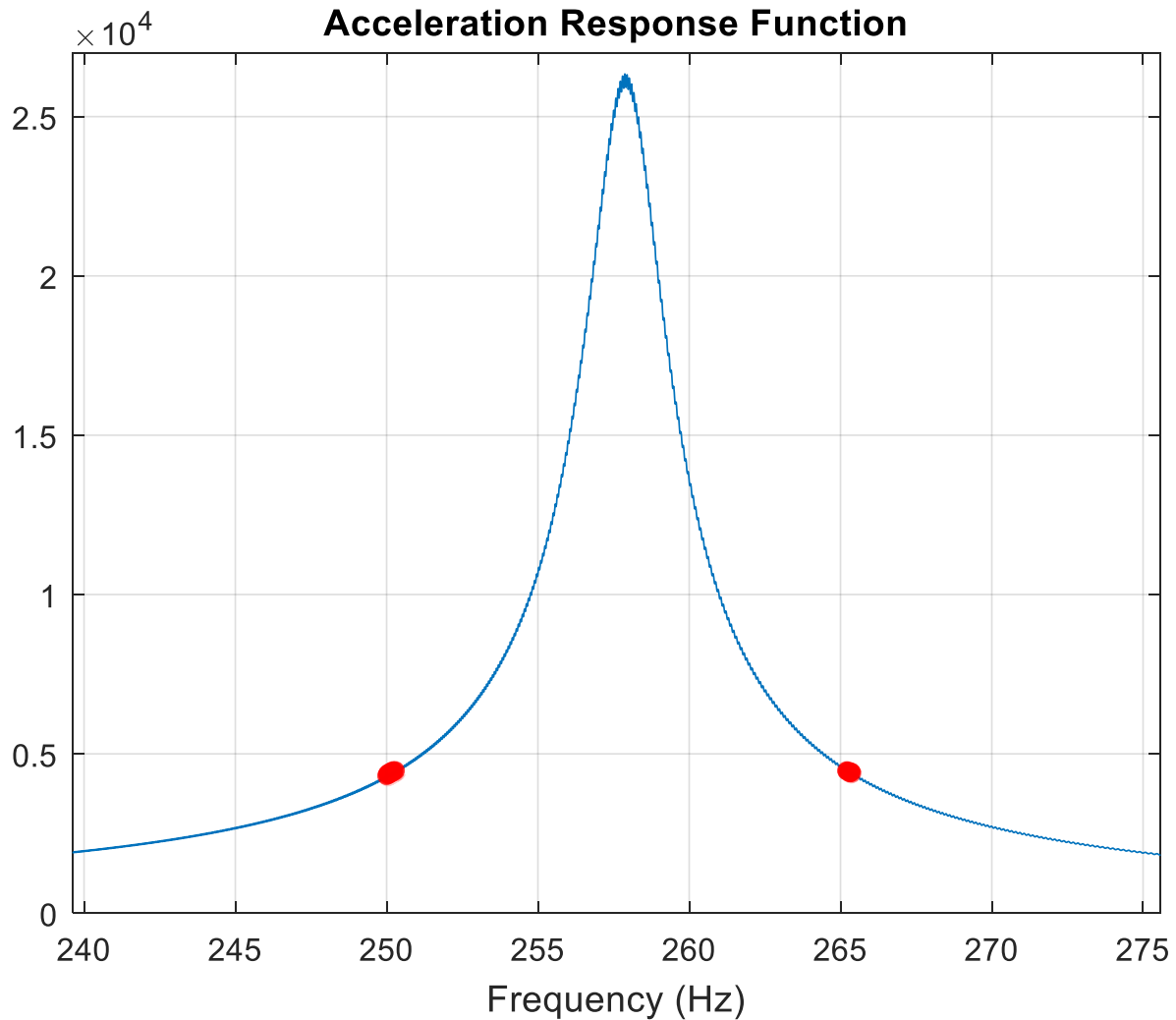
Save



FRF Curve-fitting:

FRF Curve fitting is performed on generated FRF to estimate modal parameters

To start curve fitting we need to select two points on FRF .We have selected 250Hz & 265Hz



7-plot of FRF showing arbitrarily selected points between which curve fitting is to be performed

half_power_bandwidth

half_power_bandwidth.m ver 1.6 by Tom Irvine

This method performs a curve-fit to determine the damping ratio for a system excited by base excitation or an applied force. This method is an extension of the half-power bandwidth method. The input data must be a frequency response function.

The input file should have two columns: freq (Hz) & amplitude

Enter Data

Select Data Input Method

Array Preloaded in Matlab
External ASCII Text File

Input Array Name

Frf

Select Excitation Type

Base Excitation
Applied Force

Initial Plot X-axis Limits

Automatic
Manual

Select Response Type

Acceleration
Velocity
Displacement

Select Amplitude Dimension

Amplitude
Amplitude^2

Min Freq (Hz)

100

Max Freq

500

Enter Number of Trials

10000

Enter Curve-fit Frequencies (Hz)

Start: 250, End: 265

Results

Natural Frequency (Hz)

258

Viscous Damping Ratio

0.00499

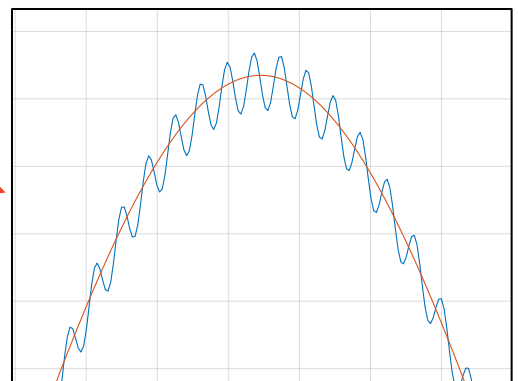
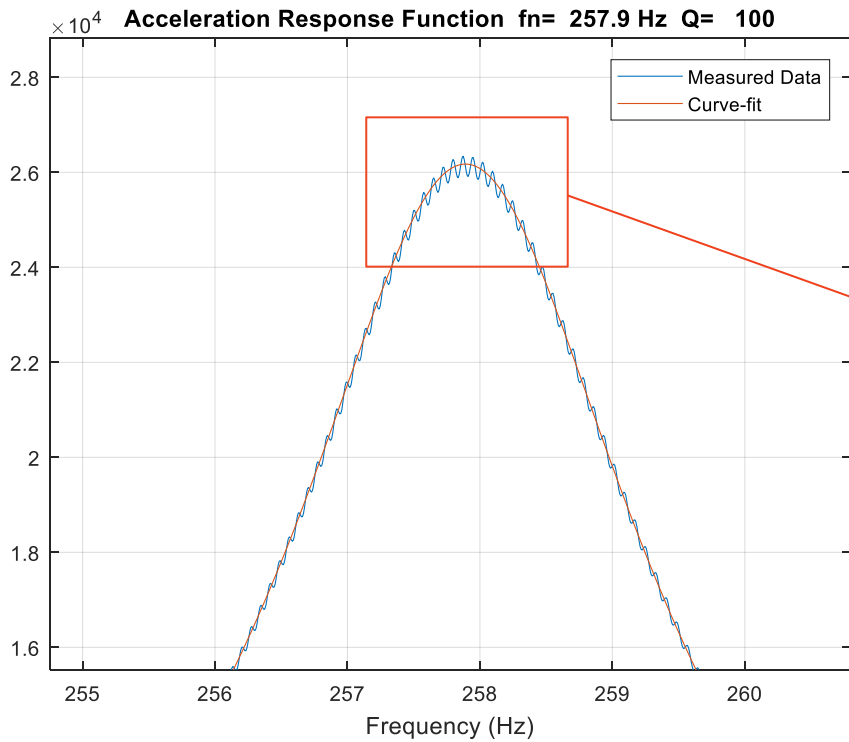
Q

100

Plot Input Function

Calculate

Return



Curve fit Results:

Modal parameter	Assumed values	Estimated values	Percent error
Natural Frequency (fn)	257.9 Hz	258 Hz	0.04%
Quality factor (Q)	100	100	0%

Comments:

- Results from FRF Curve fitting technique are more reliable and accurate with very little error.
- In order to have better FRF, sample rate of accelerometer data should be high. In our case we have used 8000Hz sampling rate.
- Curve fitting technique has eliminated the possible source of error in selecting half power points.