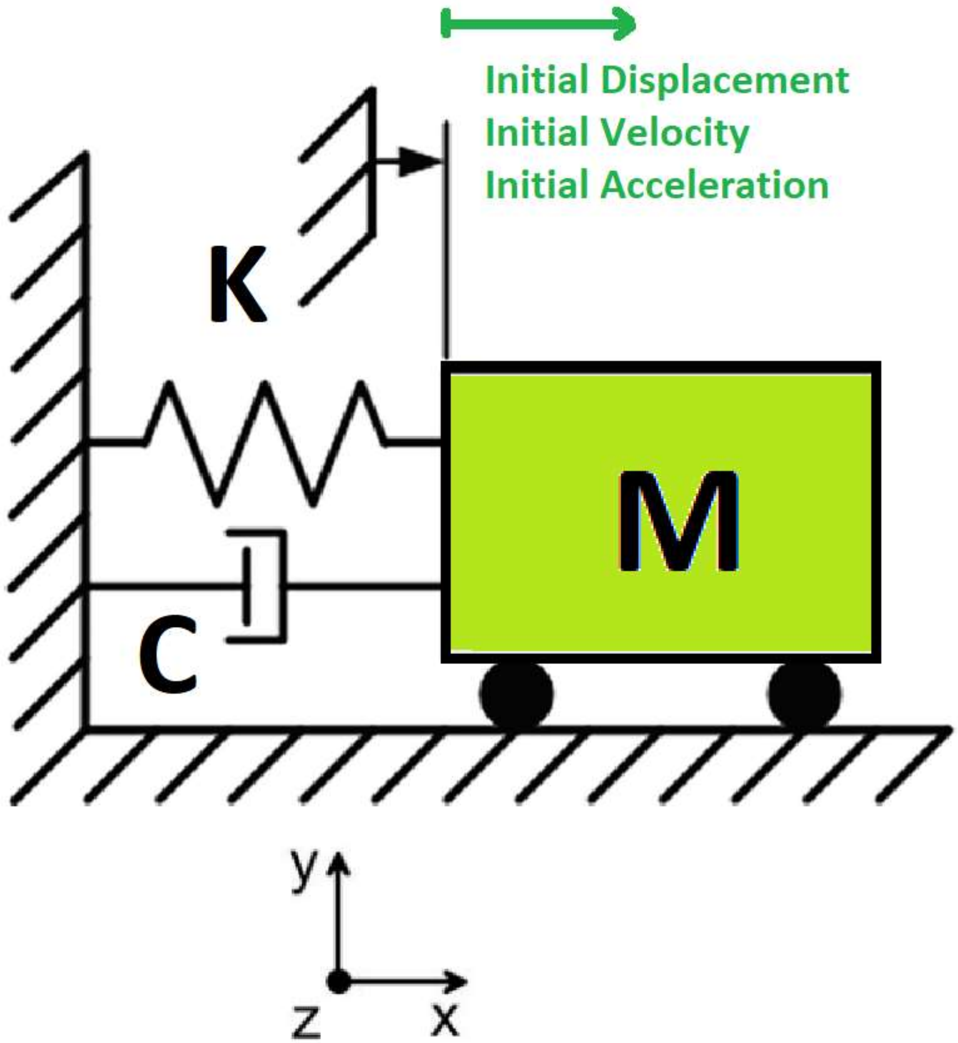
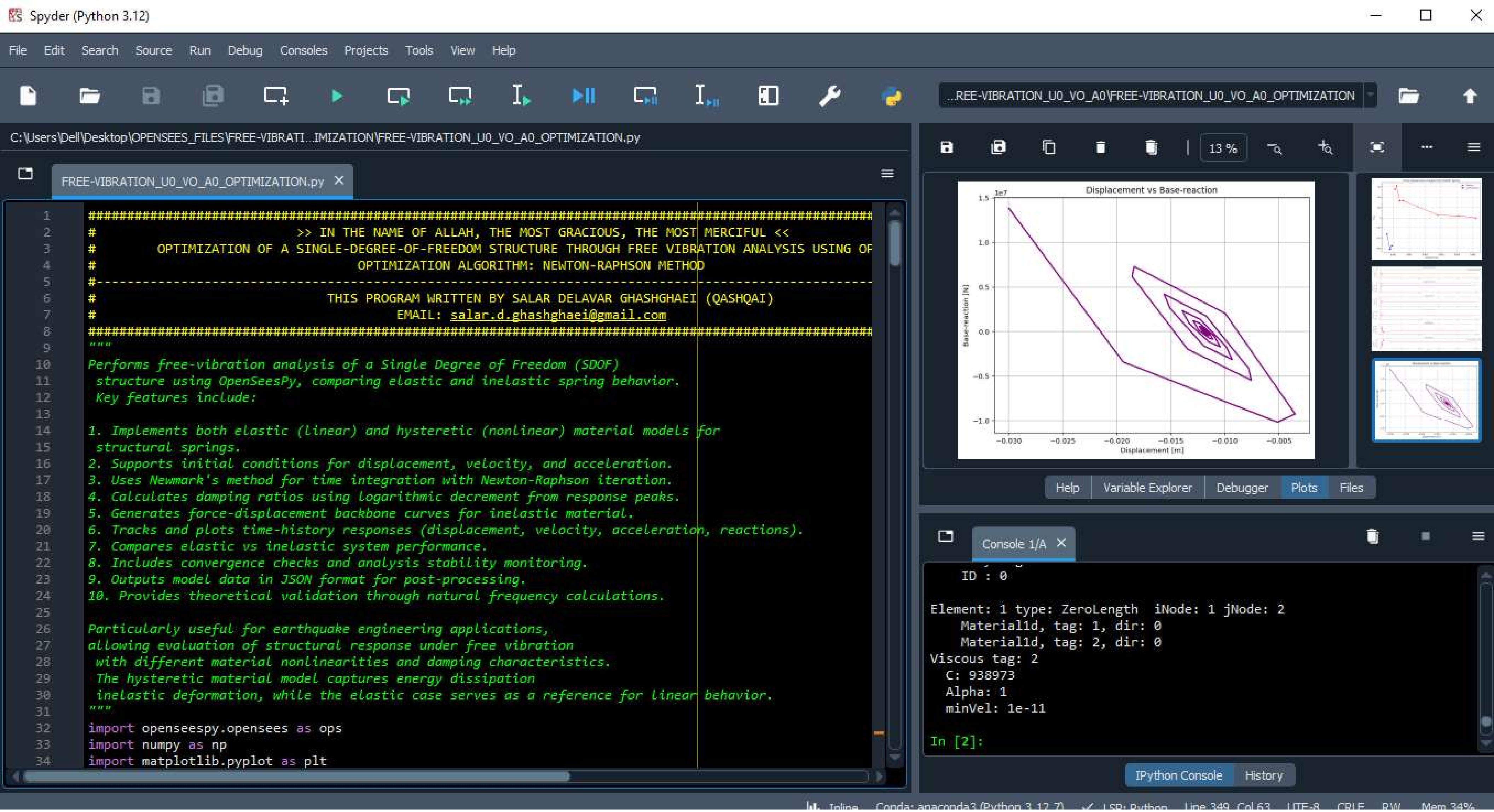
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

OPTIMIZATION OF A SINGLE-DEGREE-OF-FREEDOM STRUCTURE THROUGH FREE VIBRATION ANALYSIS USING OPENSEES

OPTIMIZATION ALGORITHM: NEWTON-RAPHSON METHOD

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)


Initial Displacement
Initial Velocity
Initial Acceleration
K
M
C
y
z
x


Spyder (Python 3.12)
File Edit Search Source Run Debug Consoles Projects Tools View Help
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C:\Users\Dell\Desktop\OPENSEES_FILES\FREE-VIBRATI...IMIZATION\FREE-VIBRATION_U0_VO_A0_OPTIMIZATION.py
FREE-VIBRATION_U0_VO_A0_OPTIMIZATION.py
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
OPTIMIZATION OF A SINGLE-DEGREE-OF-FREEDOM STRUCTURE THROUGH FREE VIBRATION ANALYSIS USING OF
OPTIMIZATION ALGORITHM: NEWTON-RAPHSON METHOD
THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
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"""
Performs free-vibration analysis of a Single Degree of Freedom (SDOF)
structure using OpenSeesPy, comparing elastic and inelastic spring behavior.
Key features include:
1. Implements both elastic (linear) and hysteretic (nonlinear) material models for
structural springs.
2. Supports initial conditions for displacement, velocity, and acceleration.
3. Uses Newmark's method for time integration with Newton-Raphson iteration.
4. Calculates damping ratios using logarithmic decrement from response peaks.
5. Generates force-displacement backbone curves for inelastic material.
6. Tracks and plots time-history responses (displacement, velocity, acceleration, reactions).
7. Compares elastic vs inelastic system performance.
8. Includes convergence checks and analysis stability monitoring.
9. Outputs model data in JSON format for post-processing.
10. Provides theoretical validation through natural frequency calculations.
Particularly useful for earthquake engineering applications,
allowing evaluation of structural response under free vibration
with different material nonlinearities and damping characteristics.
The hysteretic material model captures energy dissipation
inelastic deformation, while the elastic case serves as a reference for linear behavior.
"""
import openseespy.opensees as ops
import numpy as np
import matplotlib.pyplot as plt
13 %
Displacement vs Base-reaction
1e7
Base-reaction [N]
Displacement [m]
Help Variable Explorer Debugger Plots Files
Console 1/A
ID : 0
Element: 1 type: ZeroLength iNode: 1 jNode: 2
Material1d, tag: 1, dir: 0
Material1d, tag: 2, dir: 0
Viscous tag: 2
C: 938973
Alpha: 1
minVel: 1e-11
In [2]:
IPython Console History

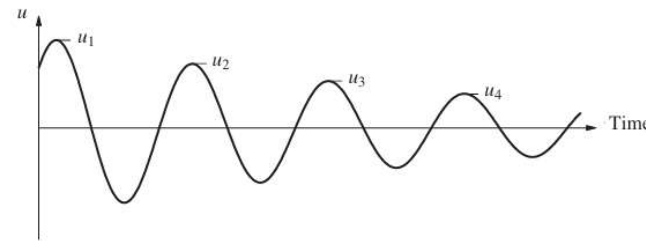
VISCOUSLY DAMPED FREE VIBRATION

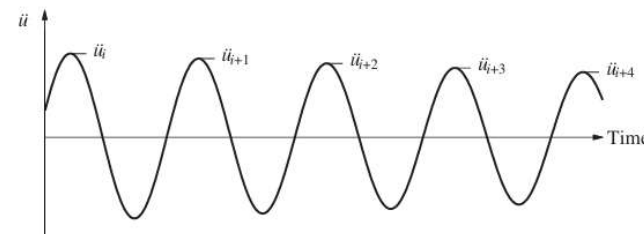
$$m\ddot{u} + c\dot{u} + ku = 0$$

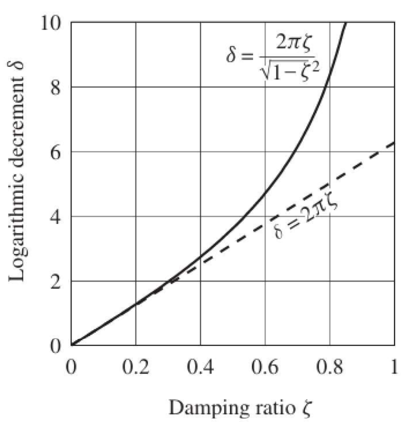
$$\ddot{u} + 2\zeta\omega_n\dot{u} + \omega_n^2 u = 0$$

$$\omega_n = \sqrt{k/m} \quad \zeta = \frac{c}{2m\omega_n} = \frac{c}{c_{cr}} \quad \omega_D = \omega_n\sqrt{1-\zeta^2}$$

$$u(t) = e^{-\zeta\omega_n t}\left[u(0)\cos\omega_D t + \frac{\dot{u}(0) + \zeta\omega_n u(0)}{\omega_D}\sin\omega_D t\right]$$





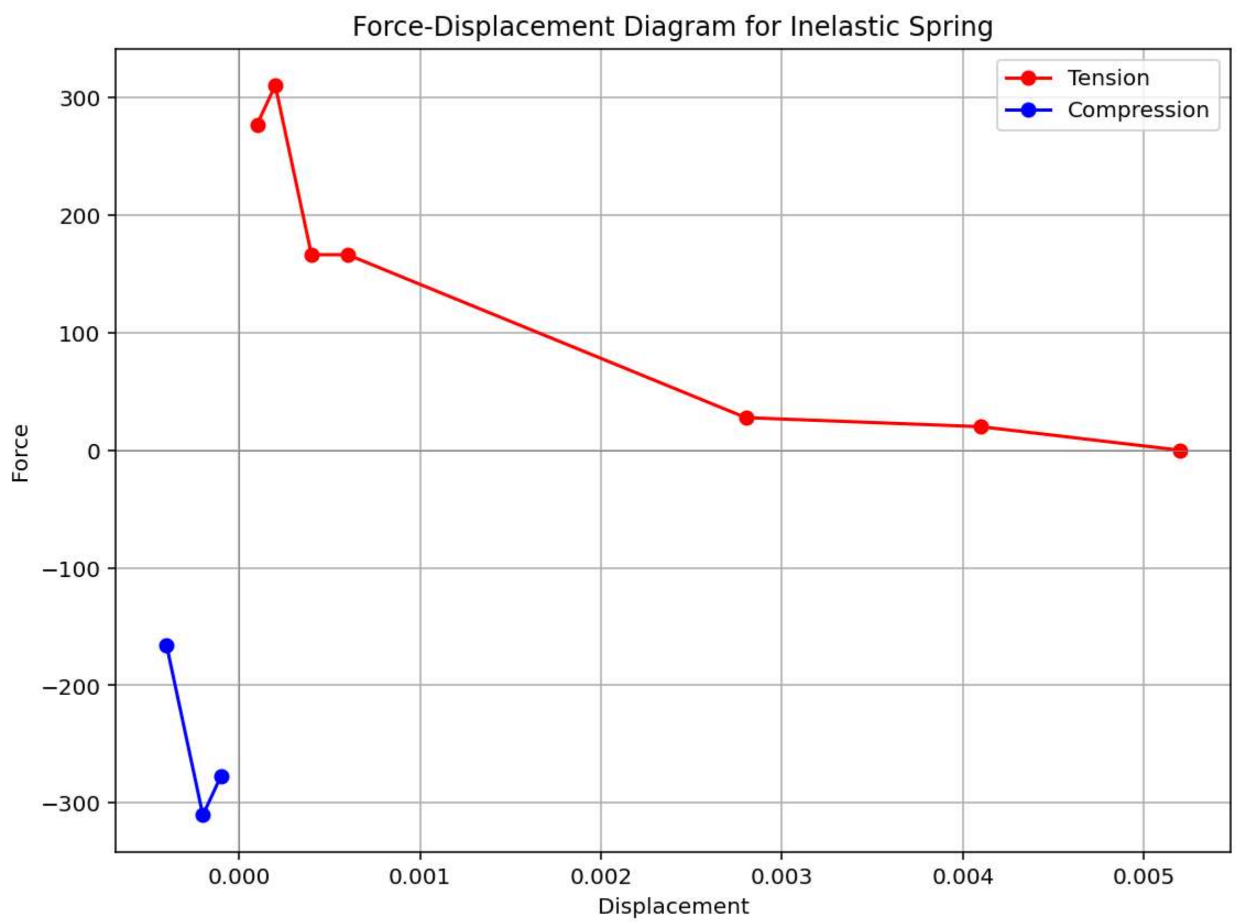


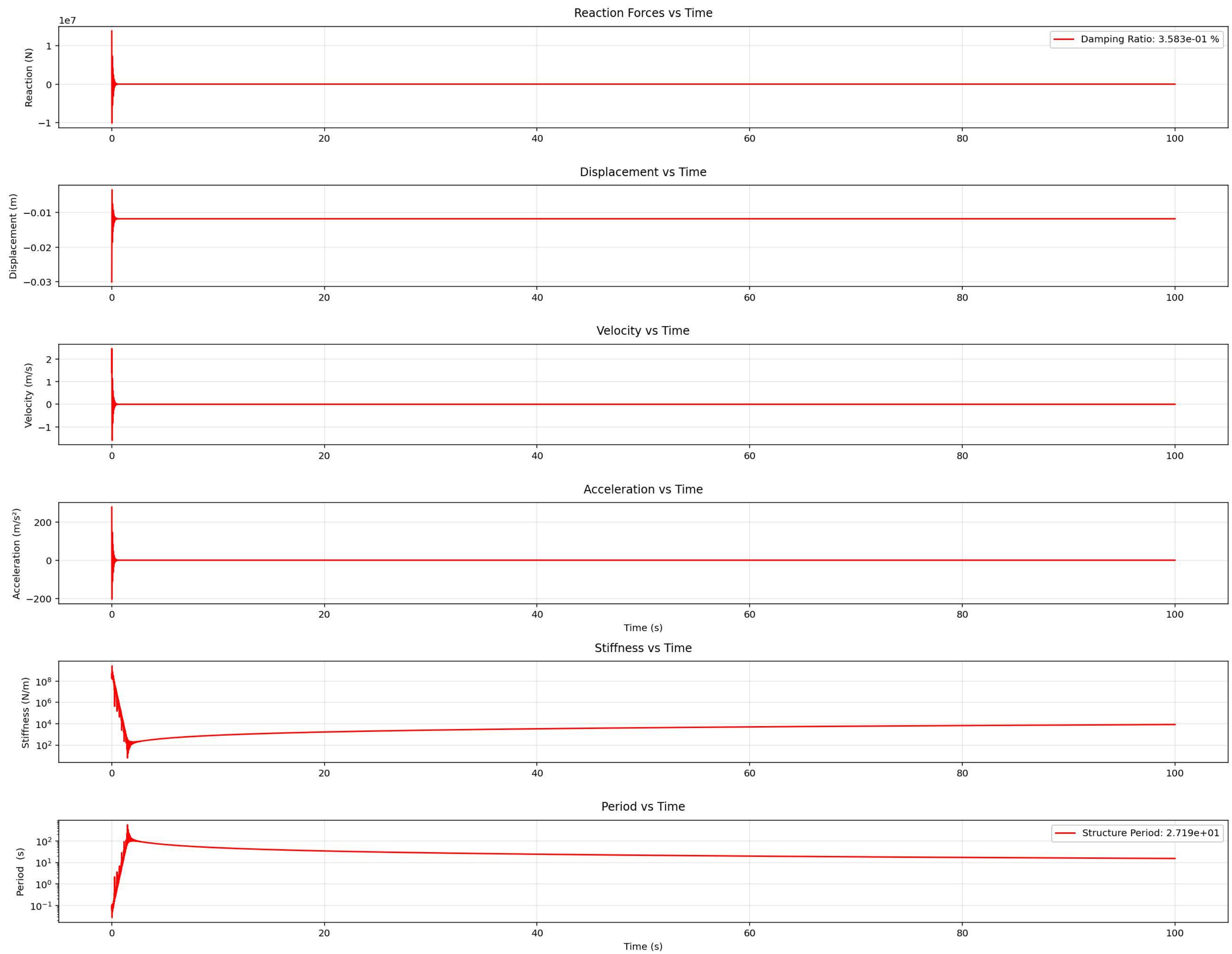
Decay of Motion

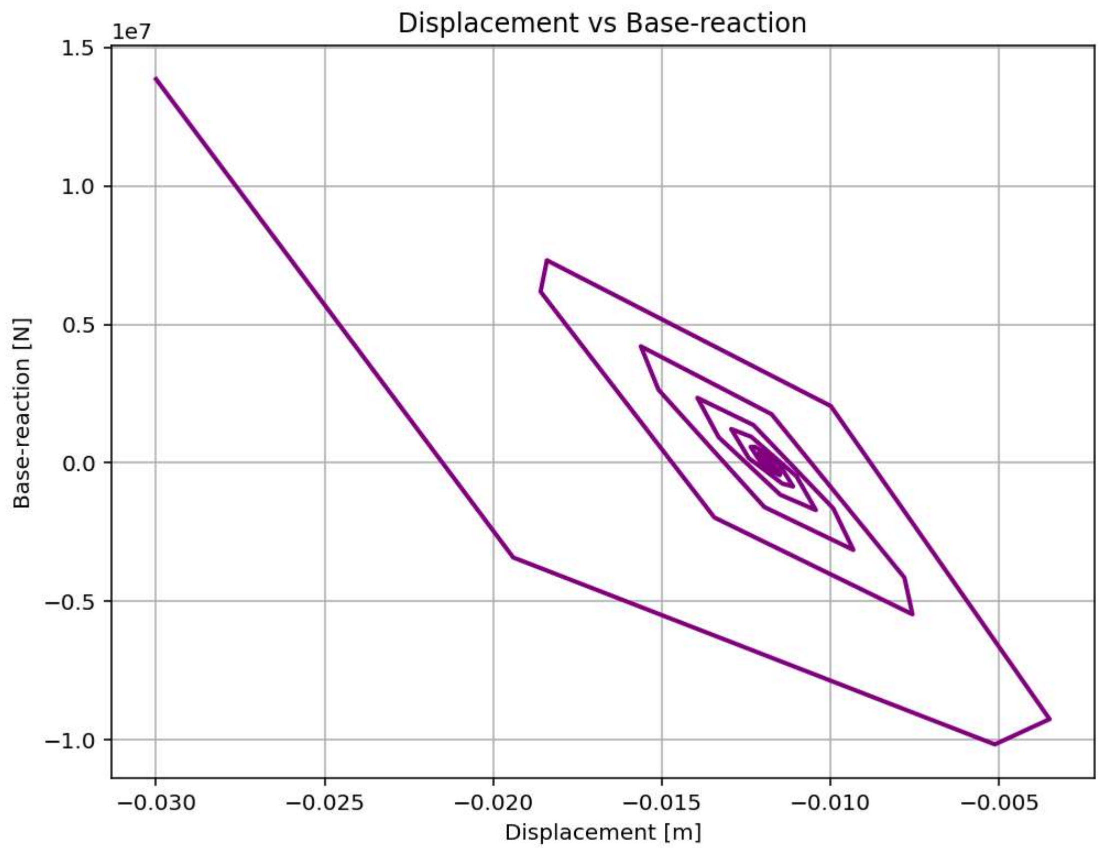
$$\delta = \ln\frac{u_i}{u_{i+1}} = 2\pi\zeta$$ **(APPROXIMATE RELATION)**

$$\delta = \ln\frac{u_i}{u_{i+1}} = \frac{2\pi\zeta}{\sqrt{1-\zeta^2}}$$ **(EXACT RELATION)**

EXACT AND APPROXIMATE RELATIONS BETWEEN LOGARITHMIC DECREMENT AND DAMPING RATIO


Force-Displacement Diagram for Inelastic Spring
Tension
Compression
Force
Displacement
300
200
100
0
−100
−200
−300
0.000
0.001
0.002
0.003
0.004
0.005


Reaction Forces vs Time
1e7
Reaction (N)
Damping Ratio: 3.583e-01 %
Displacement vs Time
Displacement (m)
Velocity vs Time
Velocity (m/s)
Acceleration vs Time
Acceleration (m/s²)
Time (s)
Stiffness vs Time
Stiffness (N/m)
Period vs Time
Period (s)
Structure Period: 2.719e+01
Time (s)



Displacement vs Base-reaction
1e7
1.5
1.0
0.5
0.0
−0.5
−1.0
Base-reaction [N]
−0.030
−0.025
−0.020
−0.015
−0.010
−0.005
Displacement [m]

```
 SUPPLY: 0.04384989
F:  0.013849889675598415
Fmin:  0.013849889675612244
Fmax:  0.013849889675584585
DF:  -1.3829215550487104e-09
DX:  -10014949.600746213
IT:  1  - RESIDUAL:  10014949.600746213  - X:  10015049.600746213

 SUPPLY: 0.01695705
F:  -0.013042953880630502
Fmin:  -0.0130429538806109
Fmax:  -0.013042953880650104
DF:  -1.960237527853792e-09
DX:  6653761.952466474
IT:  2  - RESIDUAL:  6653761.952466474  - X:  3361287.6482797386

 SUPPLY: 0.03822344
F:  0.008223439438450754
Fmin:  0.008223439438471737
Fmax:  0.008223439438429778
DF:  -2.0979745718463505e-09
DX:  -3919704.055904551
IT:  3  - RESIDUAL:  3919704.055904551  - X:  7280991.70418429

 SUPPLY: 0.02635108
F:  -0.0036489159704923835
Fmin:  -0.0036489159704485227
Fmax:  -0.0036489159705362477
DF:  -4.386248309007357e-09
DX:  831899.088567141
IT:  4  - RESIDUAL:  831899.088567141  - X:  6449092.615617149

 SUPPLY: 0.02968185
F:  -0.00031814556011616063
Fmin:  -0.00031814556007960654
Fmax:  -0.0003181455601527078
DF:  -3.655062363883132e-09
DX:  87042.44372404178
IT:  5  - RESIDUAL:  87042.44372404178  - X:  6362050.171893107

 SUPPLY: 0.02999714
F:  -2.8593443473050317e-06
Fmin:  -2.859344311406664e-06
Fmax:  -2.859344383206869e-06
DF:  -3.590010233534002e-09
DX:  796.47247815511
IT:  6  - RESIDUAL:  796.47247815511  - X:  6361253.699414952

 SUPPLY: 0.03000000
F:  -6.043326949978223e-10
Fmin:  -6.042968105079982e-10
Fmax:  -6.043685829570933e-10
DF:  -3.5886224547532204e-09
DX:  0.16840241697684538
IT:  7  - RESIDUAL:  0.16840241697684538  - X:  6361253.531012535

 SUPPLY: 0.03000000
F:  5.604891550881064e-14
Fmin:  9.194034422677078e-14
Fmax:  2.0164425684754406e-14
DF:  -3.588795927100818e-09
DX:  -1.5617749419953598e-05
IT:  8  - RESIDUAL:  1.5617749419953598e-05  - X:  6361253.531028152

 SUPPLY: 0.03000000
F:  -6.938893903907228e-18
Fmin:  3.5887959271008185e-14
Fmax:  -3.589489816491209e-14
DF:  -3.5891428717960135e-09
DX:  1.9333011116481393e-09
IT:  9  - RESIDUAL:  1.9333011116481393e-09  - X:  6361253.531028151
```

Optimum Spring Area :	6361253.531028
Iteration Counts:	9
Convergence Residual:	1.9333011116e-09

Total time (s): 8.3125