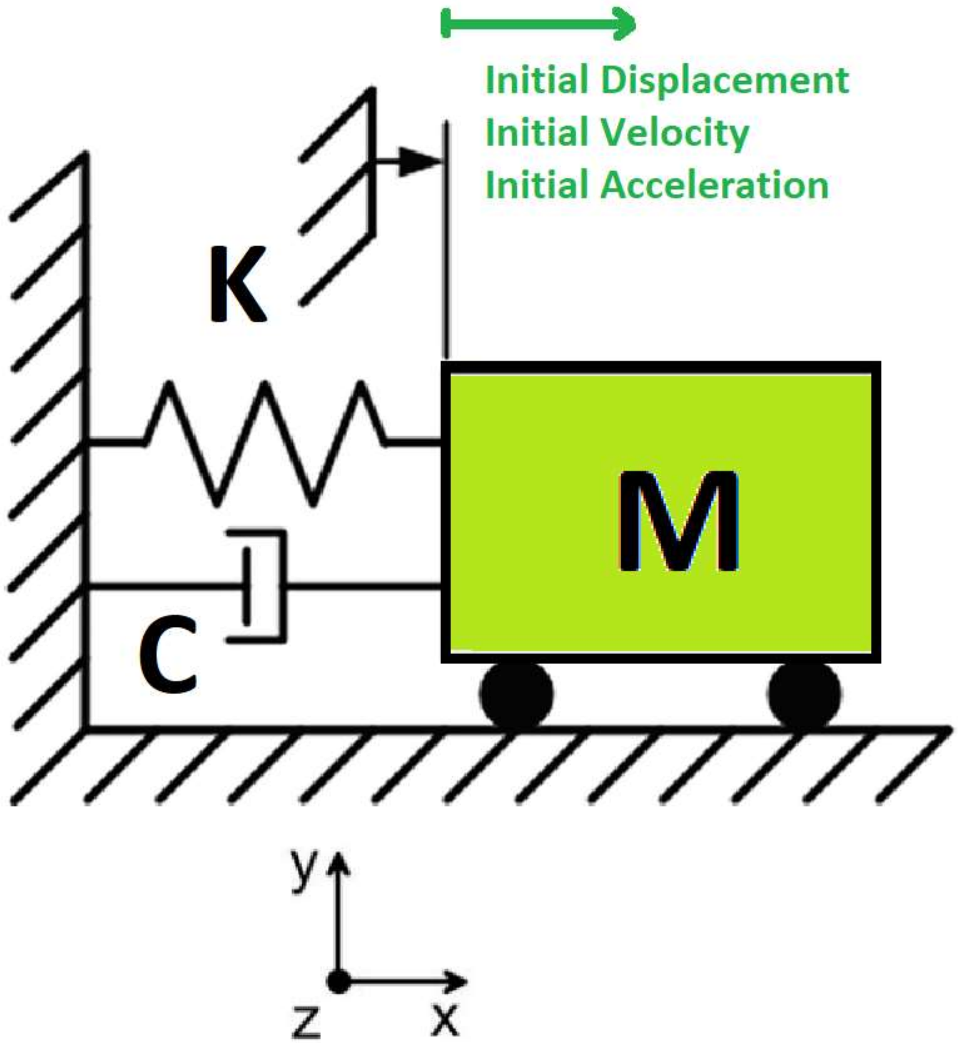
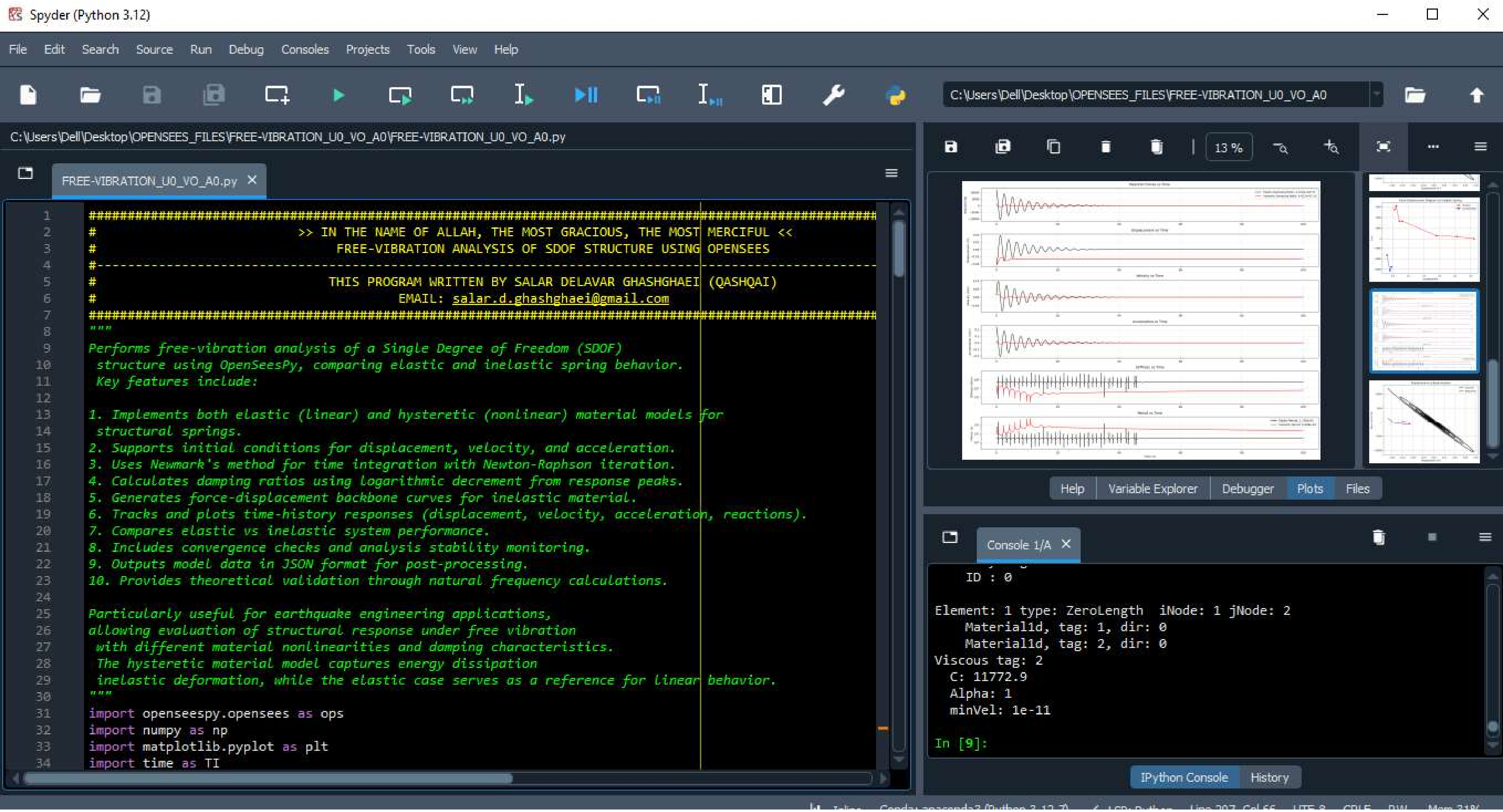
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

FREE-VIBRATION ANALYSIS OF SDOF STRUCTURE USING OPENSEES

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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FREE-VIBRATION_U0_VO_A0.py
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
FREE-VIBRATION ANALYSIS OF SDOF STRUCTURE USING OPENSEES
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
import time as TI
13 %
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: 11772.9
Alpha: 1
minVel: 1e-11
In [9]:
IPython Console History

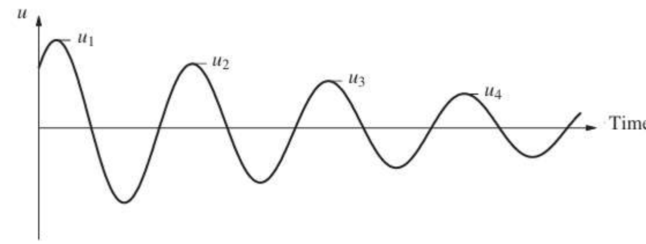
VISCOUSLY DAMPED FREE VIBRATION

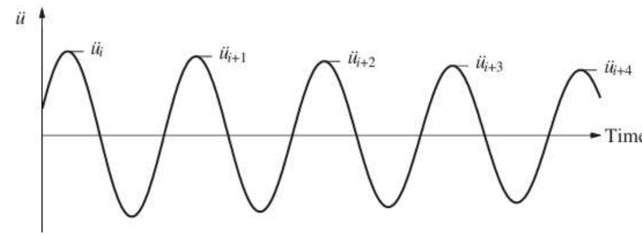
$$m\ddot{u} + c\dot{u} + ku = 0$$

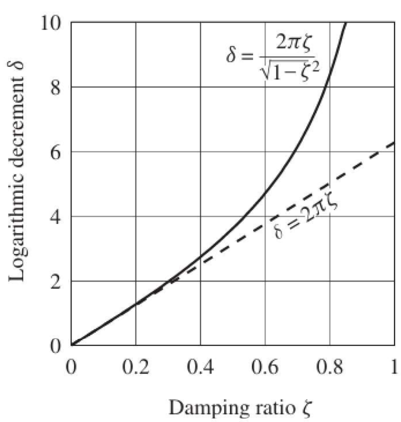
$$\ddot{u} + 2\zeta\omega_n\dot{u} + \omega_n^2 u = 0$$

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

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





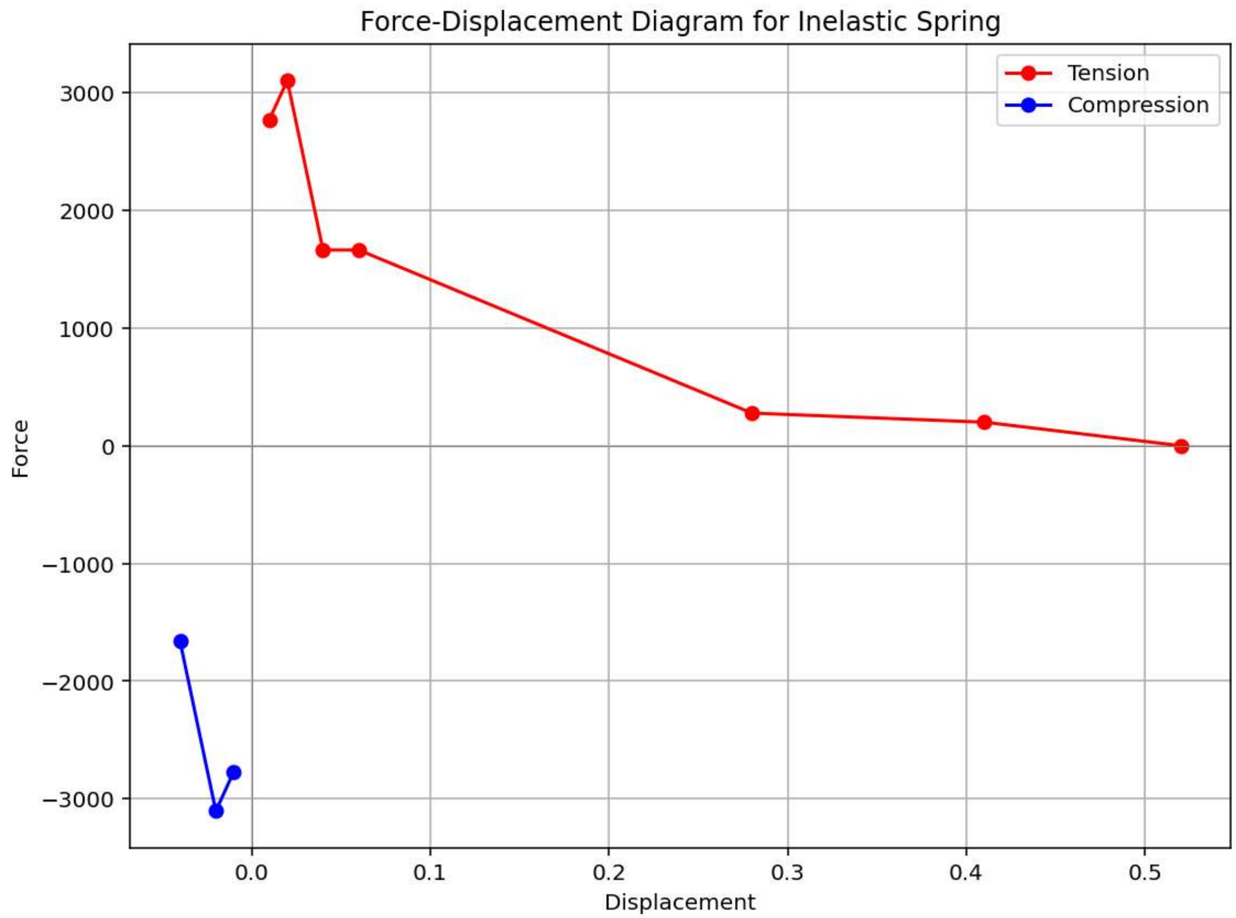


Decay of Motion

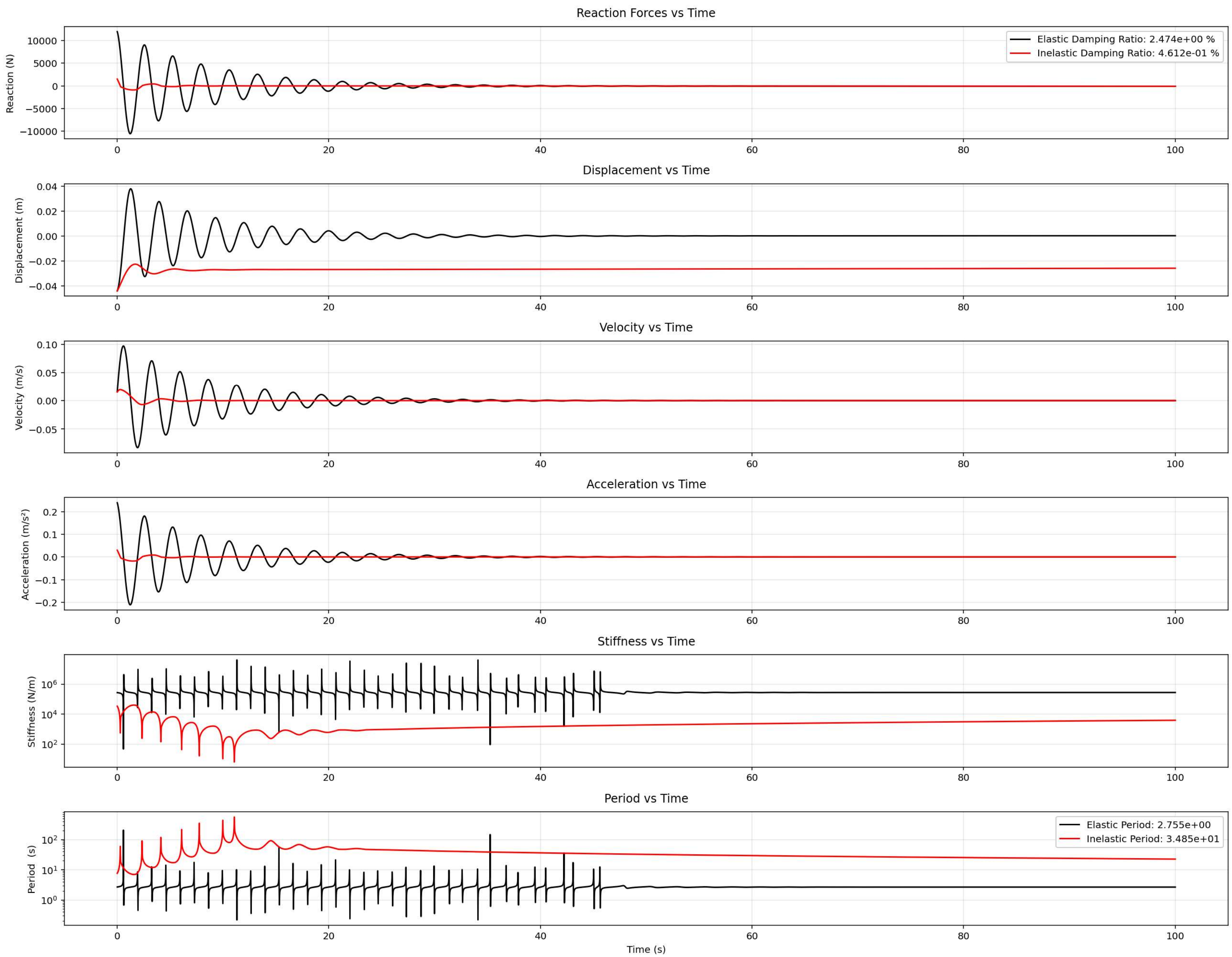
$$\delta = \ln\frac{u_i}{u_{i+1}} = 2\pi\zeta$$ **(APPROXIMATE RELATION)**

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

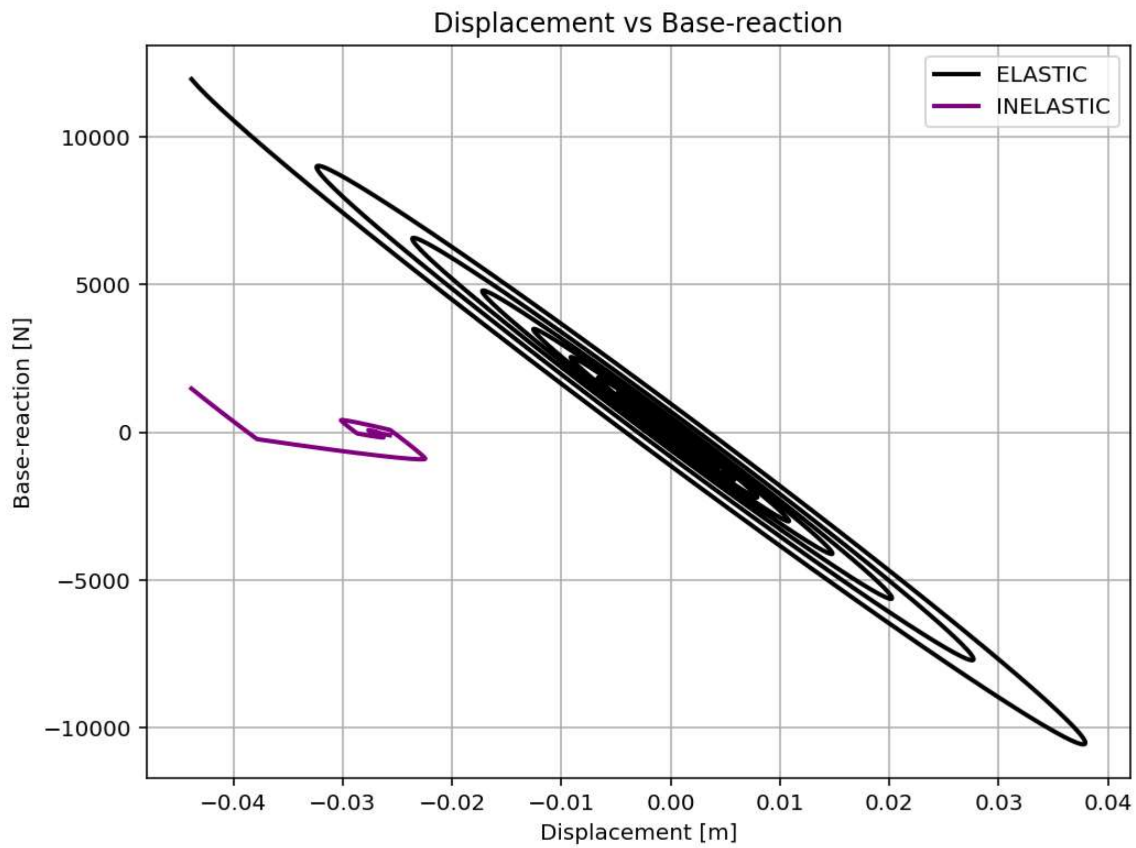
EXACT AND APPROXIMATE RELATIONS BETWEEN LOGARITHMIC DECREMENT AND DAMPING RATIO



Force-Displacement Diagram for Inelastic Spring
Tension
Compression
Force
Displacement
3000
2000
1000
0
−1000
−2000
−3000
0.0
0.1
0.2
0.3
0.4
0.5



Reaction Forces vs Time
Reaction (N)
Elastic Damping Ratio: 2.474e+00 %
Inelastic Damping Ratio: 4.612e-01 %
Displacement vs Time
Displacement (m)
Velocity vs Time
Velocity (m/s)
Acceleration vs Time
Acceleration (m/s²)
Stiffness vs Time
Stiffness (N/m)
Period vs Time
Period (s)
Elastic Period: 2.755e+00
Inelastic Period: 3.485e+01
Time (s)


Displacement vs Base-reaction
ELASTIC
INELASTIC
10000
5000
0
−5000
−10000
Base-reaction [N]
−0.04
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
0.04
Displacement [m]