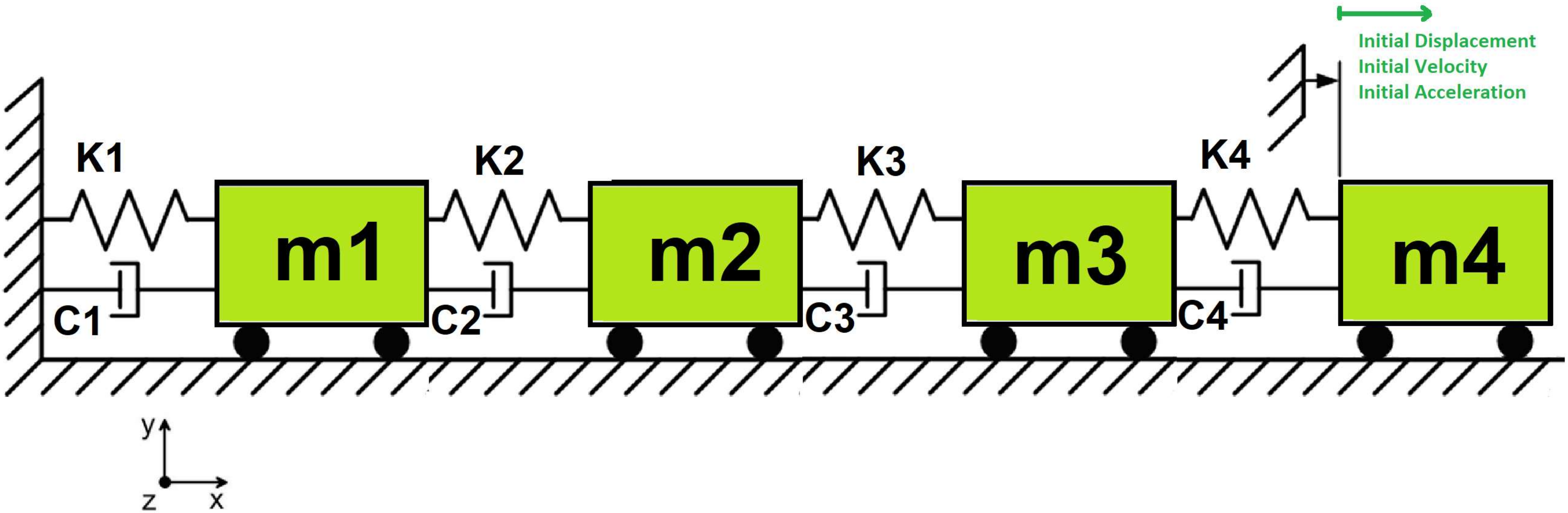
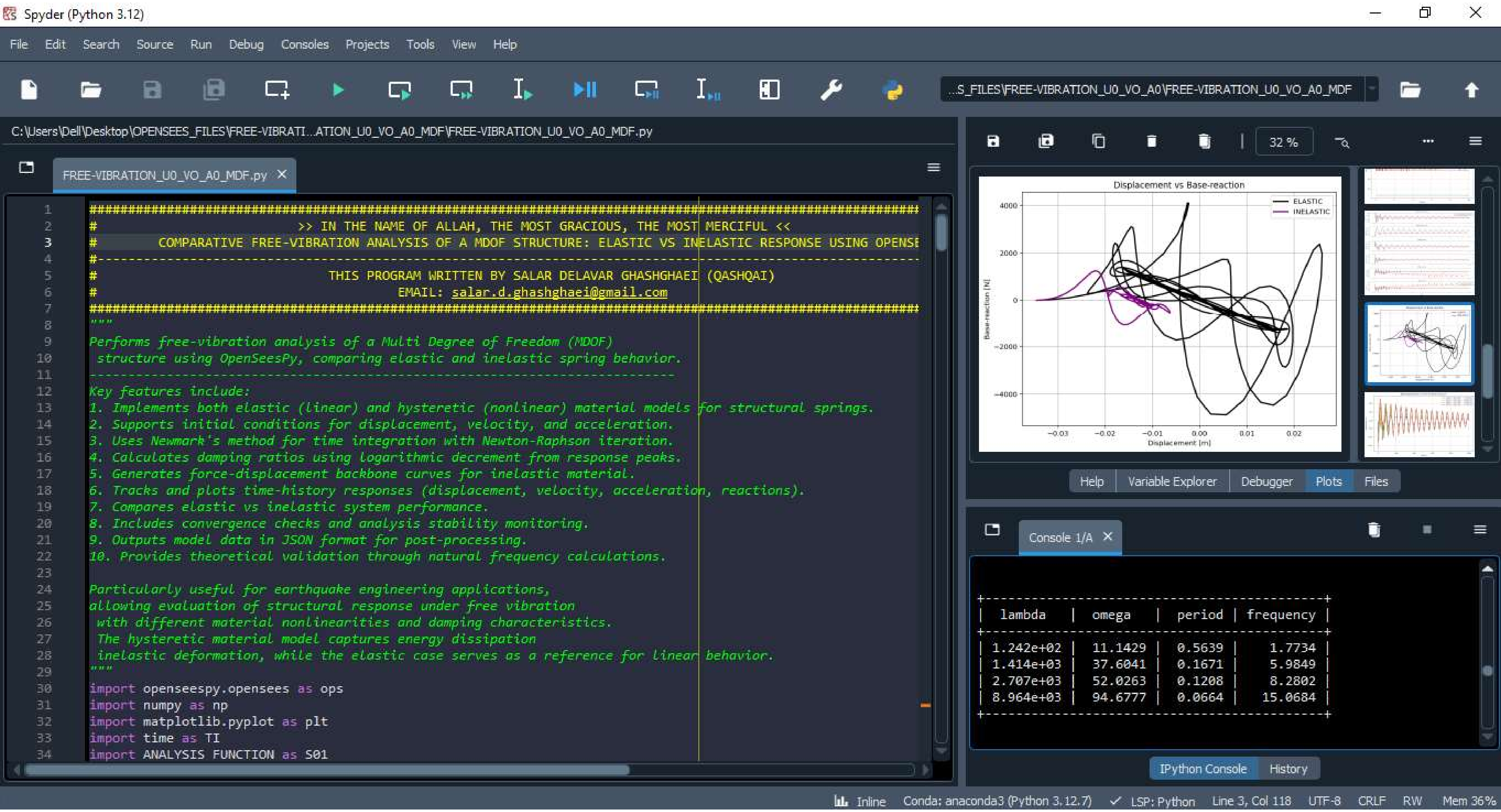
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

COMPARATIVE FREE-VIBRATION ANALYSIS OF A MDOF STRUCTURE: ELASTIC VS INELASTIC RESPONSE USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)


Initial Displacement
Initial Velocity
Initial Acceleration
K1
K2
K3
K4
m1
m2
m3
m4
C1
C2
C3
C4
y
z
x


Spyder (Python 3.12)
File Edit Search Source Run Debug Consoles Projects Tools View Help
...S_FILES\FREE-VIBRATION_U0_VO_A0\FREE-VIBRATION_U0_VO_A0_MDF
C:\Users\Dell\Desktop\OPENSEES_FILES\FREE-VIBRATI...ATION_U0_VO_A0_MDF\FREE-VIBRATION_U0_VO_A0_MDF.py
FREE-VIBRATION_U0_VO_A0_MDF.py
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
COMPARATIVE FREE-VIBRATION ANALYSIS OF A MDOF STRUCTURE: ELASTIC VS INELASTIC RESPONSE USING OPENSE
THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
EMAIL: salar.d.ghashghaei@gmail.com
Performs free-vibration analysis of a Multi Degree of Freedom (MDOF)
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
import ANALYSIS_FUNCTION as S01
32 %
Displacement vs Base-reaction
ELASTIC
INELASTIC
Base-reaction [N]
Displacement [m]
Help Variable Explorer Debugger Plots Files
Console 1/A
lambda	omega	period	frequency
1.242e+02	11.1429	0.5639	1.7734
1.414e+03	37.6041	0.1671	5.9849
2.707e+03	52.0263	0.1208	8.2802
8.964e+03	94.6777	0.0664	15.0684
IPython Console History
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 3, Col 118 UTF-8 CRLF RW Mem 36%

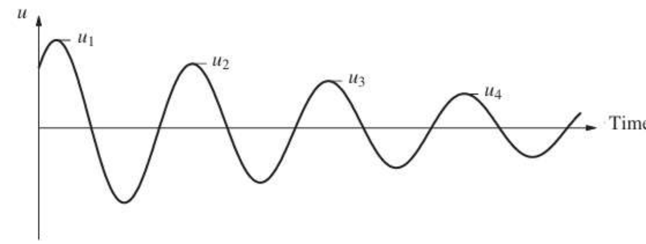
VISCOUSLY DAMPED FREE VIBRATION

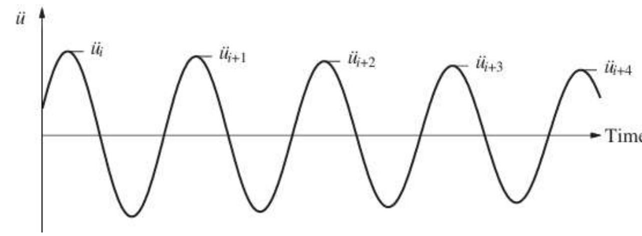
$$m\ddot{u} + c\dot{u} + ku = 0$$

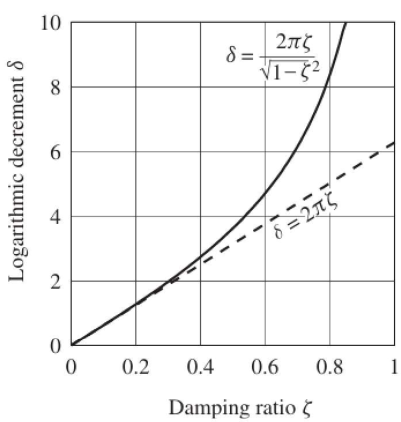
$$\ddot{u} + 2\zeta\omega_n\dot{u} + \omega_n^2 u = 0$$

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

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





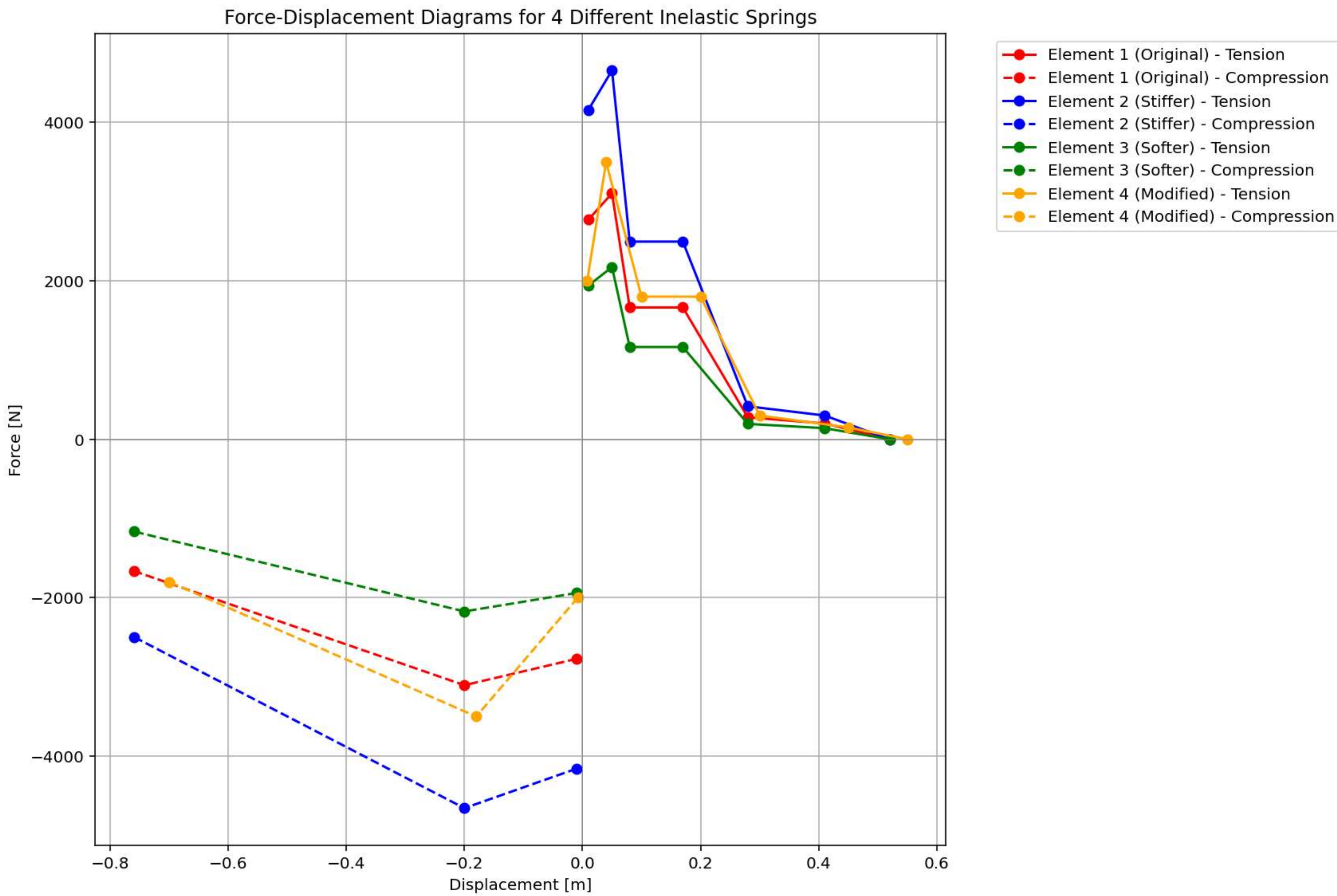


Decay of Motion

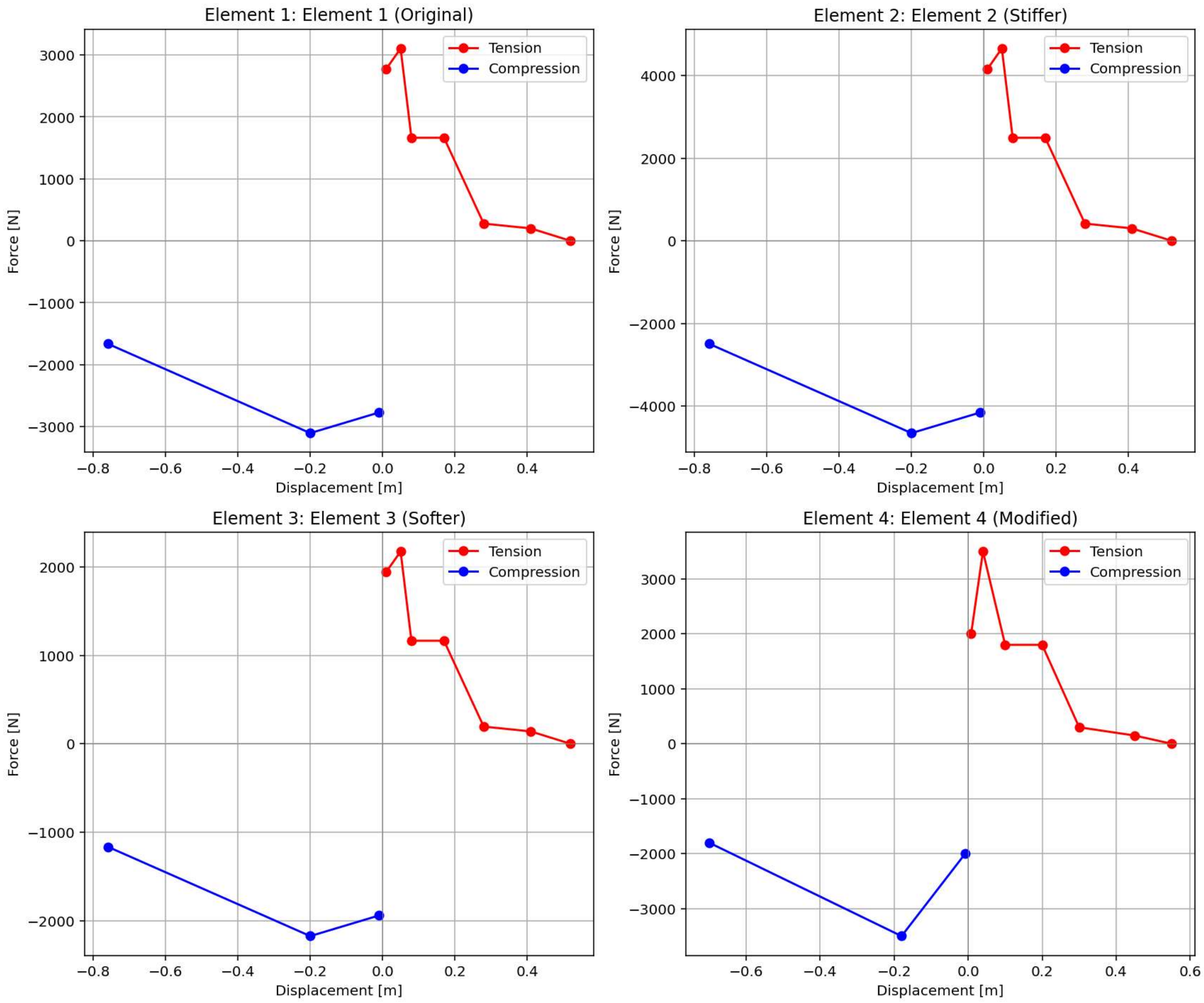
$$\delta = \ln\frac{u_i}{u_{i+1}} = 2\pi\zeta$$ **(APPROXIMATE RELATION)**

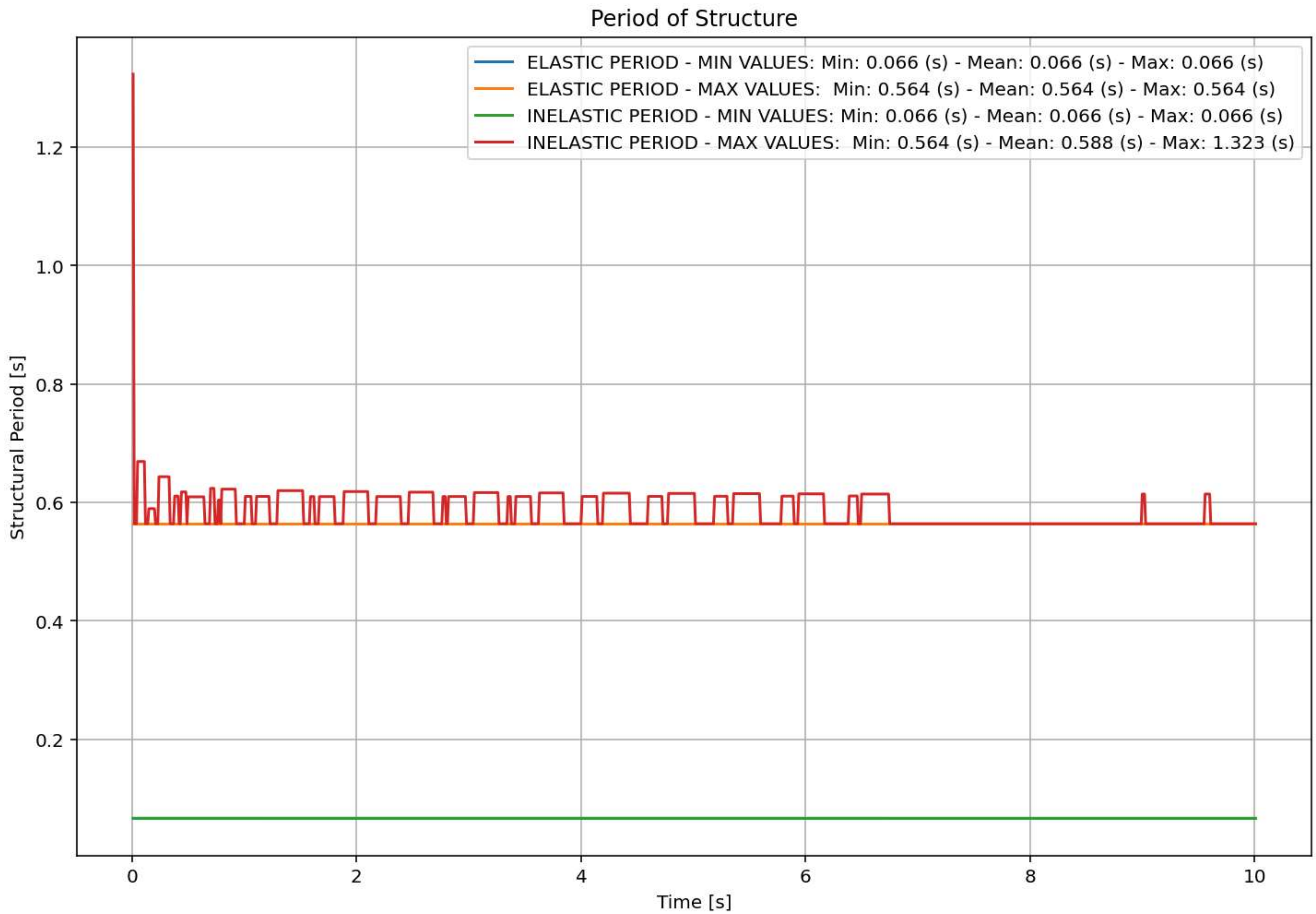
$$\delta = \ln\frac{u_i}{u_{i+1}} = \frac{2\pi\zeta}{\sqrt{1-\zeta^2}}$$ **(EXACT RELATION)**

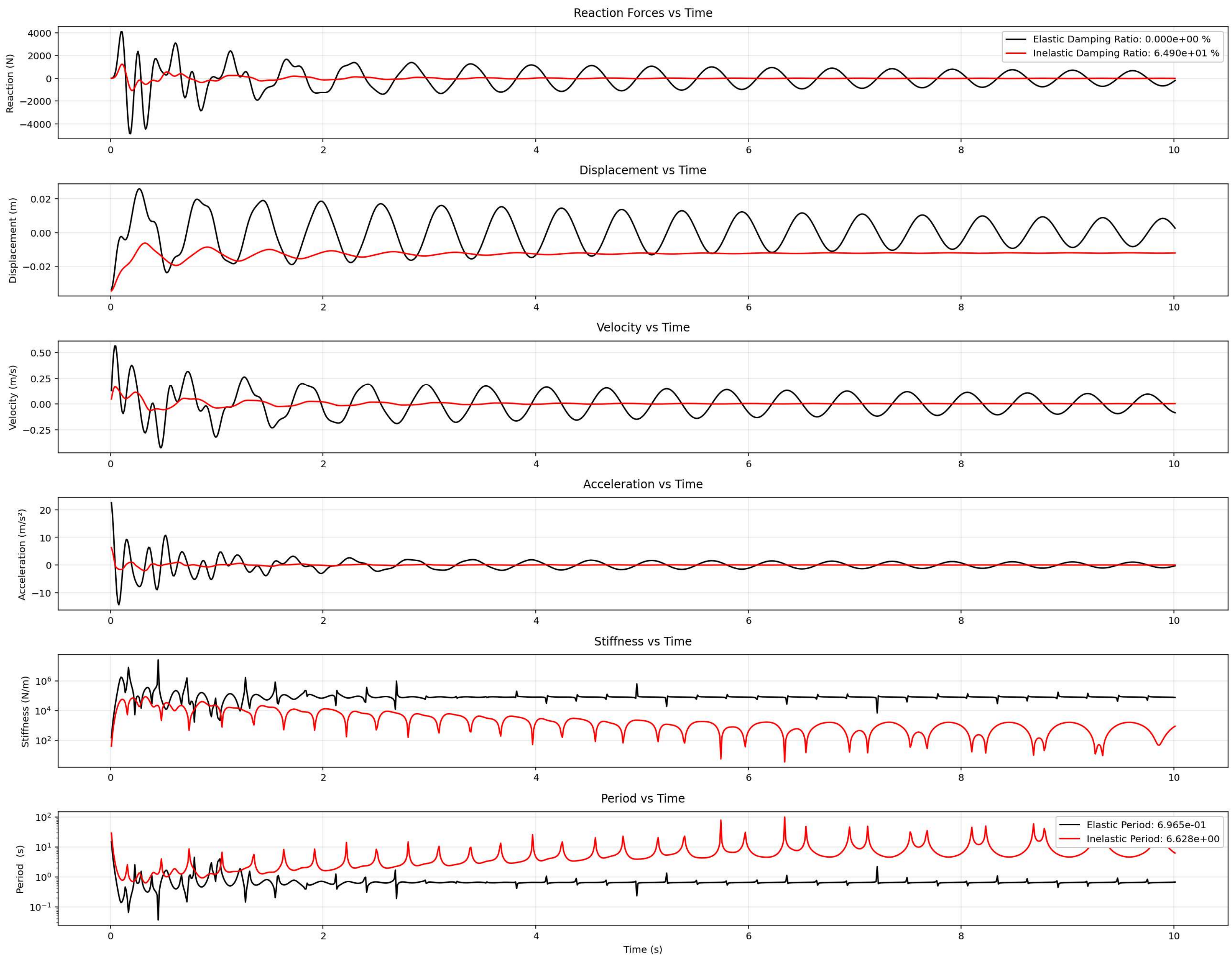
EXACT AND APPROXIMATE RELATIONS BETWEEN LOGARITHMIC DECREMENT AND DAMPING RATIO

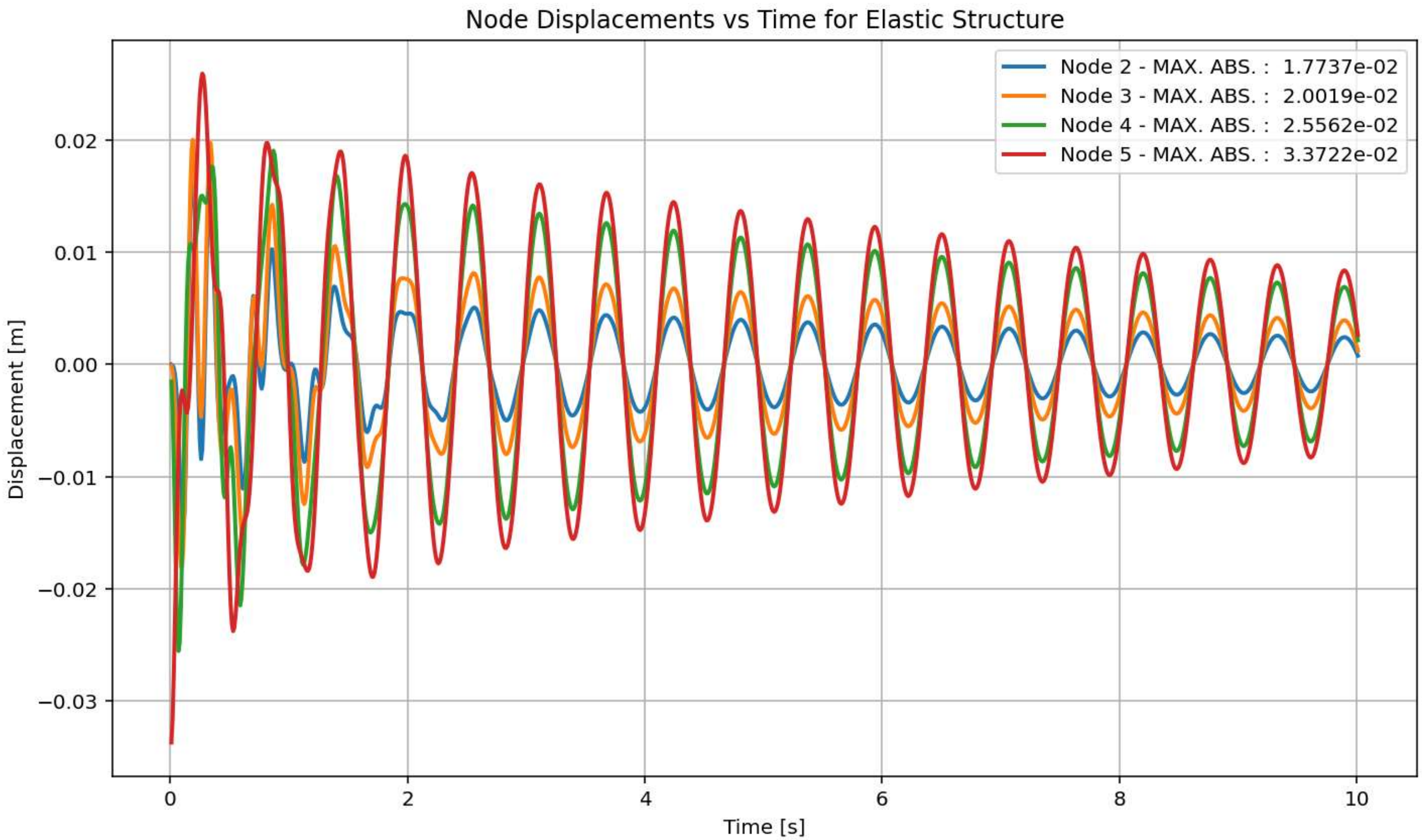


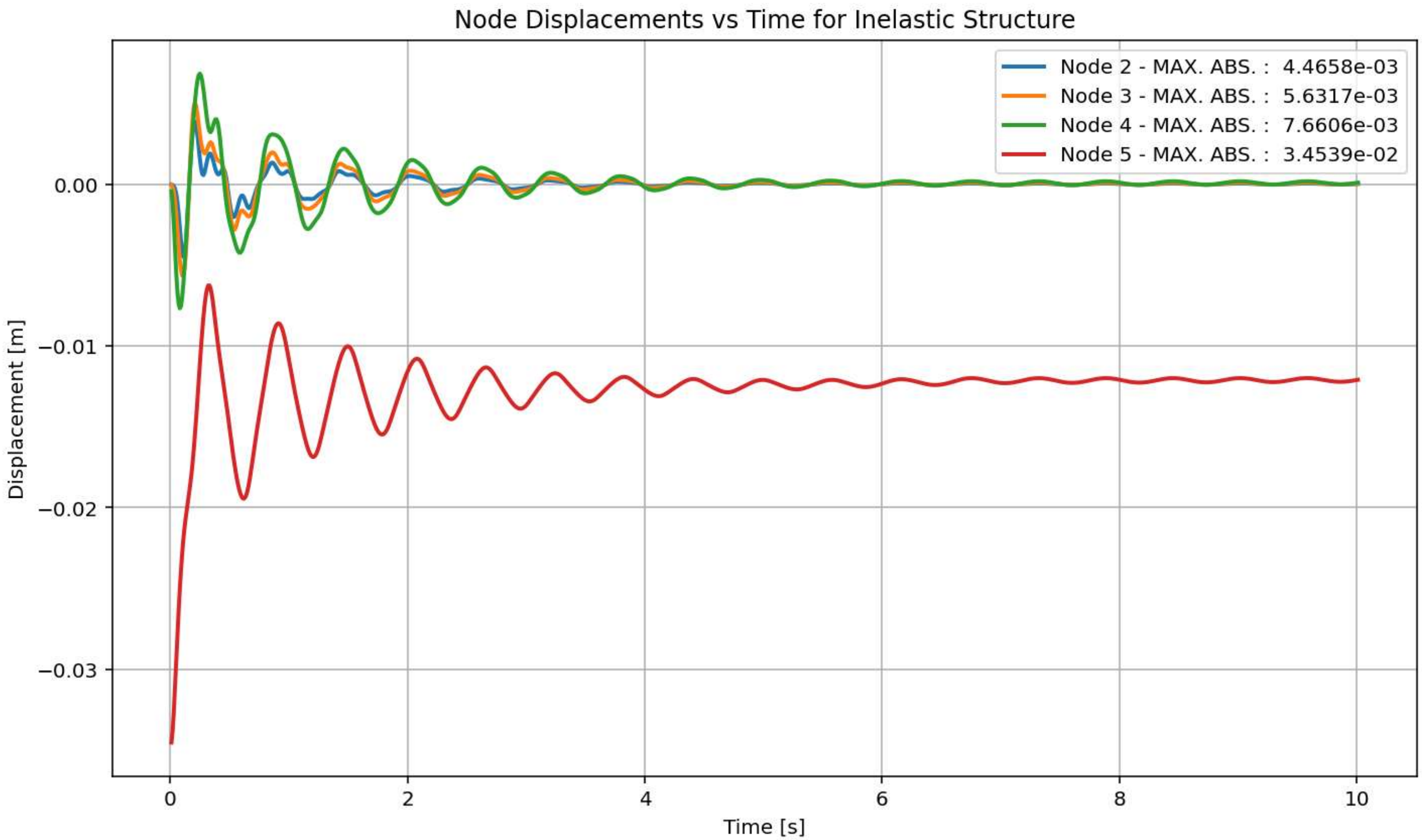
Force-Displacement Diagrams for 4 Different Inelastic Springs
Force [N]
Displacement [m]
4000
2000
0
−2000
−4000
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
Element 1 (Original) - Tension
Element 1 (Original) - Compression
Element 2 (Stiffer) - Tension
Element 2 (Stiffer) - Compression
Element 3 (Softer) - Tension
Element 3 (Softer) - Compression
Element 4 (Modified) - Tension
Element 4 (Modified) - Compression


Element 1: Element 1 (Original)
Element 2: Element 2 (Stiffer)
Element 3: Element 3 (Softer)
Element 4: Element 4 (Modified)
Tension
Compression
Force [N]
Displacement [m]

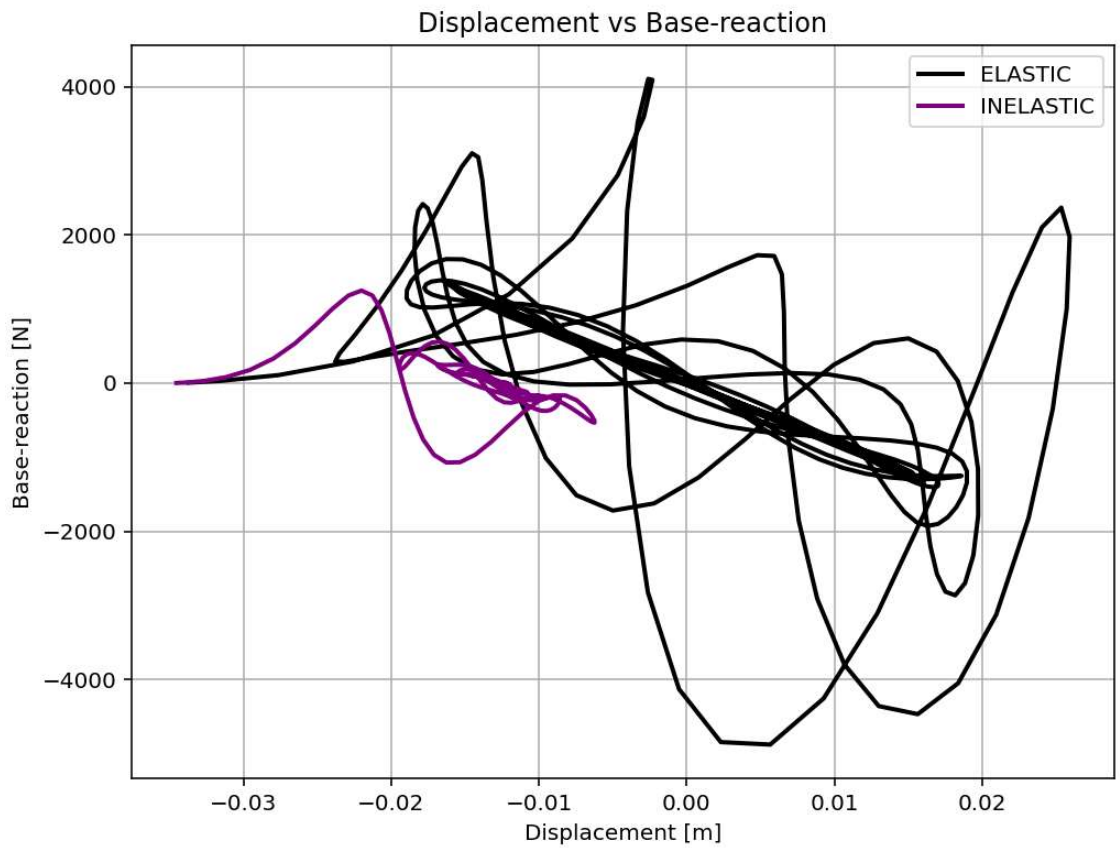

Period of Structure
ELASTIC PERIOD - MIN VALUES: Min: 0.066 (s) - Mean: 0.066 (s) - Max: 0.066 (s)
ELASTIC PERIOD - MAX VALUES: Min: 0.564 (s) - Mean: 0.564 (s) - Max: 0.564 (s)
INELASTIC PERIOD - MIN VALUES: Min: 0.066 (s) - Mean: 0.066 (s) - Max: 0.066 (s)
INELASTIC PERIOD - MAX VALUES: Min: 0.564 (s) - Mean: 0.588 (s) - Max: 1.323 (s)
Structural Period [s]
1.2
1.0
0.8
0.6
0.4
0.2
0
2
4
6
8
10
Time [s]


Reaction Forces vs Time
Elastic Damping Ratio: 0.000e+00 %
Inelastic Damping Ratio: 6.490e+01 %
Reaction (N)
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
Elastic Period: 6.965e-01
Inelastic Period: 6.628e+00
Period (s)
Time (s)


Node Displacements vs Time for Elastic Structure
Node 2 - MAX. ABS. : 1.7737e-02
Node 3 - MAX. ABS. : 2.0019e-02
Node 4 - MAX. ABS. : 2.5562e-02
Node 5 - MAX. ABS. : 3.3722e-02
Displacement [m]
Time [s]
0.02
0.01
0.00
−0.01
−0.02
−0.03
0
2
4
6
8
10



Node Displacements vs Time for Inelastic Structure
Node 2 - MAX. ABS. : 4.4658e-03
Node 3 - MAX. ABS. : 5.6317e-03
Node 4 - MAX. ABS. : 7.6606e-03
Node 5 - MAX. ABS. : 3.4539e-02
0.00
−0.01
−0.02
−0.03
Displacement [m]
0
2
4
6
8
10
Time [s]



Displacement vs Base-reaction
ELASTIC
INELASTIC
4000
2000
0
−2000
−4000
Base-reaction [N]
−0.03
−0.02
−0.01
0.00
0.01
0.02
Displacement [m]