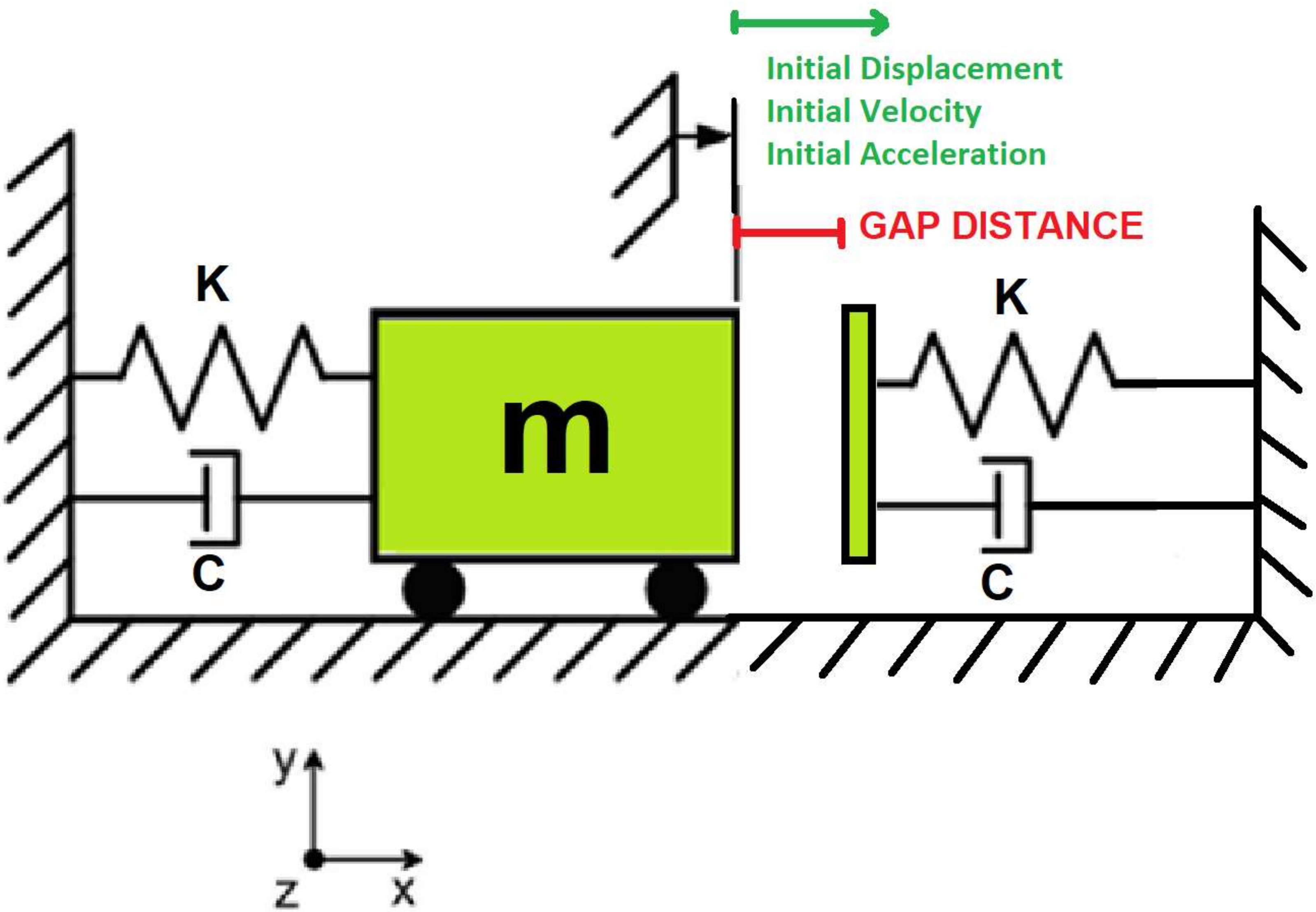
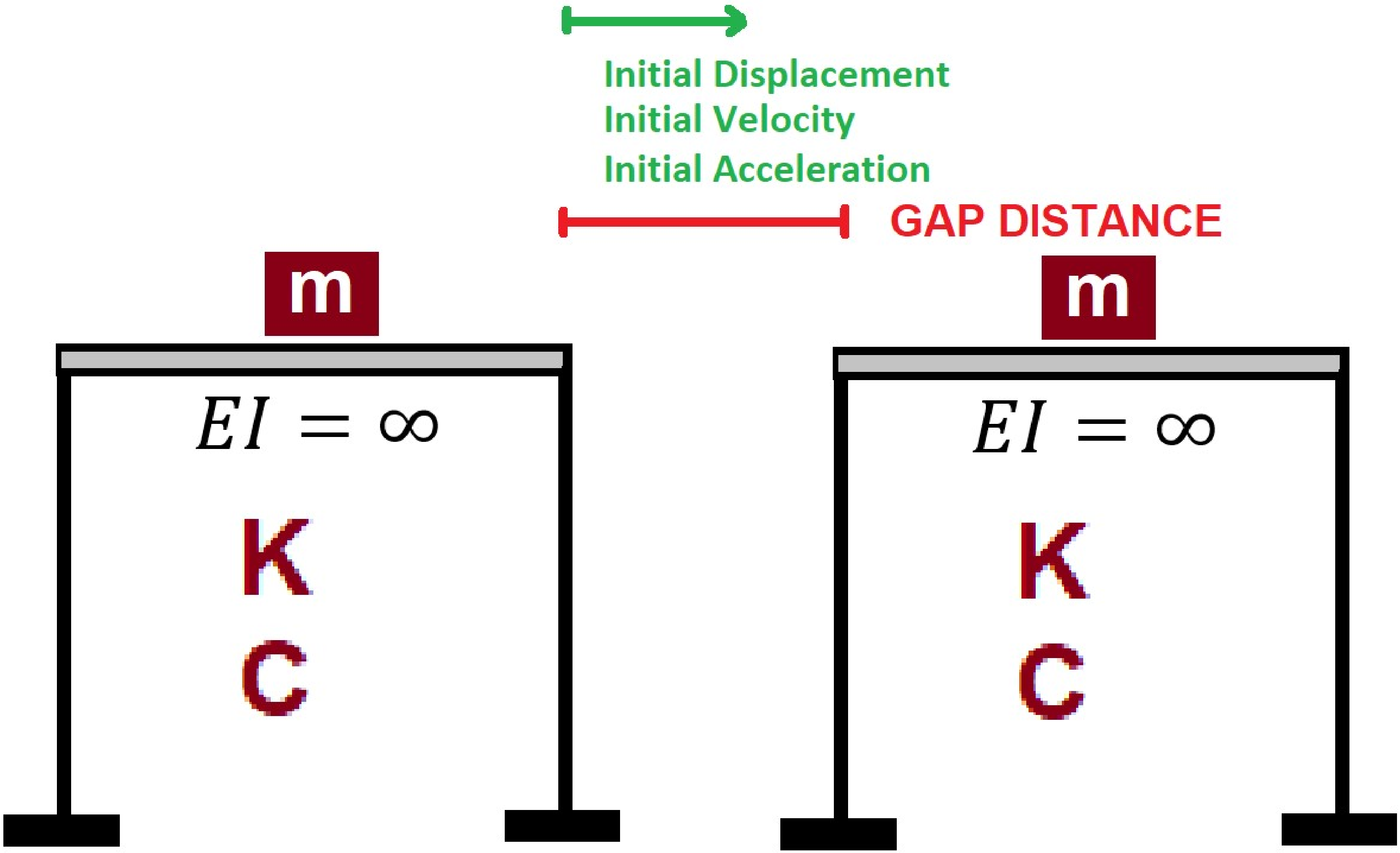
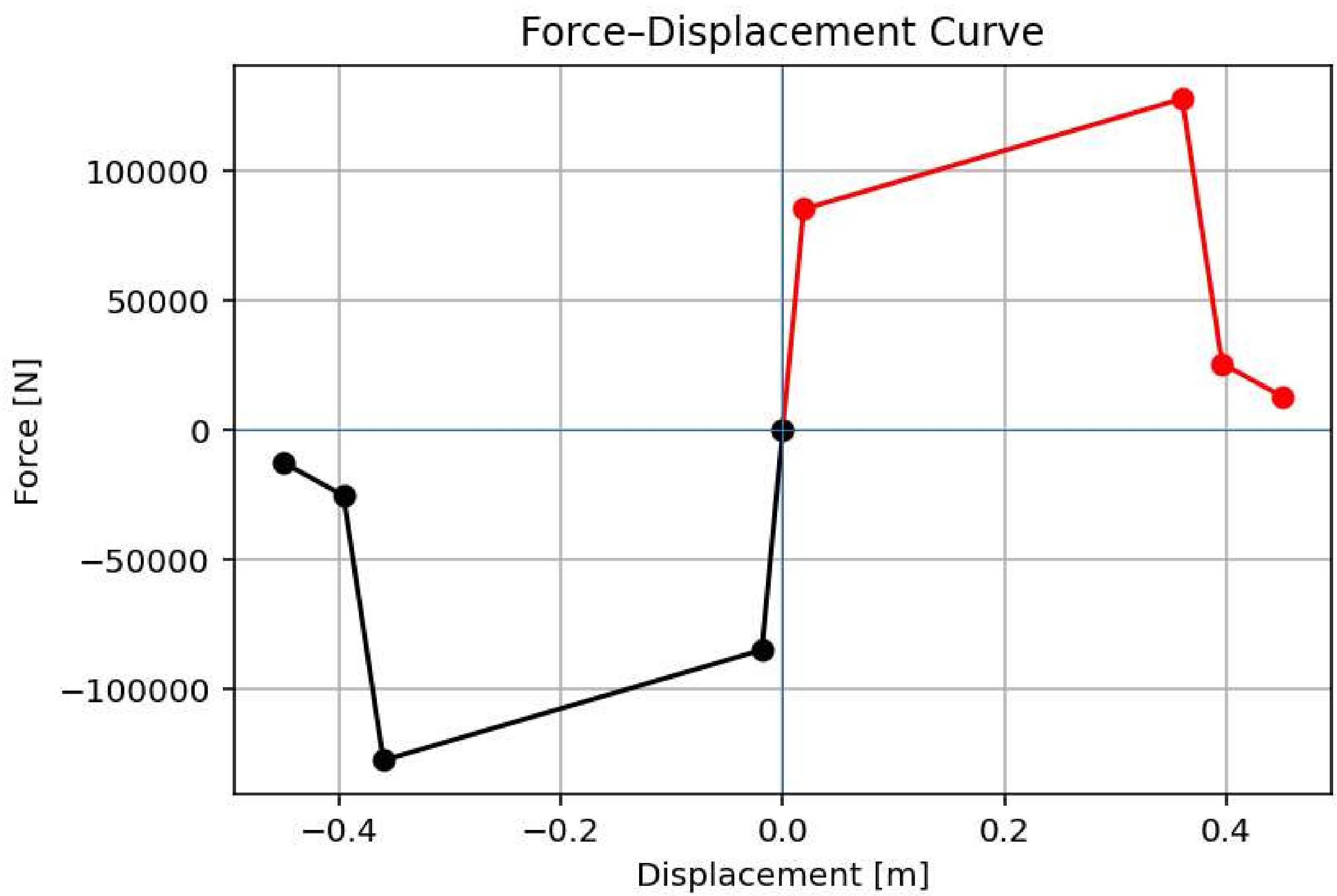
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

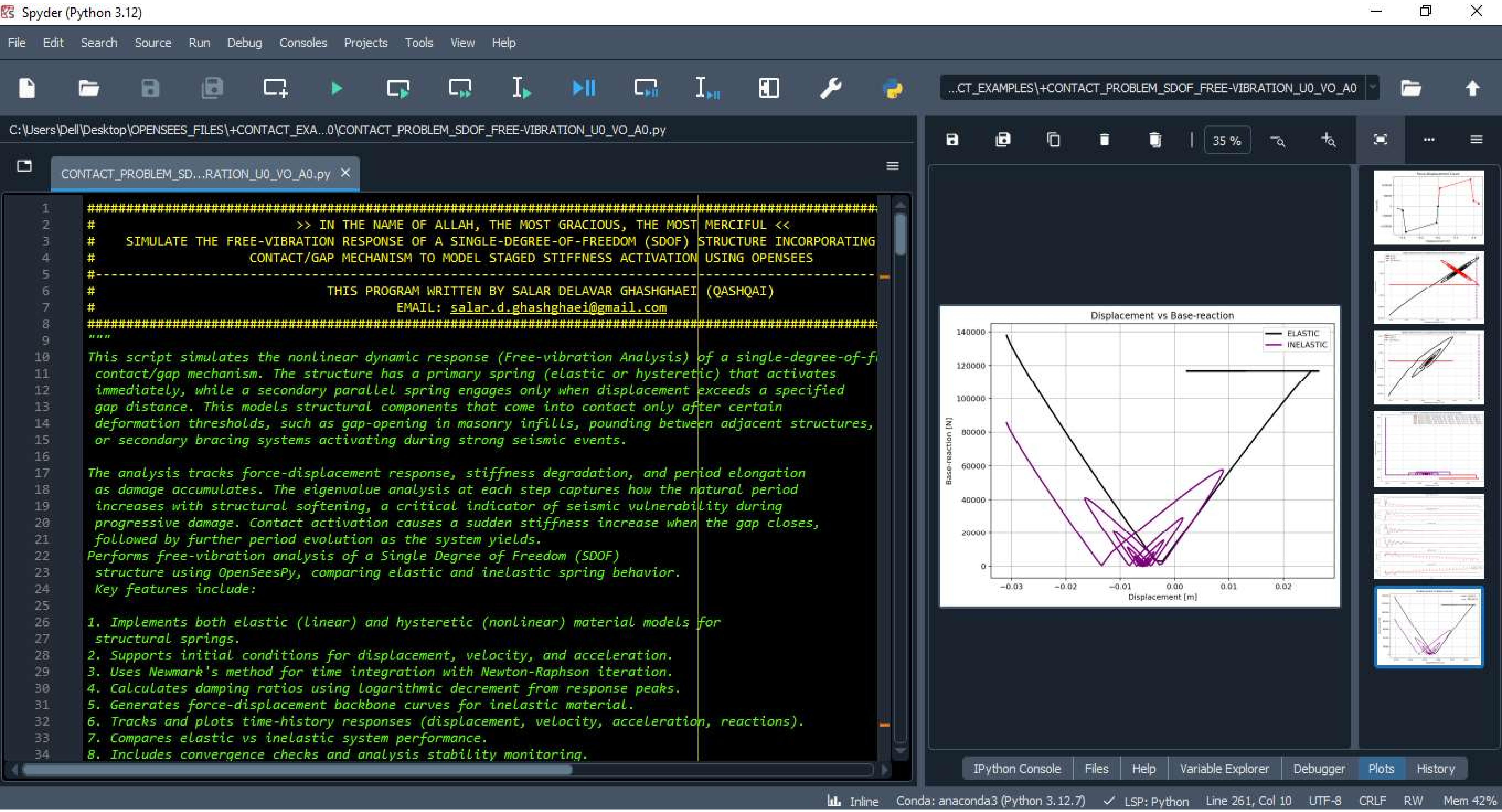
SIMULATE THE FREE-VIBRATION RESPONSE OF A SINGLE-DEGREE-OF-FREEDOM (SDOF) STRUCTURE INCORPORATING A PARALLEL CONTACT/GAP MECHANISM TO MODEL STAGED STIFFNESS ACTIVATION USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)


Initial Displacement
Initial Velocity
Initial Acceleration
GAP DISTANCE
K
m
C
K
C
y
z
x


Initial Displacement
Initial Velocity
Initial Acceleration
GAP DISTANCE
m
$EI = \infty$
K
C
m
$EI = \infty$
K
C


Force–Displacement Curve
100000
50000
0
−50000
−100000
Force [N]
−0.4
−0.2
0.0
0.2
0.4
Displacement [m]


Spyder (Python 3.12)
File Edit Search Source Run Debug Consoles Projects Tools View Help
...CT_EXAMPLES\+CONTACT_PROBLEM_SDOF_FREE-VIBRATION_U0_VO_A0
C:\Users\Dell\Desktop\OPENSEES_FILES\+CONTACT_EXA...0\CONTACT_PROBLEM_SDOF_FREE-VIBRATION_U0_VO_A0.py
CONTACT_PROBLEM_SD...RATION_U0_VO_A0.py
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
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CONTACT/GAP MECHANISM TO MODEL STAGED STIFFNESS ACTIVATION USING OPENSEES
THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
EMAIL: salar.d.ghashghaei@gmail.com
"""
This script simulates the nonlinear dynamic response (Free-vibration Analysis) of a single-degree-of-f
 contact/gap mechanism. The structure has a primary spring (elastic or hysteretic) that activates
 immediately, while a secondary parallel spring engages only when displacement exceeds a specified
 gap distance. This models structural components that come into contact only after certain
 deformation thresholds, such as gap-opening in masonry infills, pounding between adjacent structures,
 or secondary bracing systems activating during strong seismic events.
The analysis tracks force-displacement response, stiffness degradation, and period elongation
 as damage accumulates. The eigenvalue analysis at each step captures how the natural period
 increases with structural softening, a critical indicator of seismic vulnerability during
 progressive damage. Contact activation causes a sudden stiffness increase when the gap closes,
 followed by further period evolution as the system yields.
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.
35 %
Displacement vs Base-reaction
ELASTIC
INELASTIC
Base-reaction [N]
Displacement [m]
IPython Console Files Help Variable Explorer Debugger Plots History
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 261, Col 10 UTF-8 CRLF RW Mem 42%

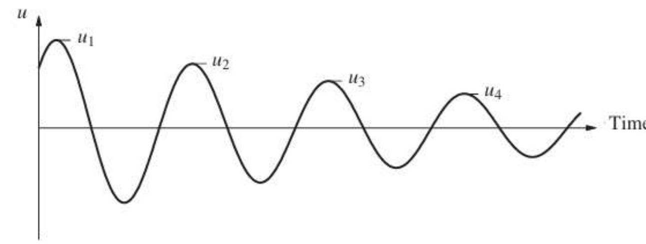
VISCOUSLY DAMPED FREE VIBRATION

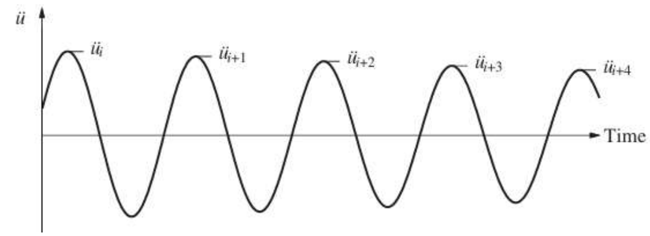
$$m\ddot{u} + c\dot{u} + ku = 0$$

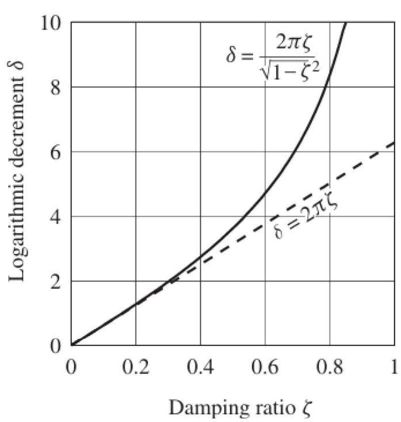
$$\ddot{u} + 2\zeta\omega_n\dot{u} + \omega_n^2 u = 0$$

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

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





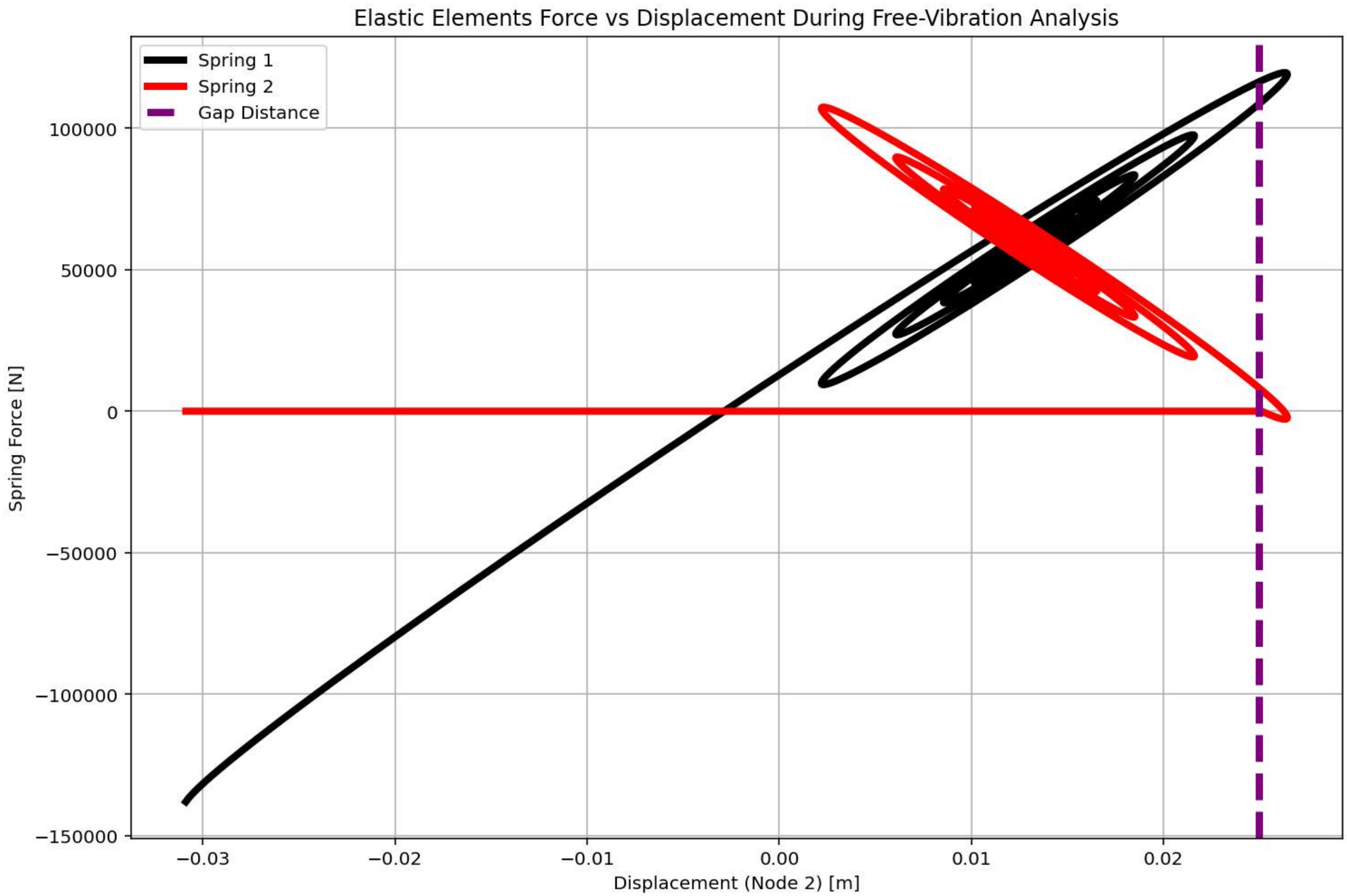


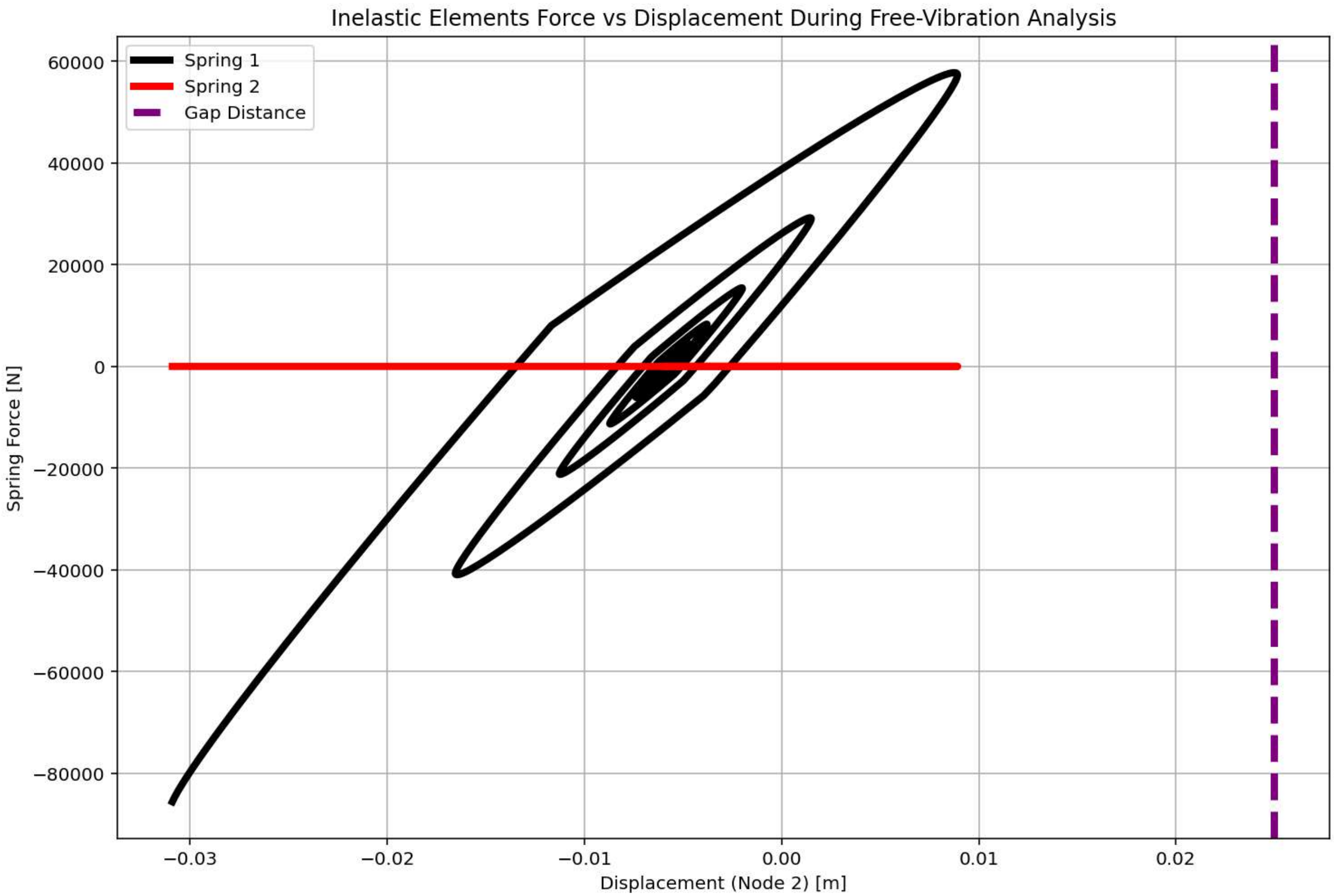
Decay of Motion

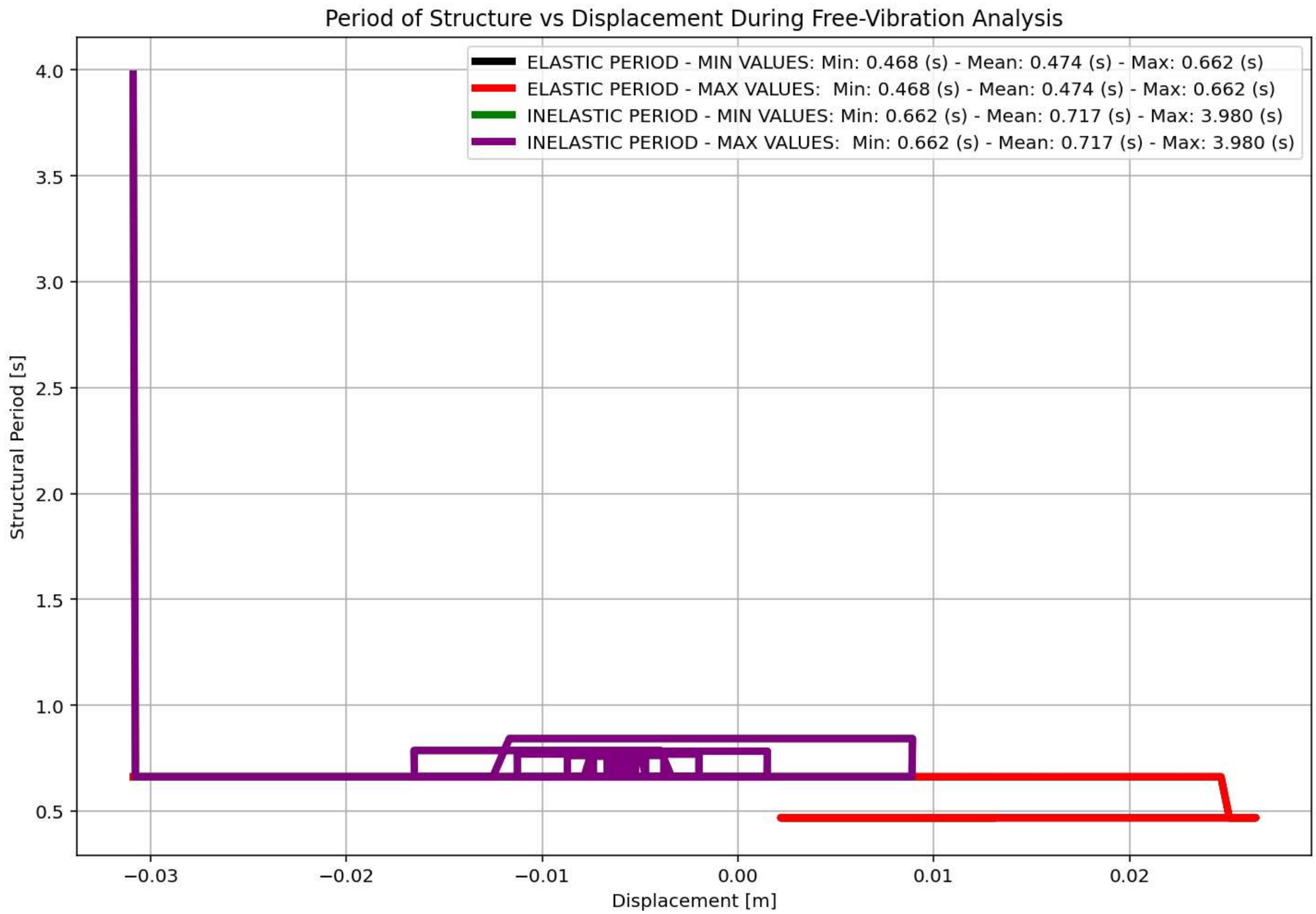
$$\delta = \ln\frac{u_i}{u_{i+1}} = 2\pi\zeta$$ **(APPROXIMATE RELATION)**

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

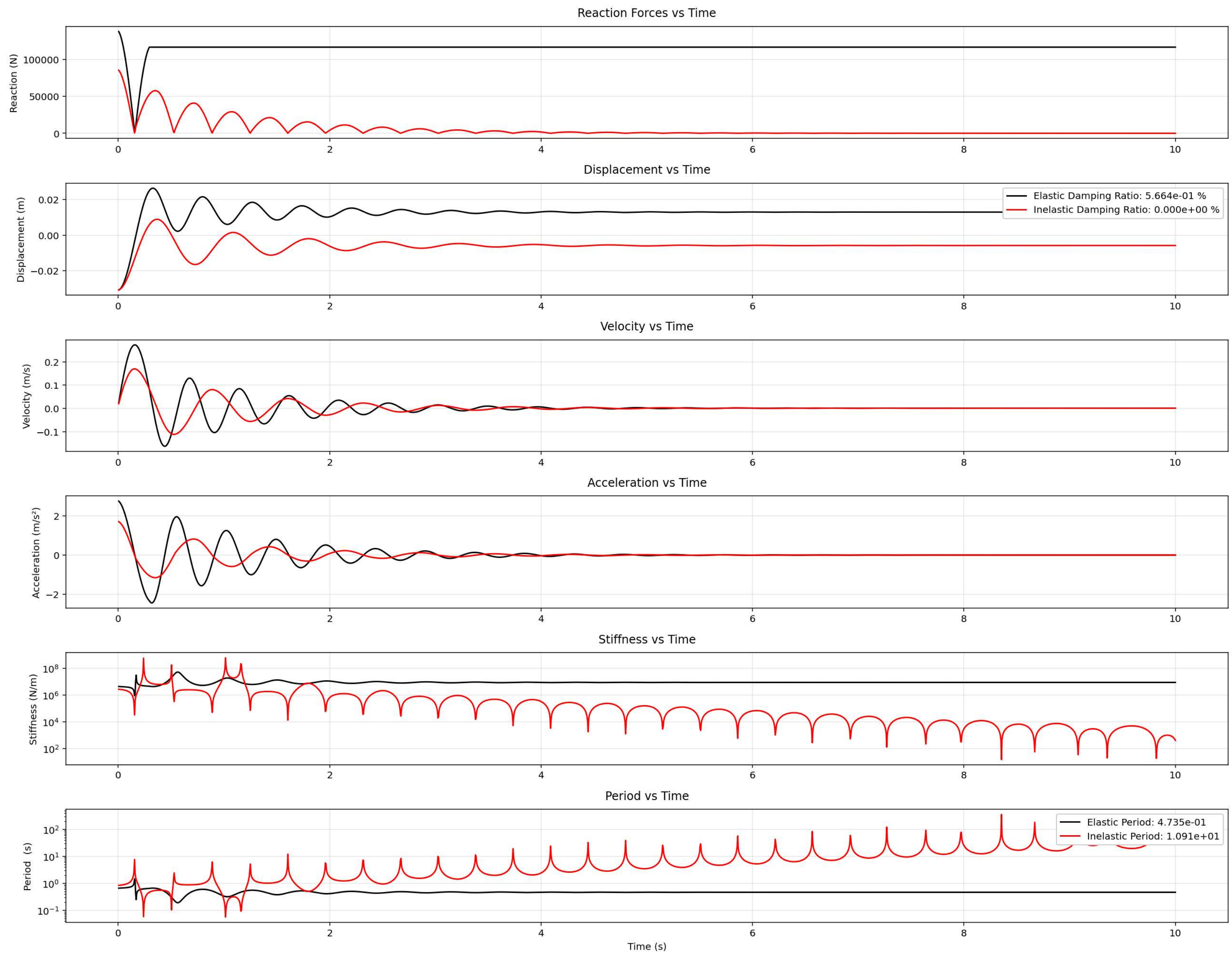
EXACT AND APPROXIMATE RELATIONS BETWEEN LOGARITHMIC DECREMENT AND DAMPING RATIO

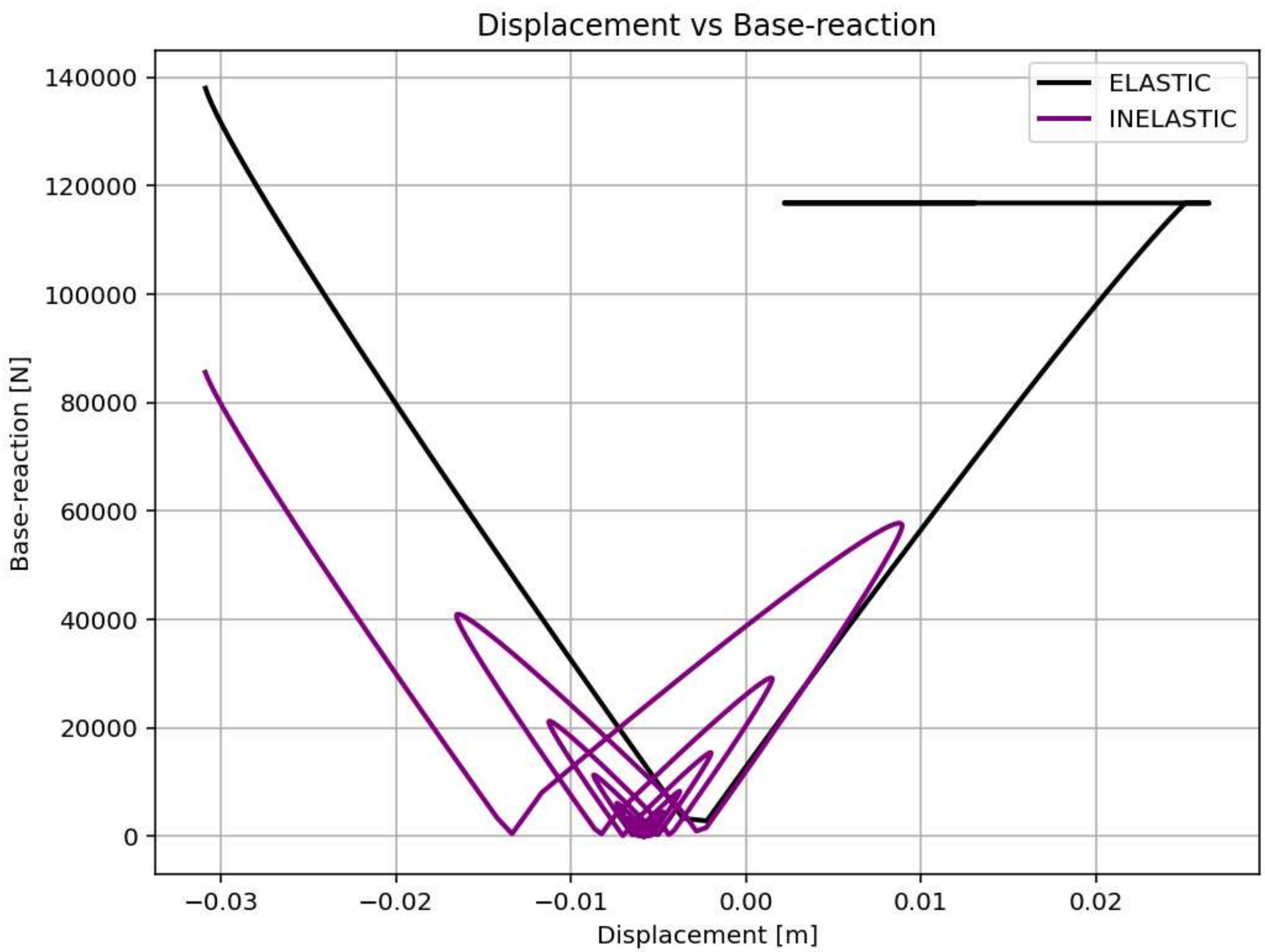

Elastic Elements Force vs Displacement During Free-Vibration Analysis
Spring 1
Spring 2
Gap Distance
Spring Force [N]
100000
50000
0
−50000
−100000
−150000
−0.03
−0.02
−0.01
0.00
0.01
0.02
Displacement (Node 2) [m]


Inelastic Elements Force vs Displacement During Free-Vibration Analysis
Spring 1
Spring 2
Gap Distance
60000
40000
20000
0
−20000
−40000
−60000
−80000
Spring Force [N]
−0.03
−0.02
−0.01
0.00
0.01
0.02
Displacement (Node 2) [m]

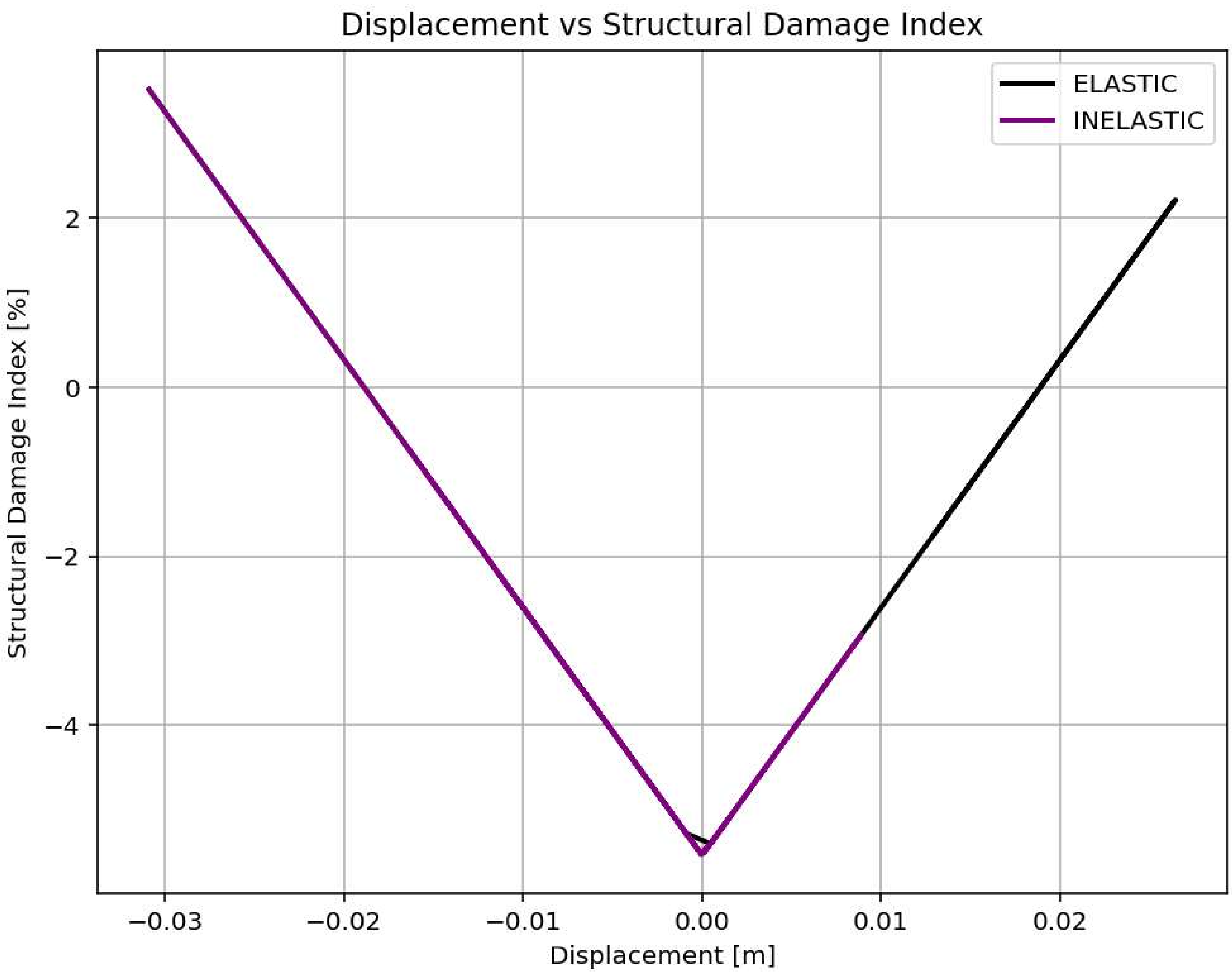


Period of Structure vs Displacement During Free-Vibration Analysis
ELASTIC PERIOD - MIN VALUES: Min: 0.468 (s) - Mean: 0.474 (s) - Max: 0.662 (s)
ELASTIC PERIOD - MAX VALUES: Min: 0.468 (s) - Mean: 0.474 (s) - Max: 0.662 (s)
INELASTIC PERIOD - MIN VALUES: Min: 0.662 (s) - Mean: 0.717 (s) - Max: 3.980 (s)
INELASTIC PERIOD - MAX VALUES: Min: 0.662 (s) - Mean: 0.717 (s) - Max: 3.980 (s)
Structural Period [s]
Displacement [m]
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
−0.03
−0.02
−0.01
0.00
0.01
0.02


Reaction Forces vs Time
Reaction (N)
Displacement vs Time
Displacement (m)
Elastic Damping Ratio: 5.664e-01 %
Inelastic Damping Ratio: 0.000e+00 %
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: 4.735e-01
Inelastic Period: 1.091e+01
Time (s)



Displacement vs Base-reaction
ELASTIC
INELASTIC
Base-reaction [N]
140000
120000
100000
80000
60000
40000
20000
0
−0.03
−0.02
−0.01
0.00
0.01
0.02
Displacement [m]



Displacement vs Structural Damage Index
ELASTIC
INELASTIC
Structural Damage Index [%]
2
0
−2
−4
−0.03
−0.02
−0.01
0.00
0.01
0.02
Displacement [m]