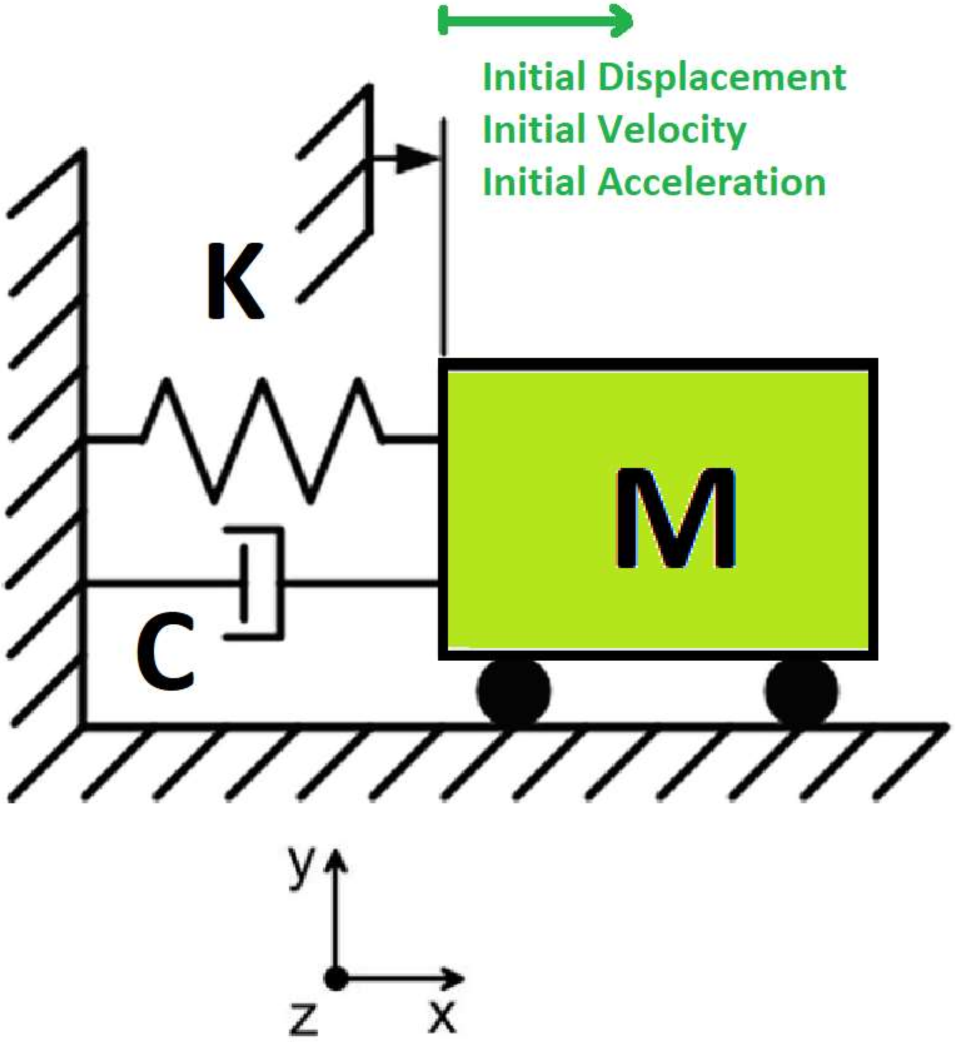
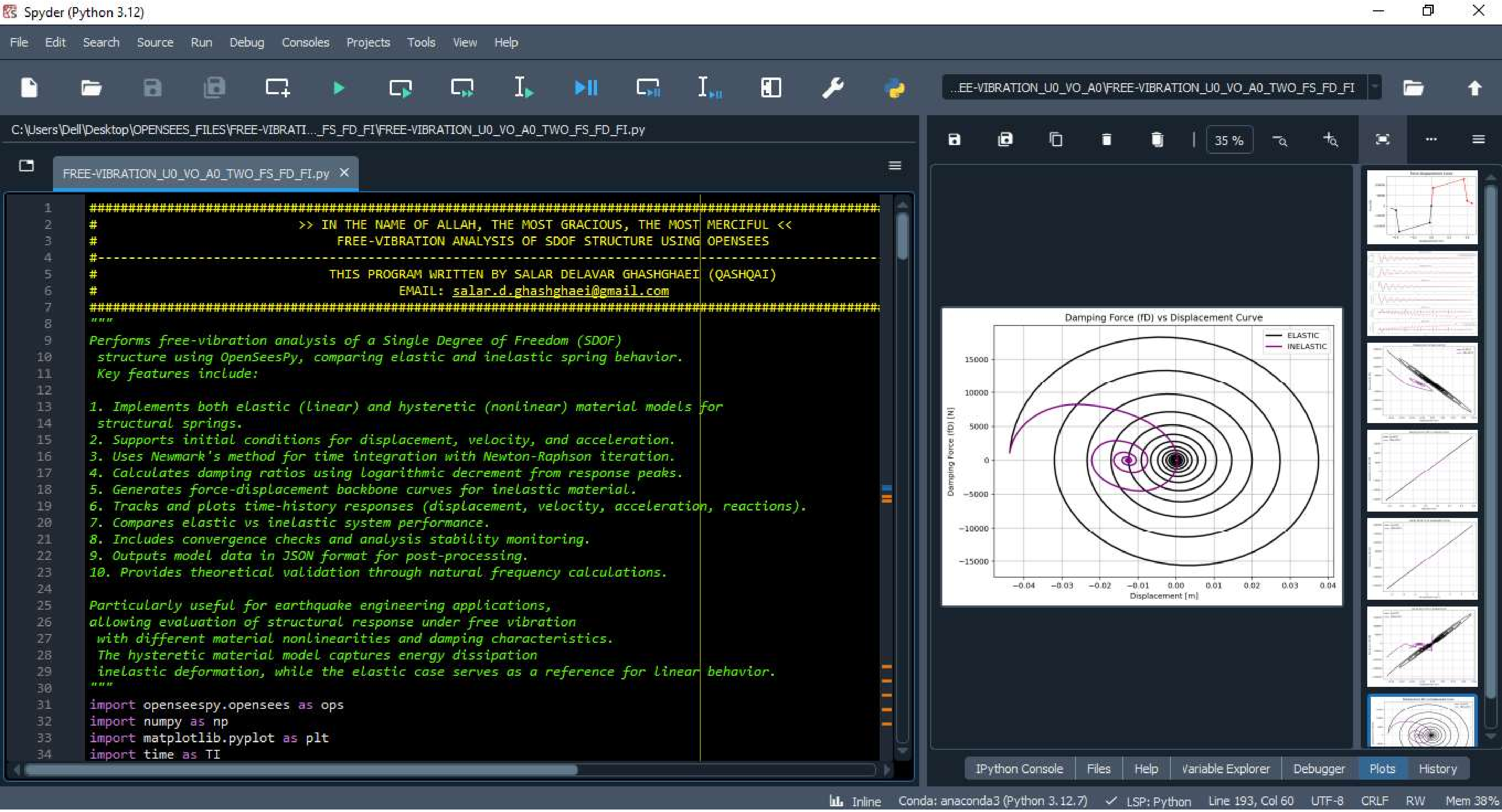
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

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
...EE-VIBRATION_U0_VO_A0\FREE-VIBRATION_U0_VO_A0_TWO_FS_FD_FI
C:\Users\Dell\Desktop\OPENSEES_FILES\FREE-VIBRATI..._FS_FD_FI\FREE-VIBRATION_U0_VO_A0_TWO_FS_FD_FI.py
FREE-VIBRATION_U0_VO_A0_TWO_FS_FD_FI.py
35 %
Damping Force (fD) vs Displacement Curve
ELASTIC
INELASTIC
Damping Force (fD) [N]
15000
10000
5000
0
−5000
−10000
−15000
−0.04
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
0.04
Displacement [m]
IPython Console Files Help Variable Explorer Debugger Plots History
Inline
Conda: anaconda3 (Python 3.12.7)
LSP: Python
Line 193, Col 60
UTF-8
CRLF
RW
Mem 38%

```
##################################################################################################################
#                              >> 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
```
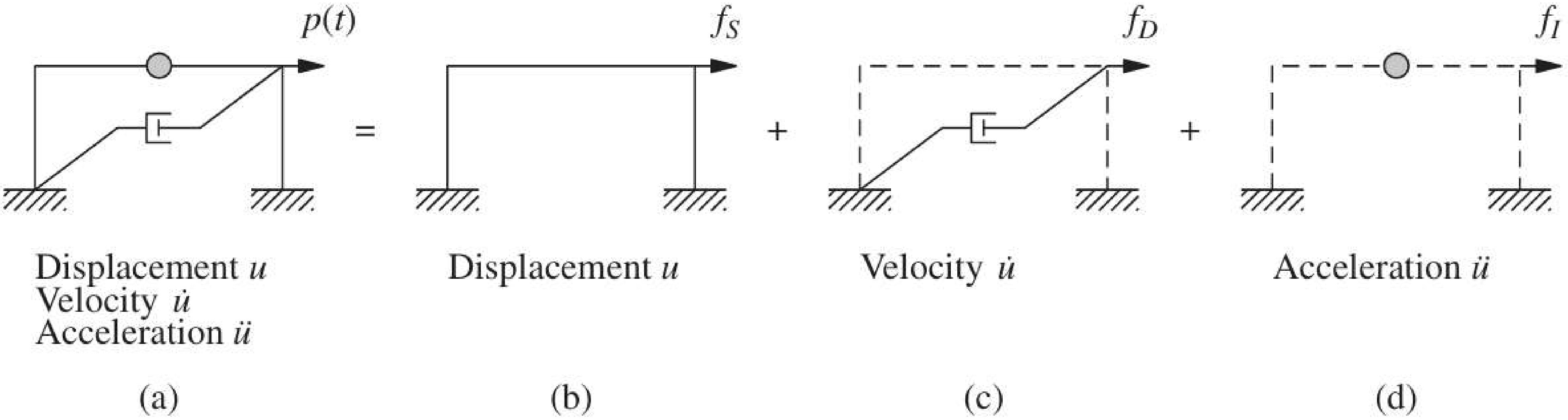
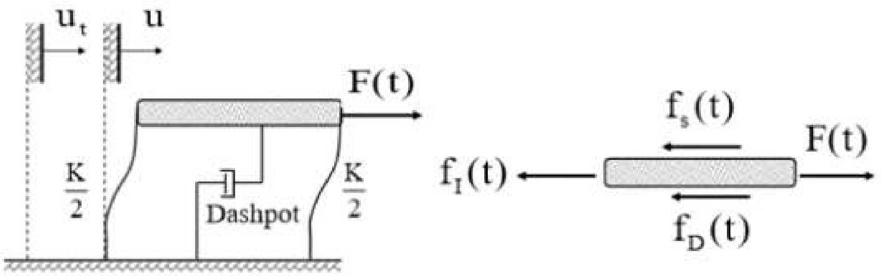
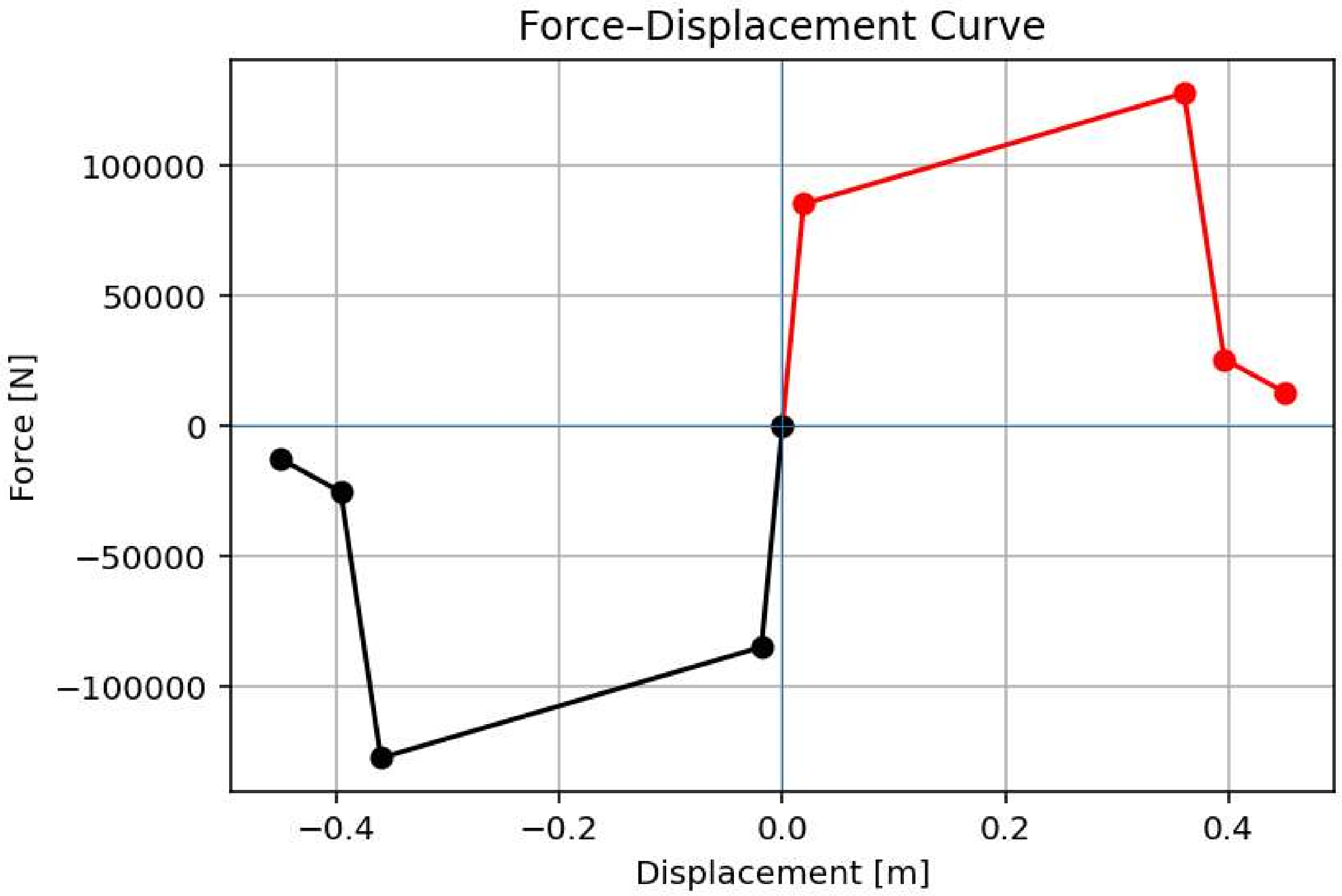



(a) System; (b) stiffness component; (c) damping component; (d) mass component.




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

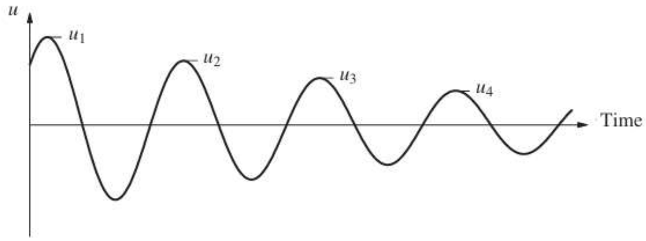
VISCOUSLY DAMPED FREE VIBRATION

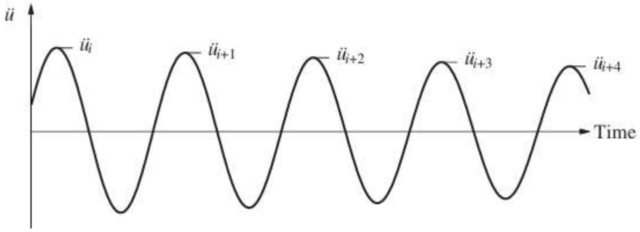
$$m\ddot{u} + c\dot{u} + ku = 0$$

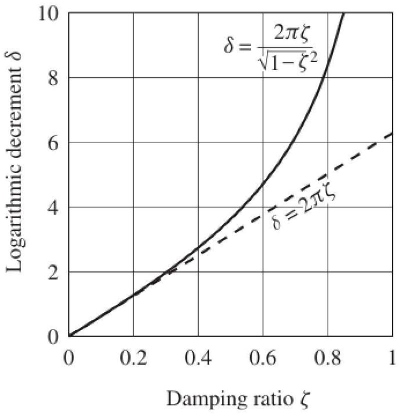
$$\ddot{u} + 2\zeta\omega_n\dot{u} + \omega_n^2 u = 0$$

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

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





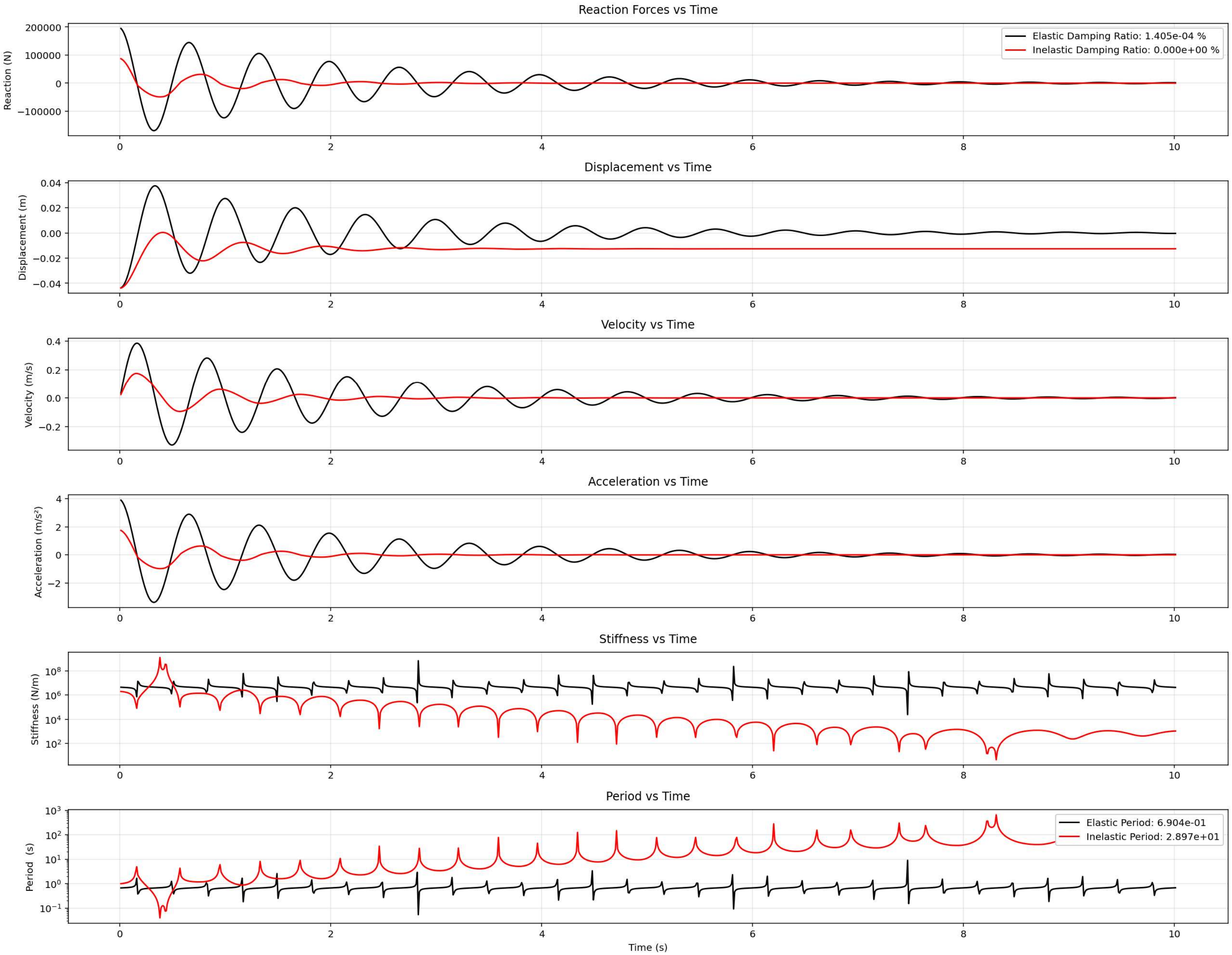


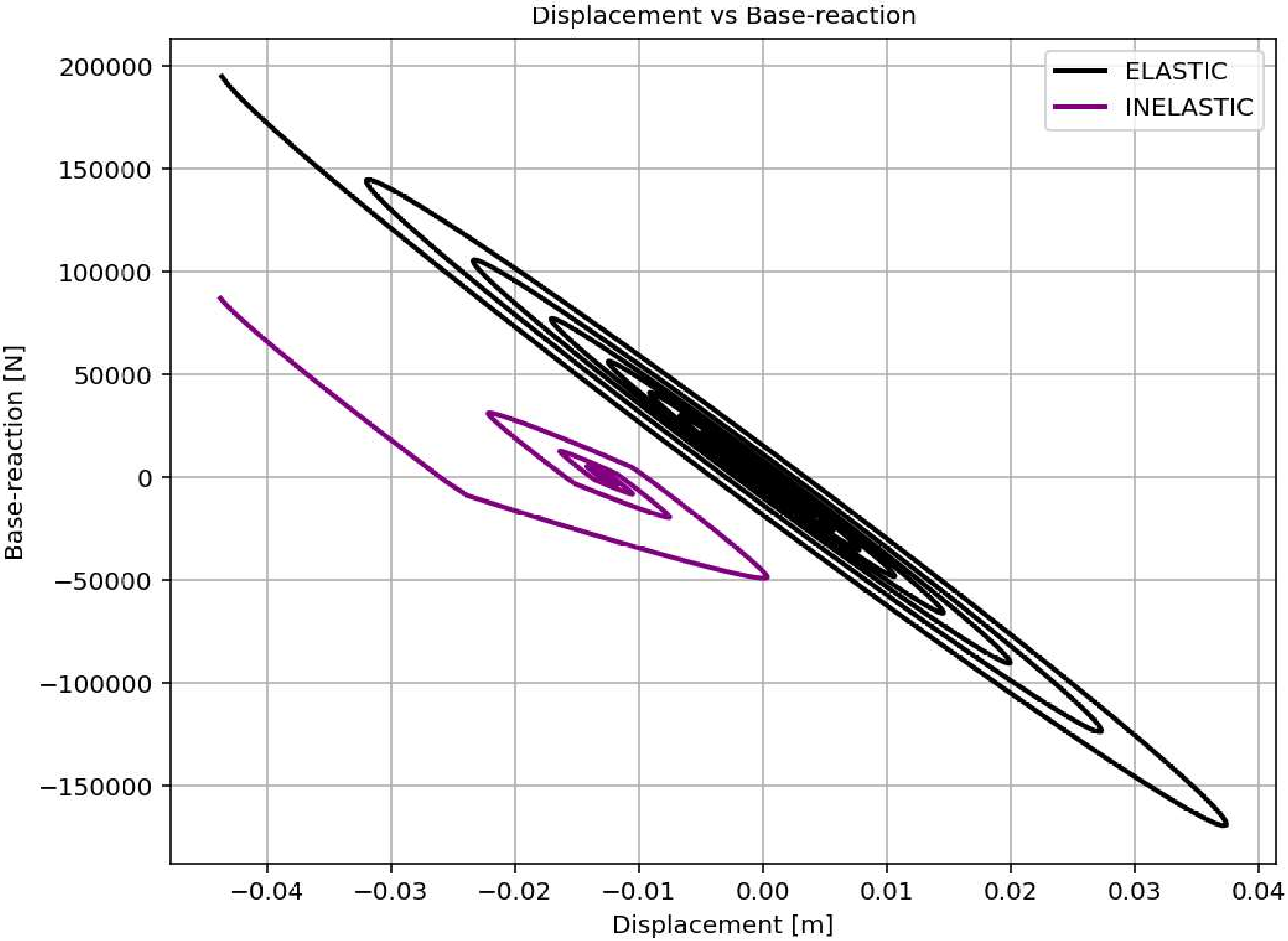
EXACT AND APPROXIMATE RELATIONS BETWEEN LOGARITHMIC DECREMENT AND DAMPING RATIO

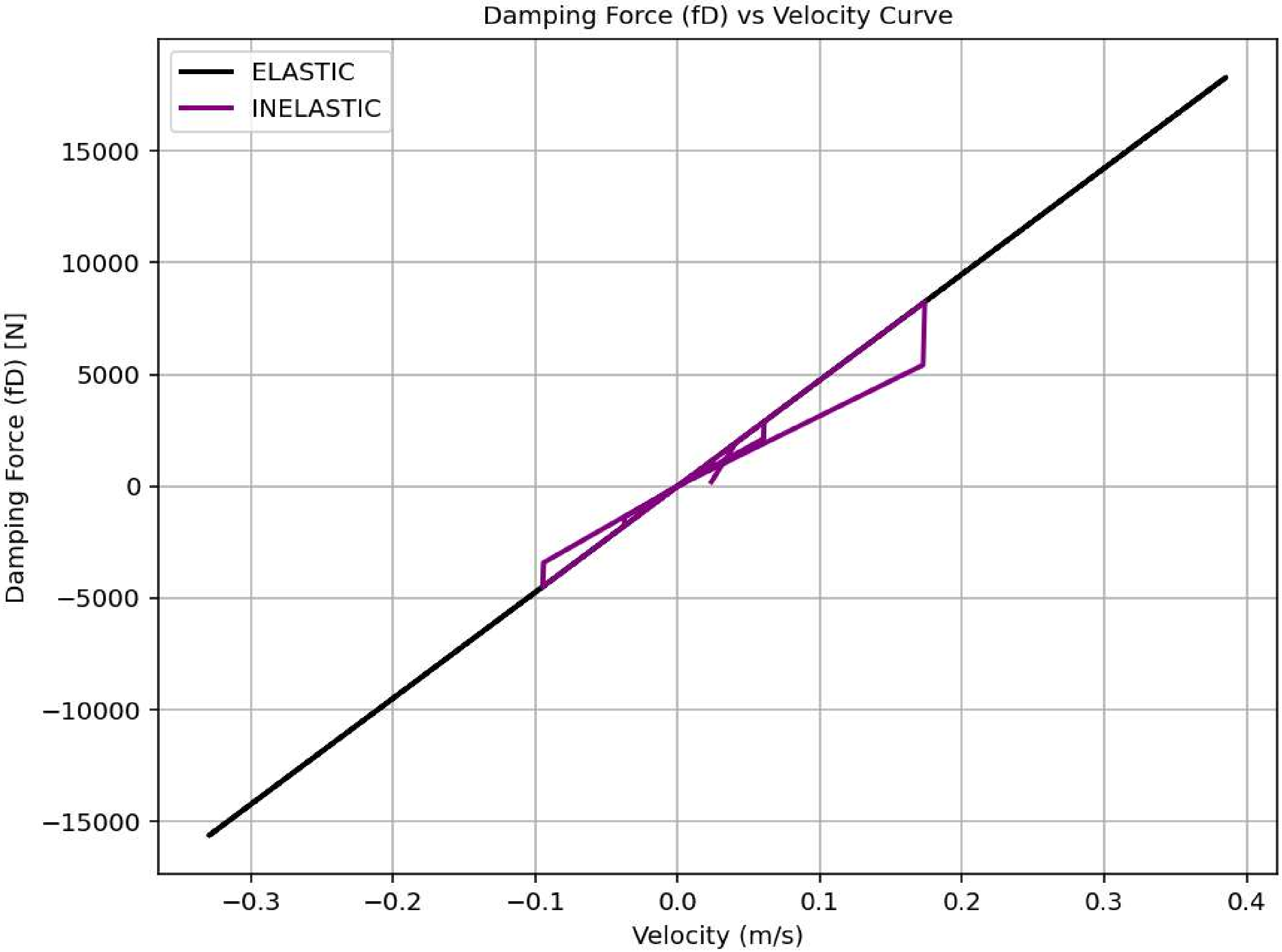
Decay of Motion

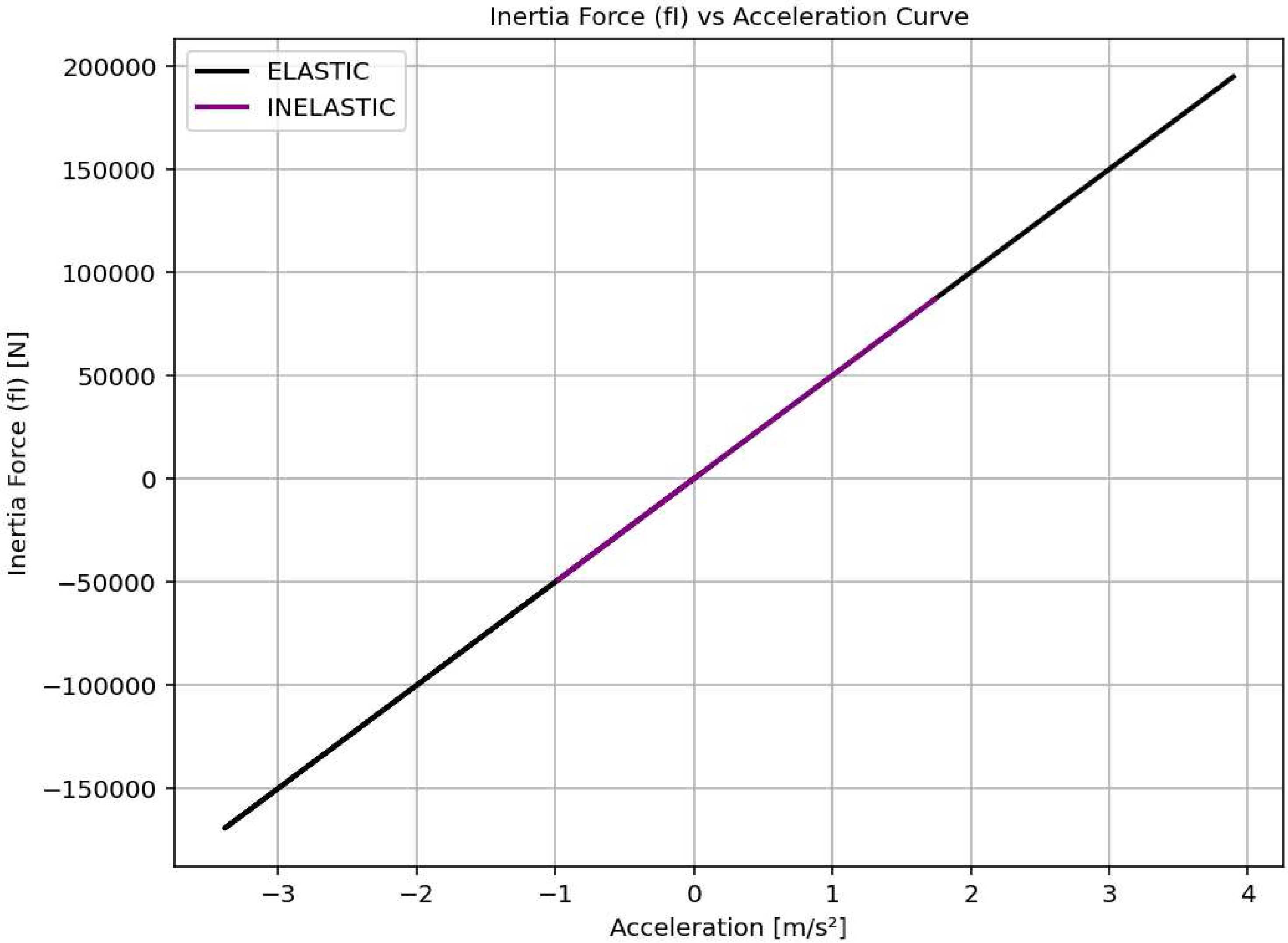
$$\delta = \ln\frac{u_i}{u_{i+1}} = 2\pi\zeta$$ **(APPROXIMATE RELATION)**

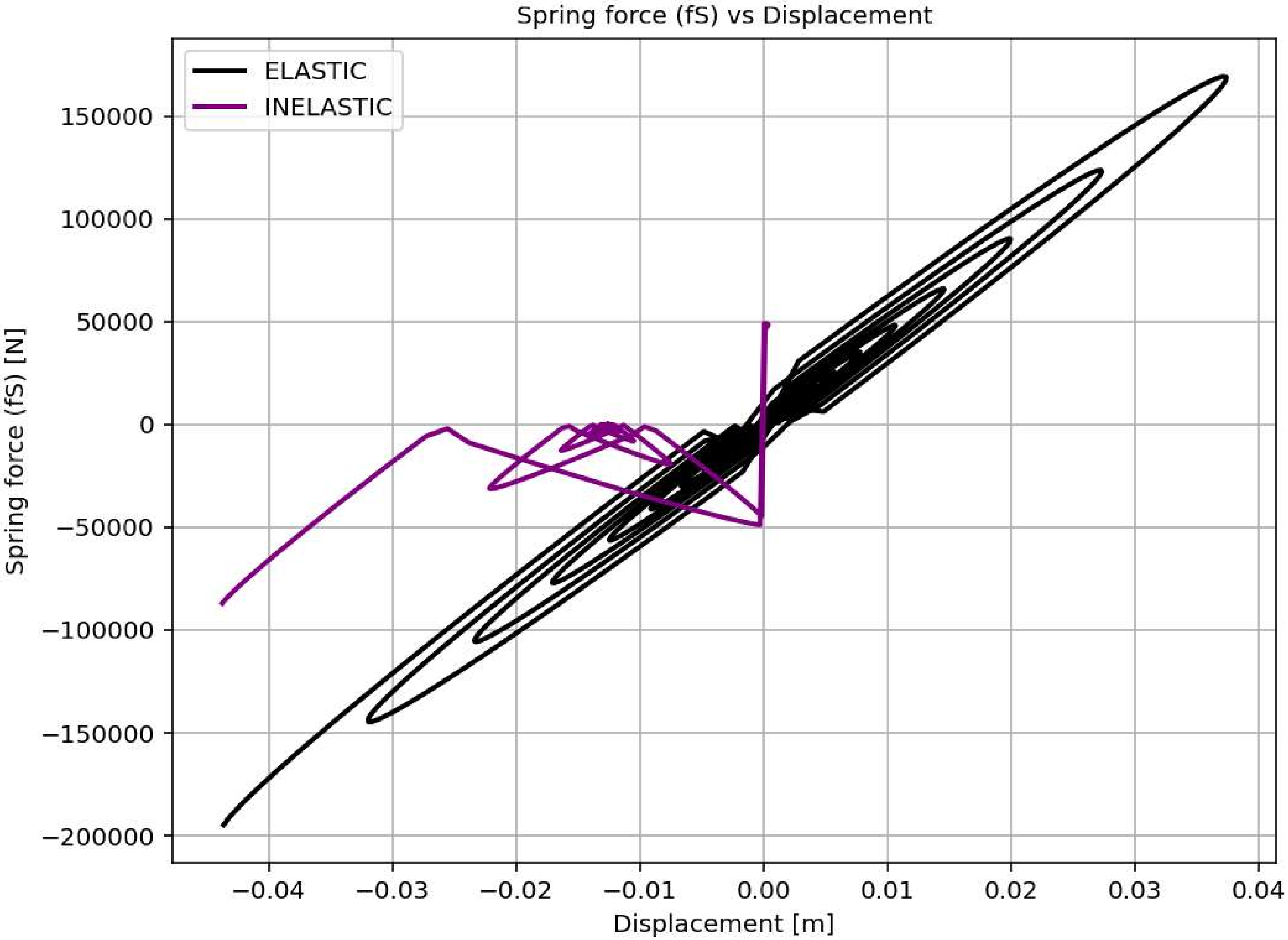
$$\delta = \ln\frac{u_i}{u_{i+1}} = \frac{2\pi\zeta}{\sqrt{1-\zeta^2}}$$ **(EXACT RELATION)**

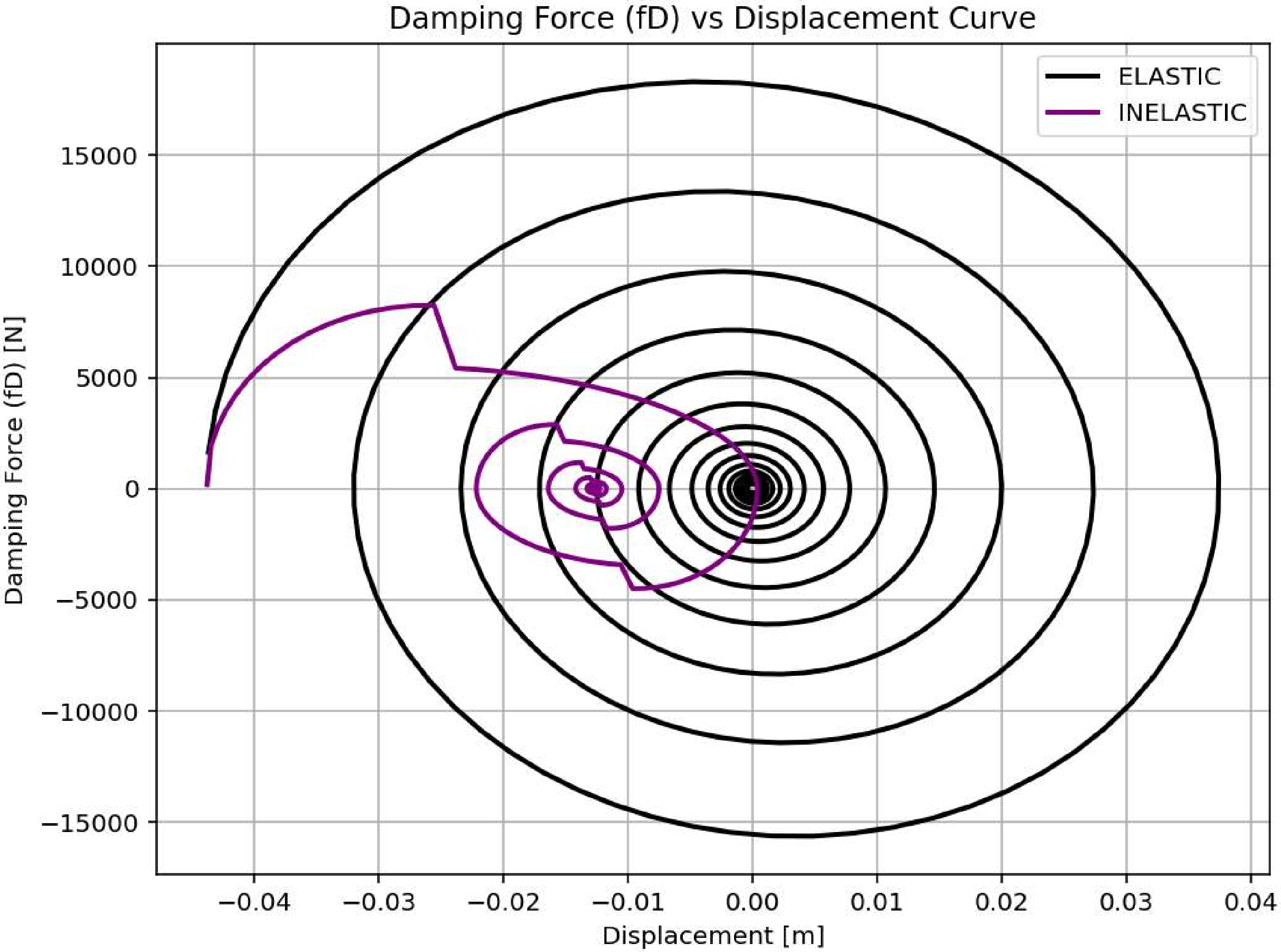

Reaction Forces vs Time
Reaction (N)
200000
100000
0
−100000
Elastic Damping Ratio: 1.405e-04 %
Inelastic Damping Ratio: 0.000e+00 %
Displacement vs Time
Displacement (m)
0.04
0.02
0.00
−0.02
−0.04
Velocity vs Time
Velocity (m/s)
0.4
0.2
0.0
−0.2
Acceleration vs Time
Acceleration (m/s²)
4
2
0
−2
Stiffness vs Time
Stiffness (N/m)
10^8
10^6
10^4
10^2
Period vs Time
Period (s)
10^3
10^2
10^1
10^0
10^{-1}
Elastic Period: 6.904e-01
Inelastic Period: 2.897e+01
0
2
4
6
8
10
Time (s)


Displacement vs Base-reaction
ELASTIC
INELASTIC
Base-reaction [N]
200000
150000
100000
50000
0
−50000
−100000
−150000
−0.04
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
0.04
Displacement [m]


Damping Force (fD) vs Velocity Curve
ELASTIC
INELASTIC
15000
10000
5000
0
−5000
−10000
−15000
Damping Force (fD) [N]
−0.3
−0.2
−0.1
0.0
0.1
0.2
0.3
0.4
Velocity (m/s)


Inertia Force (fI) vs Acceleration Curve
ELASTIC
INELASTIC
Inertia Force (fI) [N]
200000
150000
100000
50000
0
−50000
−100000
−150000
−3
−2
−1
0
1
2
3
4
Acceleration [m/s²]


Spring force (fS) vs Displacement
ELASTIC
INELASTIC
150000
100000
50000
0
−50000
−100000
−150000
−200000
Spring force (fS) [N]
−0.04
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
0.04
Displacement [m]


Damping Force (fD) vs Displacement Curve
ELASTIC
INELASTIC
Damping Force (fD) [N]
15000
10000
5000
0
−5000
−10000
−15000
−0.04
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
0.04
Displacement [m]