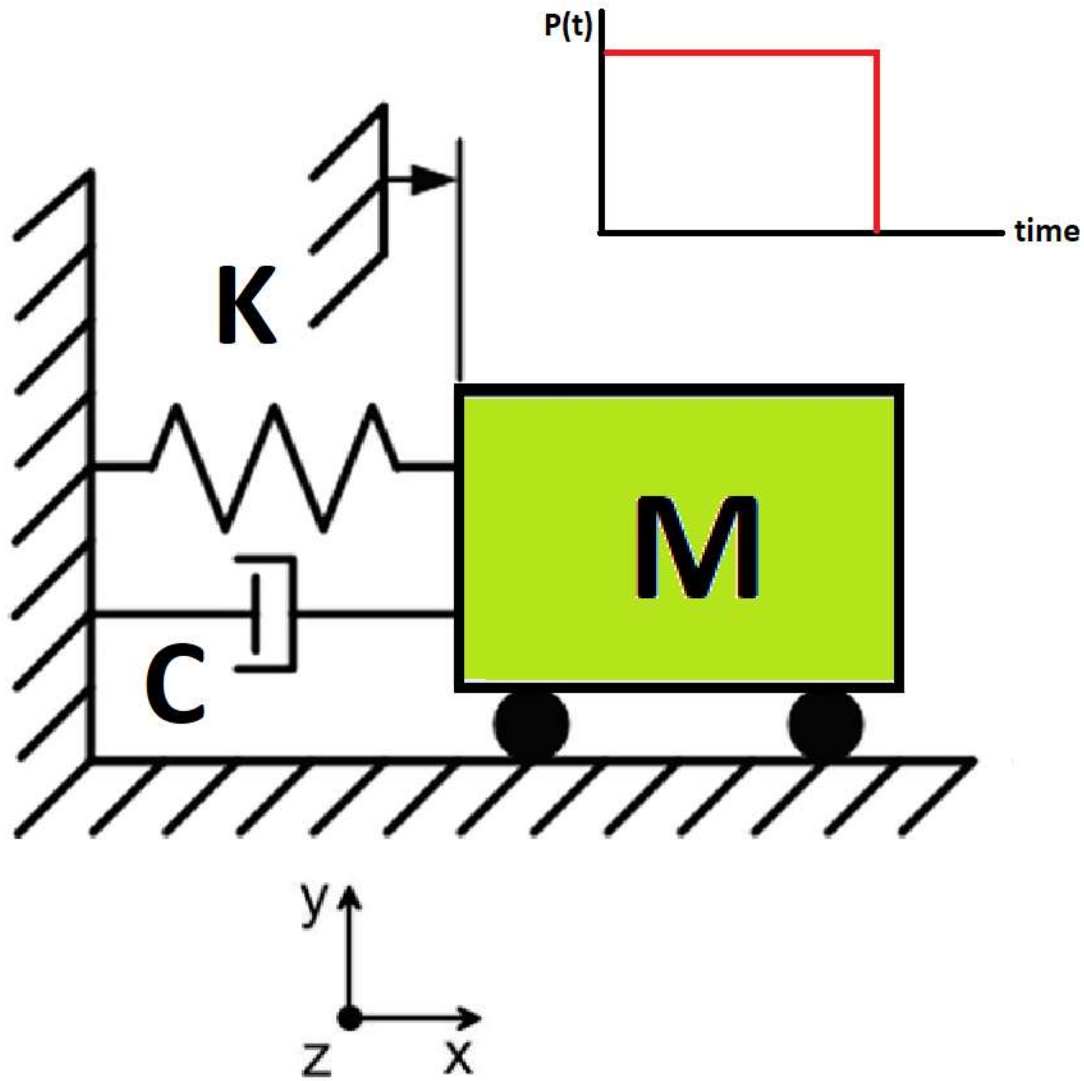
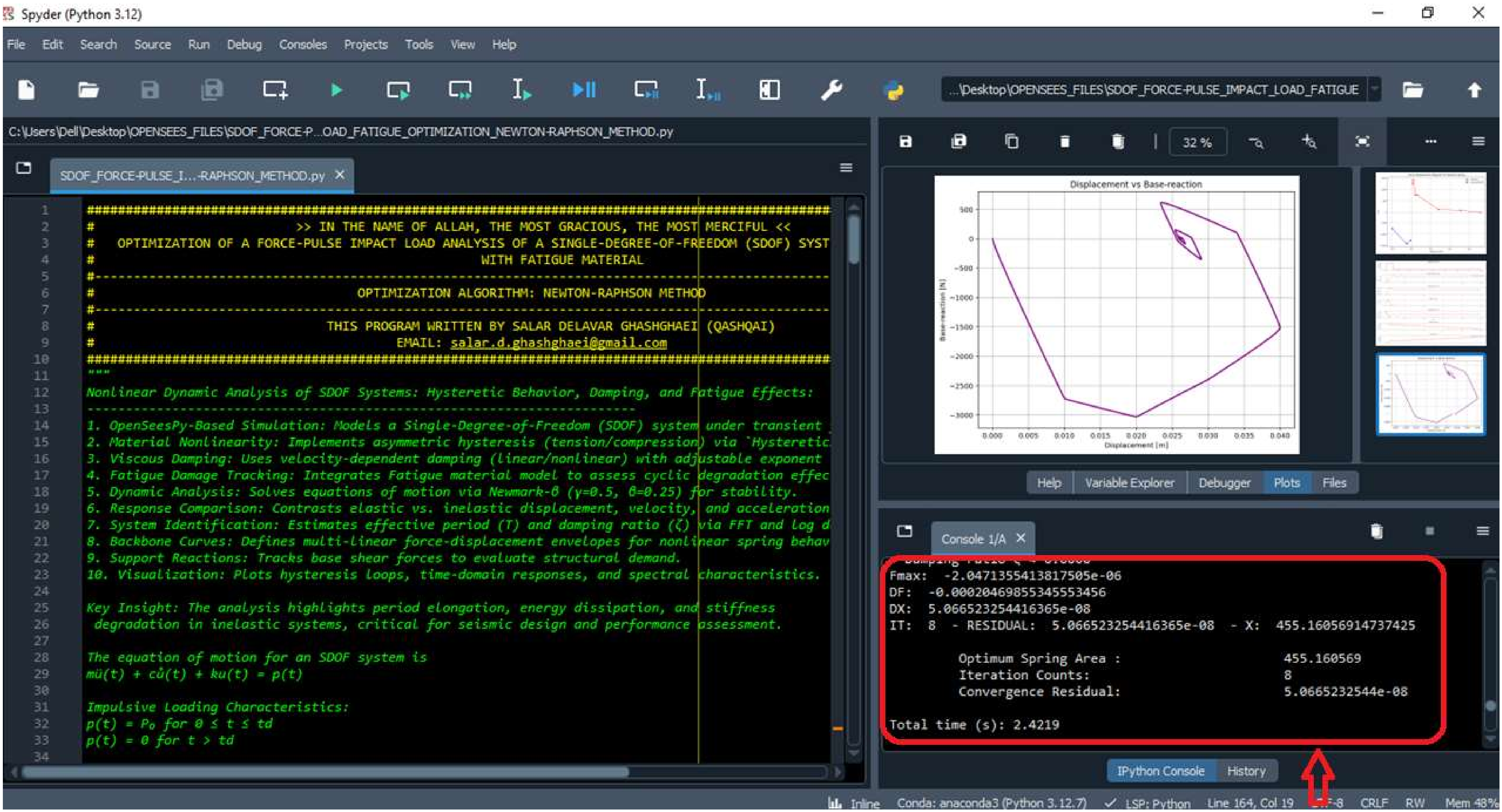
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

OPTIMIZATION OF A FORCE-PULSE IMPACT LOAD ANALYSIS OF A SINGLE-DEGREE-OF-FREEDOM (SDOF) SYSTEM USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)


P(t)
time
K
C
M
y
z
x



Spyder (Python 3.12)
File Edit Search Source Run Debug Consoles Projects Tools View Help
...\Desktop\OPENSEES_FILES\SDOF_FORCE-PULSE_IMPACT_LOAD_FATIGUE
C:\Users\Dell\Desktop\OPENSEES_FILES\SDOF_FORCE-P...OAD_FATIGUE_OPTIMIZATION_NEWTON-RAPHSON_METHOD.py
SDOF_FORCE-PULSE_I...-RAPHSON_METHOD.py
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
OPTIMIZATION OF A FORCE-PULSE IMPACT LOAD ANALYSIS OF A SINGLE-DEGREE-OF-FREEDOM (SDOF) SYST
WITH FATIGUE MATERIAL
OPTIMIZATION ALGORITHM: NEWTON-RAPHSON METHOD
THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
EMAIL: salar.d.ghashghaei@gmail.com
"""
Nonlinear Dynamic Analysis of SDOF Systems: Hysteretic Behavior, Damping, and Fatigue Effects:
1. OpenSeesPy-Based Simulation: Models a Single-Degree-of-Freedom (SDOF) system under transient
2. Material Nonlinearity: Implements asymmetric hysteresis (tension/compression) via `Hysteretic
3. Viscous Damping: Uses velocity-dependent damping (linear/nonlinear) with adjustable exponent
4. Fatigue Damage Tracking: Integrates Fatigue material model to assess cyclic degradation effec
5. Dynamic Analysis: Solves equations of motion via Newmark-β (γ=0.5, β=0.25) for stability.
6. Response Comparison: Contrasts elastic vs. inelastic displacement, velocity, and acceleration
7. System Identification: Estimates effective period (T) and damping ratio (ζ) via FFT and log d
8. Backbone Curves: Defines multi-linear force-displacement envelopes for nonlinear spring behav
9. Support Reactions: Tracks base shear forces to evaluate structural demand.
10. Visualization: Plots hysteresis loops, time-domain responses, and spectral characteristics.
Key Insight: The analysis highlights period elongation, energy dissipation, and stiffness
degradation in inelastic systems, critical for seismic design and performance assessment.
The equation of motion for an SDOF system is
mü(t) + cu̇(t) + ku(t) = p(t)
Impulsive Loading Characteristics:
p(t) = P₀ for 0 ≤ t ≤ td
p(t) = 0 for t > td
32 %
Displacement vs Base-reaction
Base-reaction [N]
Displacement [m]
Help Variable Explorer Debugger Plots Files
Console 1/A
Fmax: -2.0471355413817505e-06
DF: -0.00020469855345553456
DX: 5.066523254416365e-08
IT: 8 - RESIDUAL: 5.066523254416365e-08 - X: 455.16056914737425
Optimum Spring Area : 455.160569
Iteration Counts: 8
Convergence Residual: 5.0665232544e-08
Total time (s): 2.4219
IPython Console History
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 164, Col 19 CRLF RW Mem 48%

IT: 6 - RESIDUAL: 1.2674278050826335 - X: 455.15496531261266

Period T ≈ 3.847 s
Damping ratio ζ ≈ 0.0000
SUPPLY: 0.04000115
F: 1.147050329011745e-06
Period T ≈ 3.847 s
Damping ratio ζ ≈ 0.0000
Fmin: 3.1938197959102688e-06
Period T ≈ 3.847 s
Damping ratio ζ ≈ 0.0000
Fmax: -8.999481584462399e-07
DF: -0.00020468839771782543
DX: -0.0056038854268282414
IT: 7 - RESIDUAL: 0.0056038854268282414 - X: 455.16056919803947

Period T ≈ 3.847 s
Damping ratio ζ ≈ 0.0000
SUPPLY: 0.04000000
F: -1.0371099812278572e-11
Period T ≈ 3.847 s
Damping ratio ζ ≈ 0.0000
Fmin: 2.0468355277289407e-06
Period T ≈ 3.847 s
Damping ratio ζ ≈ 0.0000
Fmax: -2.0471355413817505e-06
DF: -0.00020469855345553456
DX: 5.066523254416365e-08
IT: 8 - RESIDUAL: 5.066523254416365e-08 - X: 455.16056914737425

Optimum Spring Area :   455.160569
Iteration Counts: 8
Convergence Residual: 5.0665232544e-08
Total time (s): 2.4219

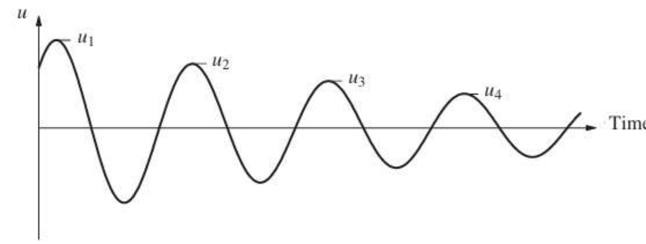
VISCOUSLY DAMPED FREE VIBRATION

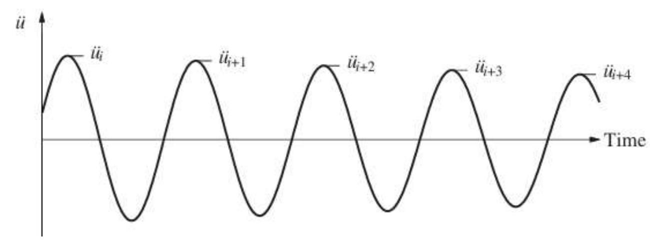
$$m\ddot{u} + c\dot{u} + ku = 0$$

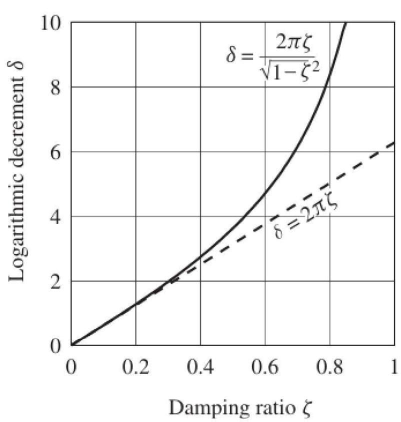
$$\ddot{u} + 2\zeta\omega_n\dot{u} + \omega_n^2 u = 0$$

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

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





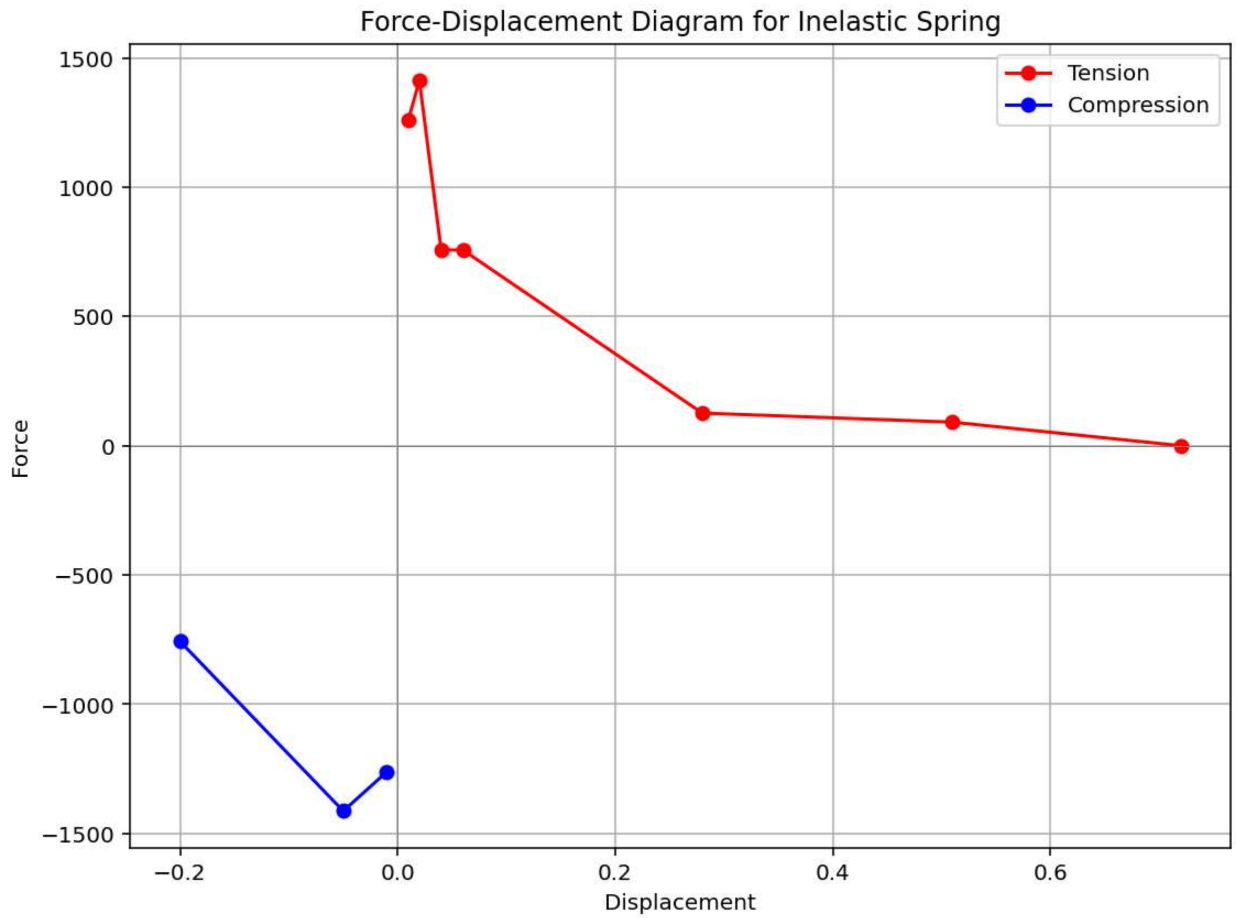


Decay of Motion

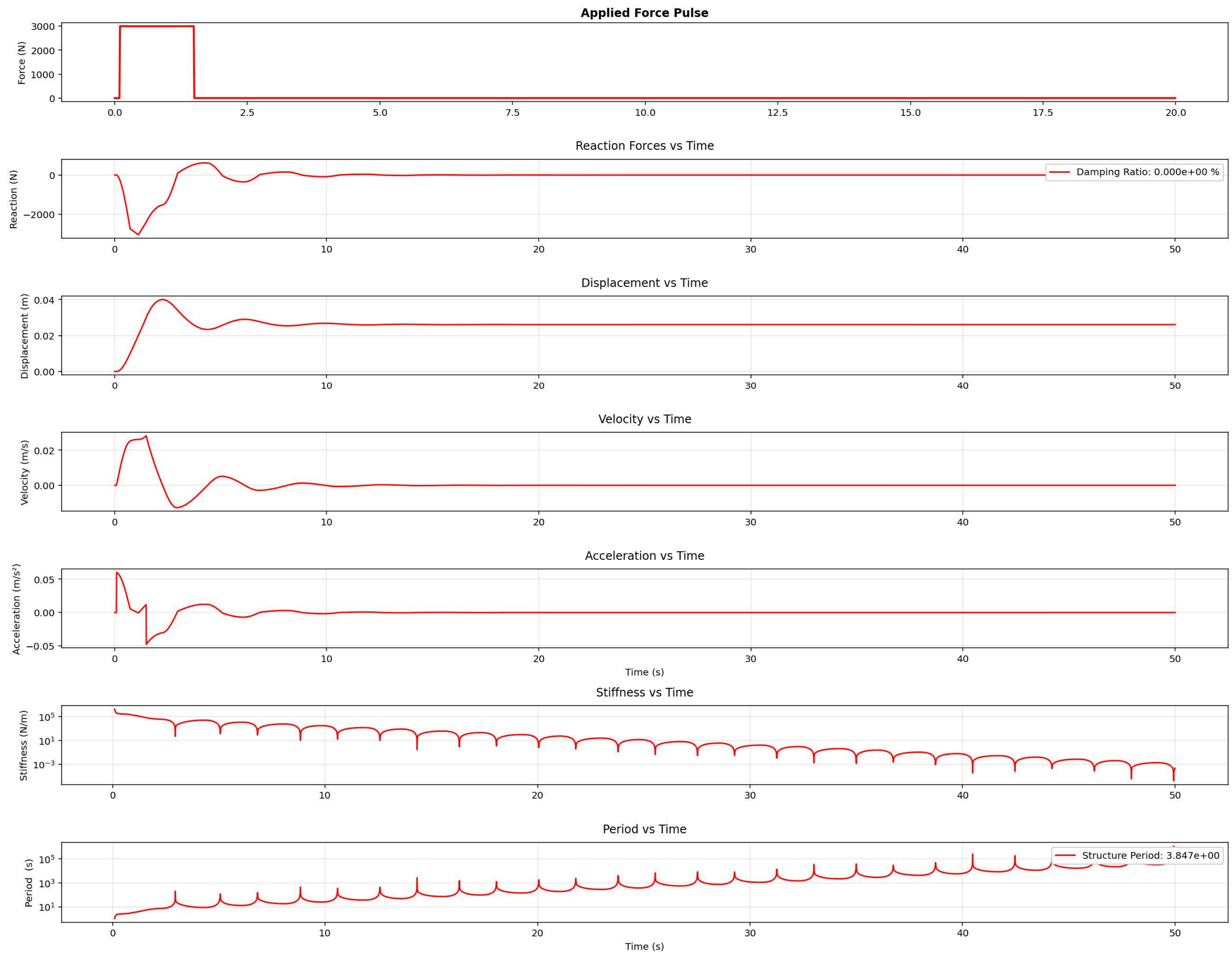
$$\delta = \ln\frac{u_i}{u_{i+1}} = 2\pi\zeta$$ **(APPROXIMATE RELATION)**

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

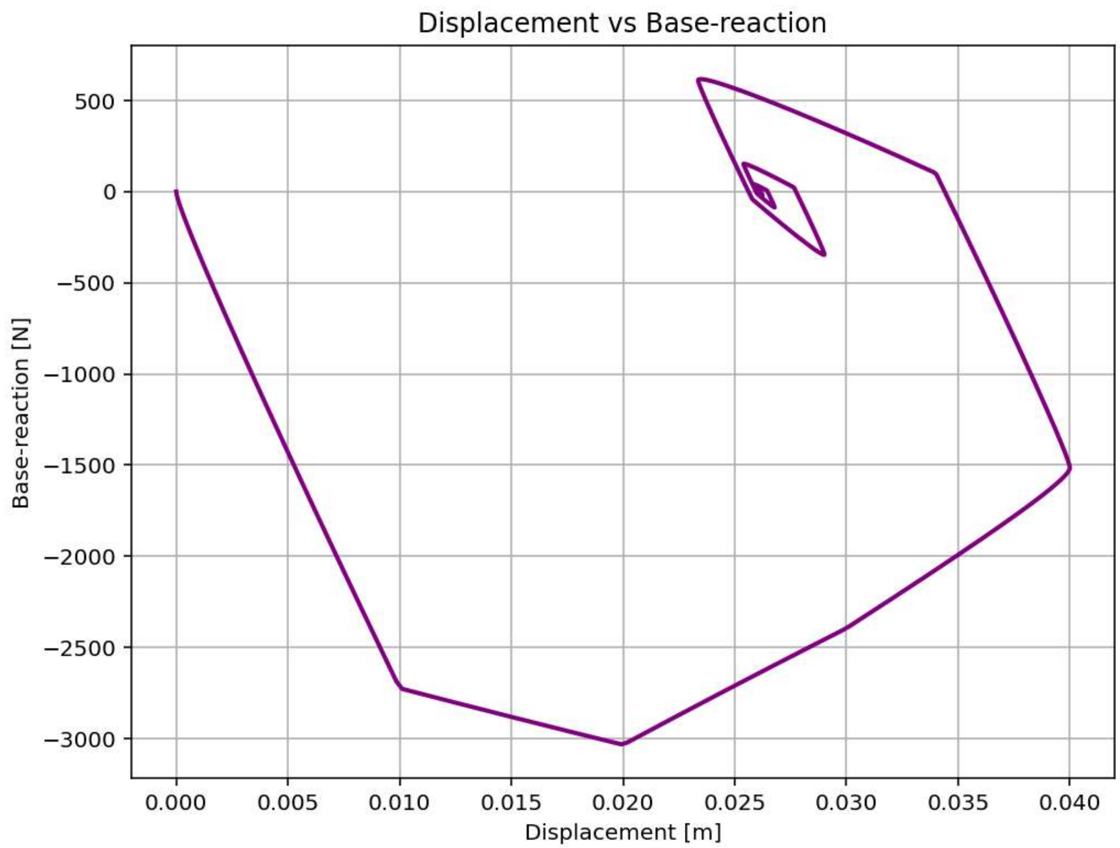
EXACT AND APPROXIMATE RELATIONS BETWEEN LOGARITHMIC DECREMENT AND DAMPING RATIO



Force-Displacement Diagram for Inelastic Spring
Tension
Compression
Force
Displacement
1500
1000
500
0
−500
−1000
−1500
−0.2
0.0
0.2
0.4
0.6



Applied Force Pulse
Force (N)
Reaction Forces vs Time
Reaction (N)
Damping Ratio: 0.000e+00 %
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: 3.847e+00
Time (s)



Displacement vs Base-reaction
500
0
−500
−1000
−1500
−2000
−2500
−3000
Base-reaction [N]
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
Displacement [m]