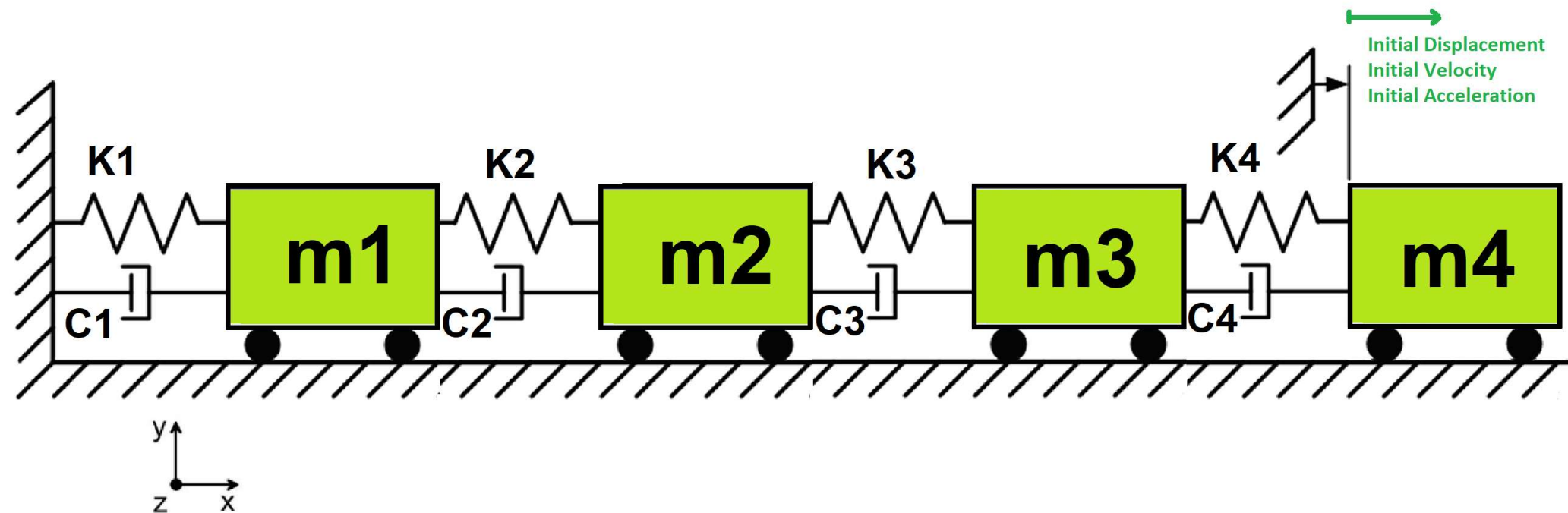


>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

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

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)



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#####
#                               >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
# COMPARATIVE FREE-VIBRATION AN PUSHOVER ANALYSIS OF A MDOF STRUCTURE: ELASTIC VS INELASTIC RESPONSE USING C
#-----
#                               THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
#                               EMAIL: salar.d.ghashghaei@gmail.com
#####
"""
Performs free-vibration and pushover 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
```

...FILES\FREE-VIBRATION\_U0\_VO\_A0\FREE-VIBRATION\_&\_PUSHOVER\_MDF

22 %

Help Variable Explorer Debugger Plots Files

Console 1/A

0.000e+00	0.0000	inf	0.0000
9.862e+02	31.4031	0.2001	4.9980
1.714e+03	41.4039	0.1518	6.5896
7.792e+03	88.2714	0.0712	14.0488

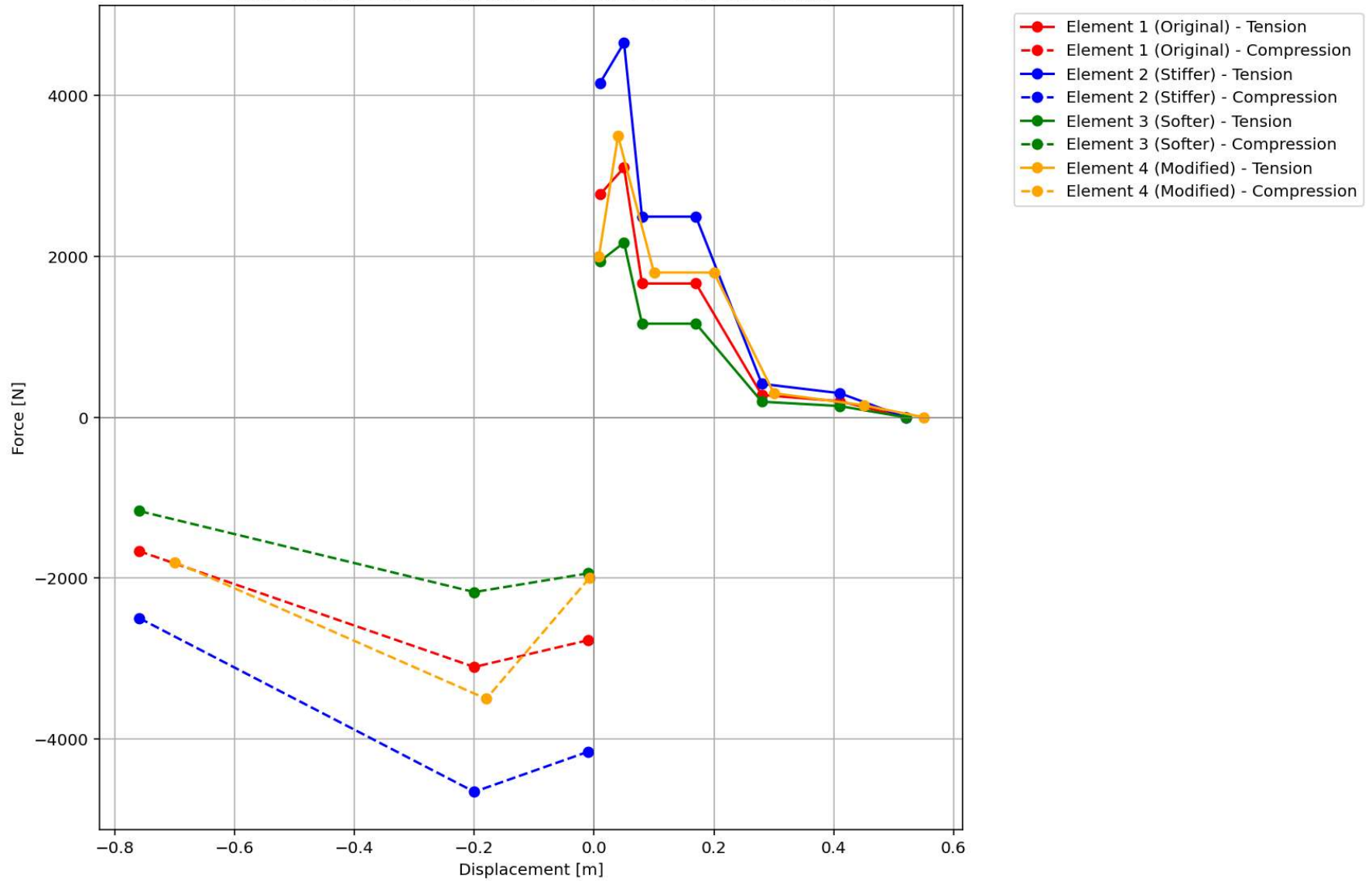
1000 0.09456982097593604 -1168.4557642175732

Total Analysis Durations (s): 4.0938

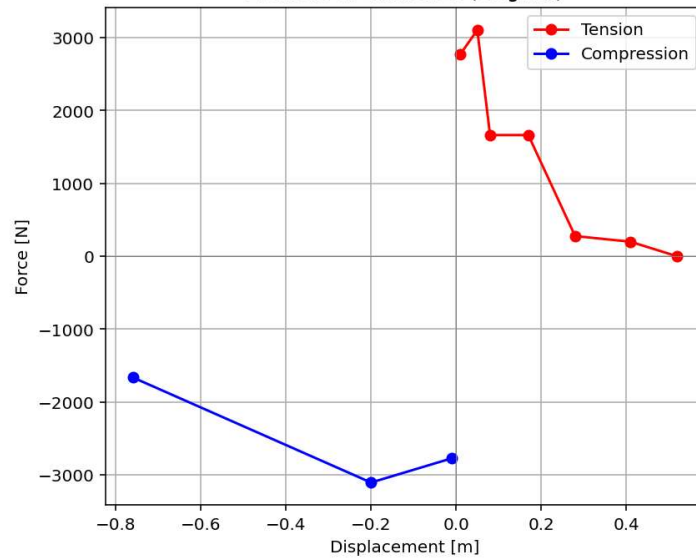
IPython Console History

Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 42, Col 35 UTF-8 CRLF RW Mem 39%

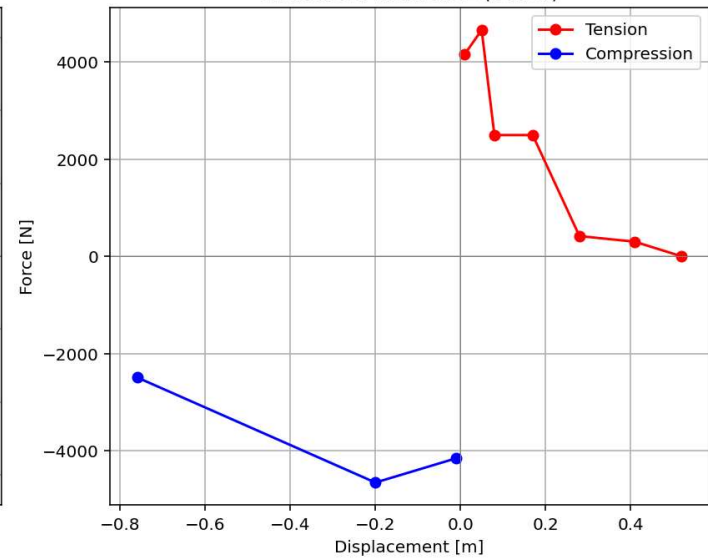
## Force-Displacement Diagrams for 4 Different Inelastic Springs



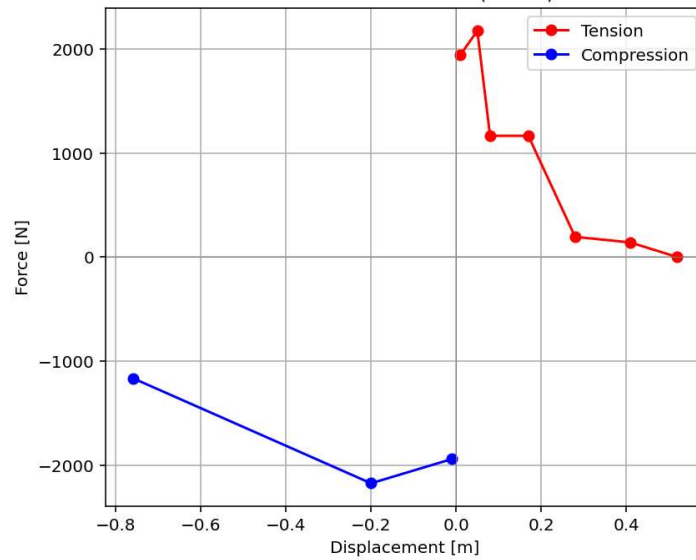
Element 1: Element 1 (Original)



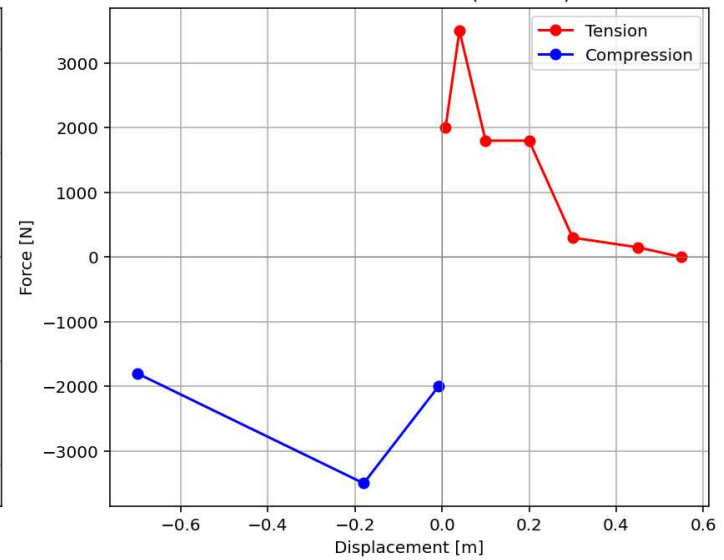
Element 2: Element 2 (Stiffer)



Element 3: Element 3 (Softer)



Element 4: Element 4 (Modified)



# FREE-VIBRATION ANALYSIS

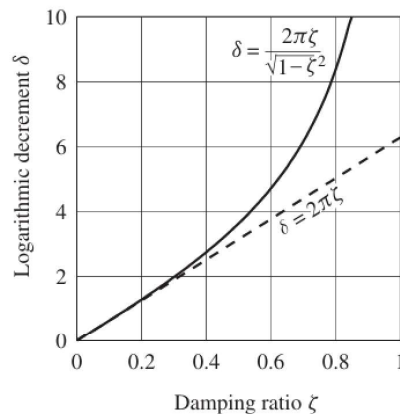
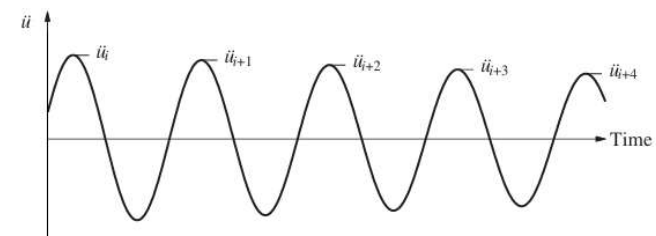
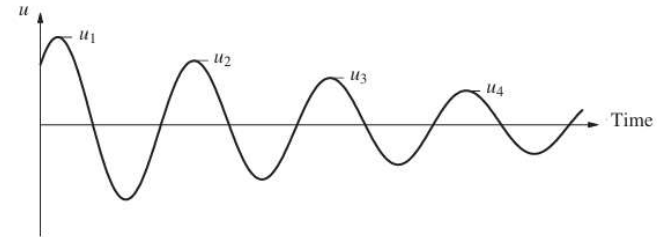
## VISCOUSLY DAMPED FREE VIBRATION

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

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

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

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

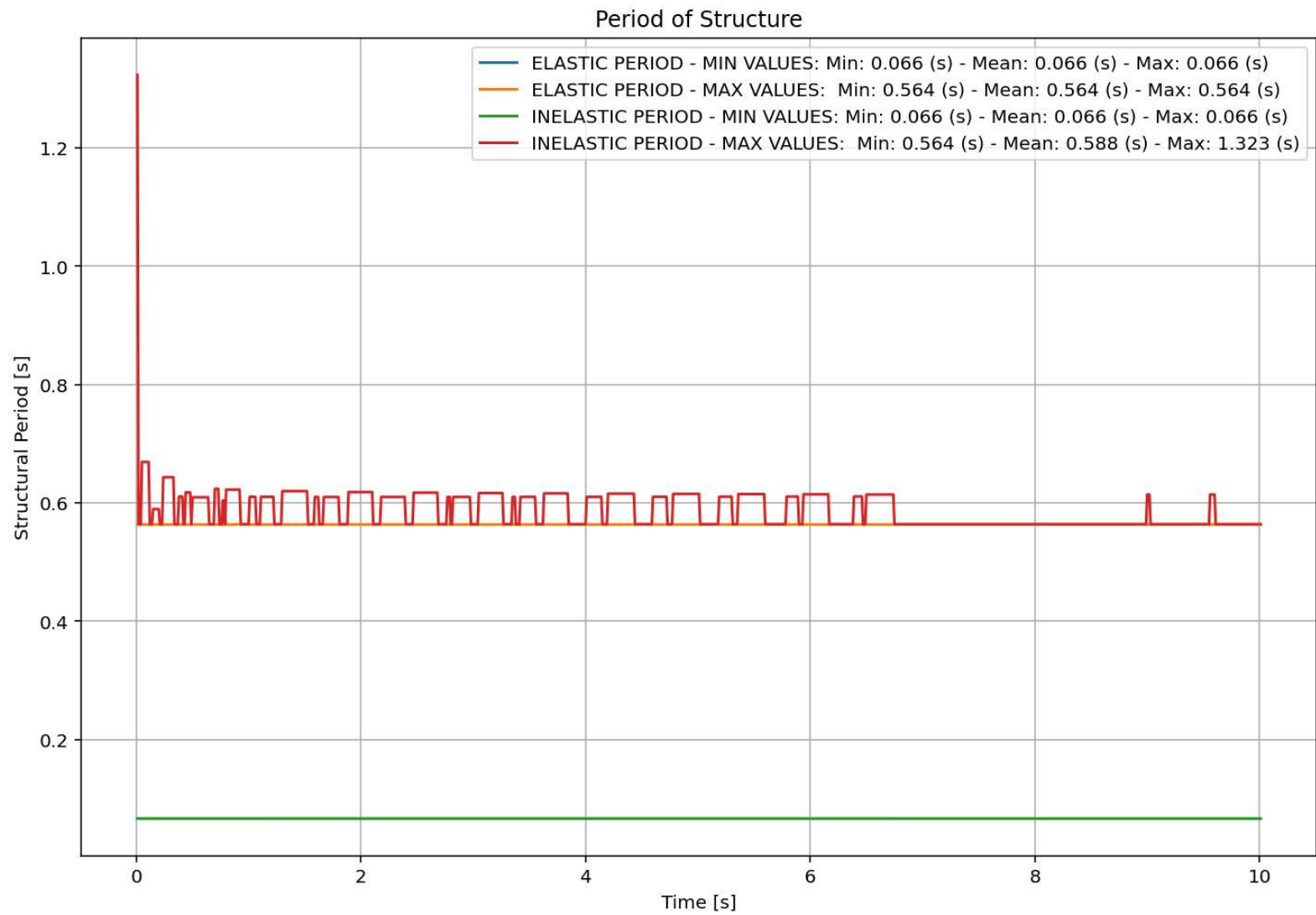


### Decay of Motion

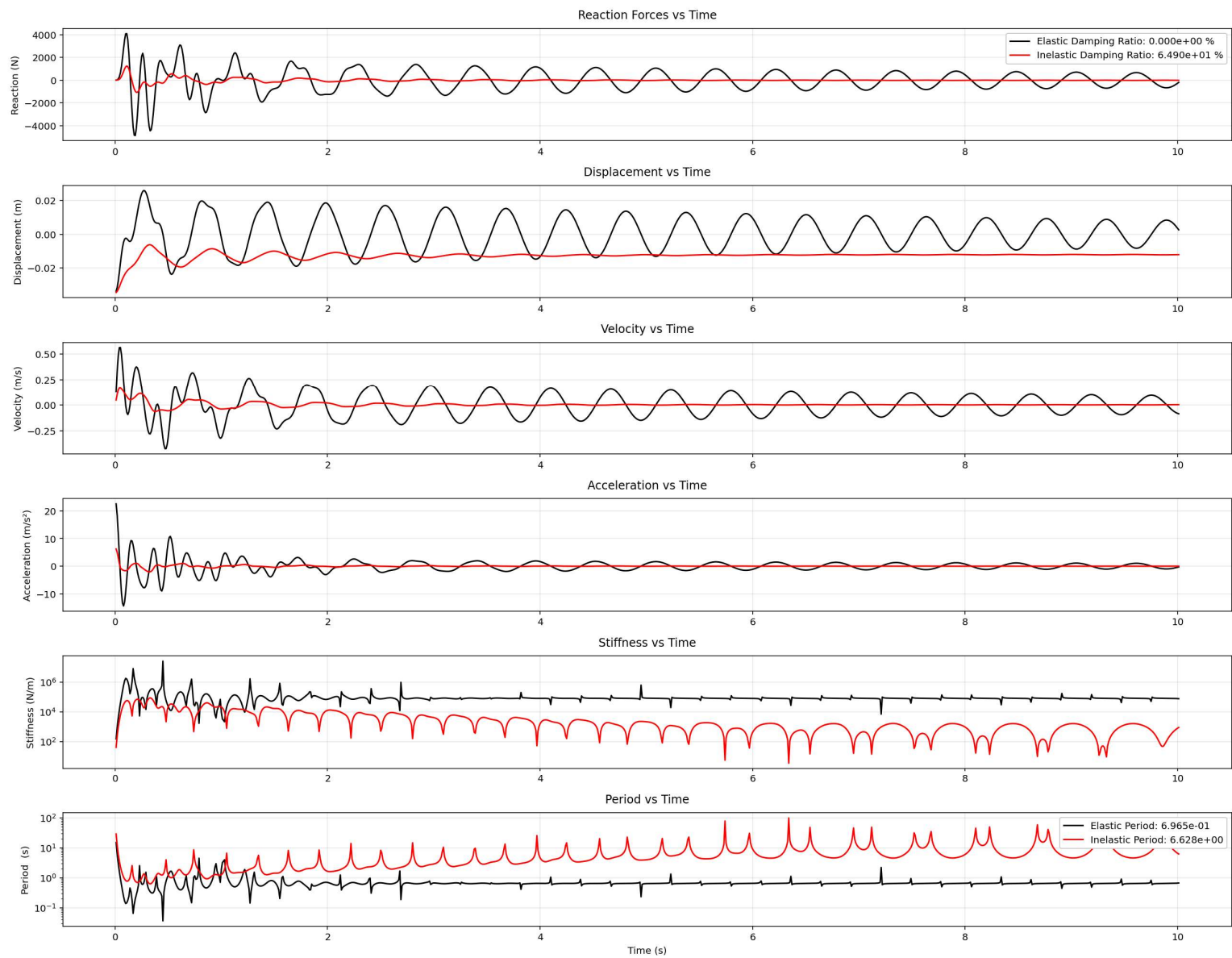
$$\delta = \ln \frac{u_i}{u_{i+1}} = 2\pi\zeta \quad (\text{APPROXIMATE RELATION})$$

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

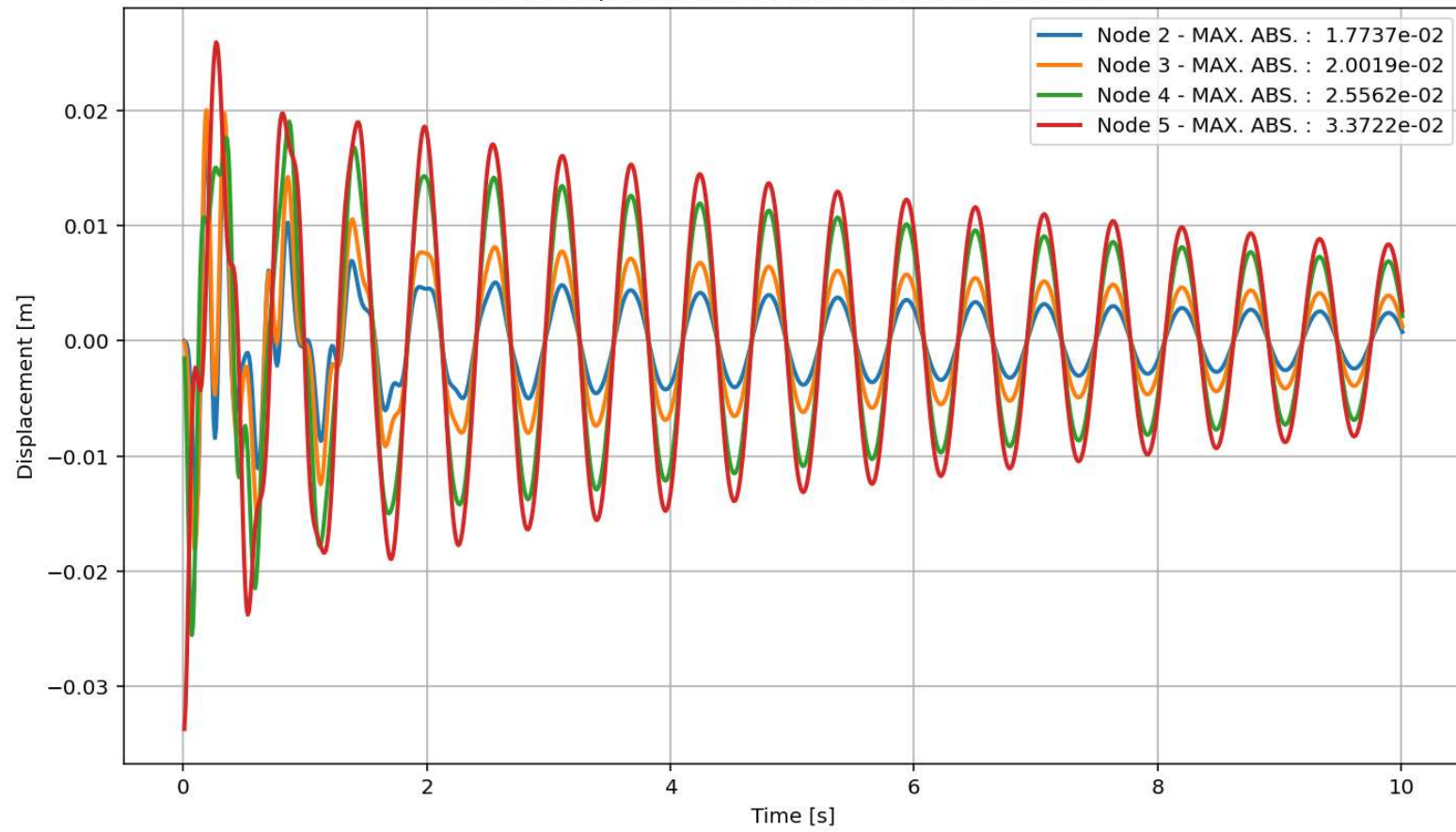
EXACT AND APPROXIMATE RELATIONS BETWEEN LOGARITHMIC DECREMENT AND DAMPING RATIO

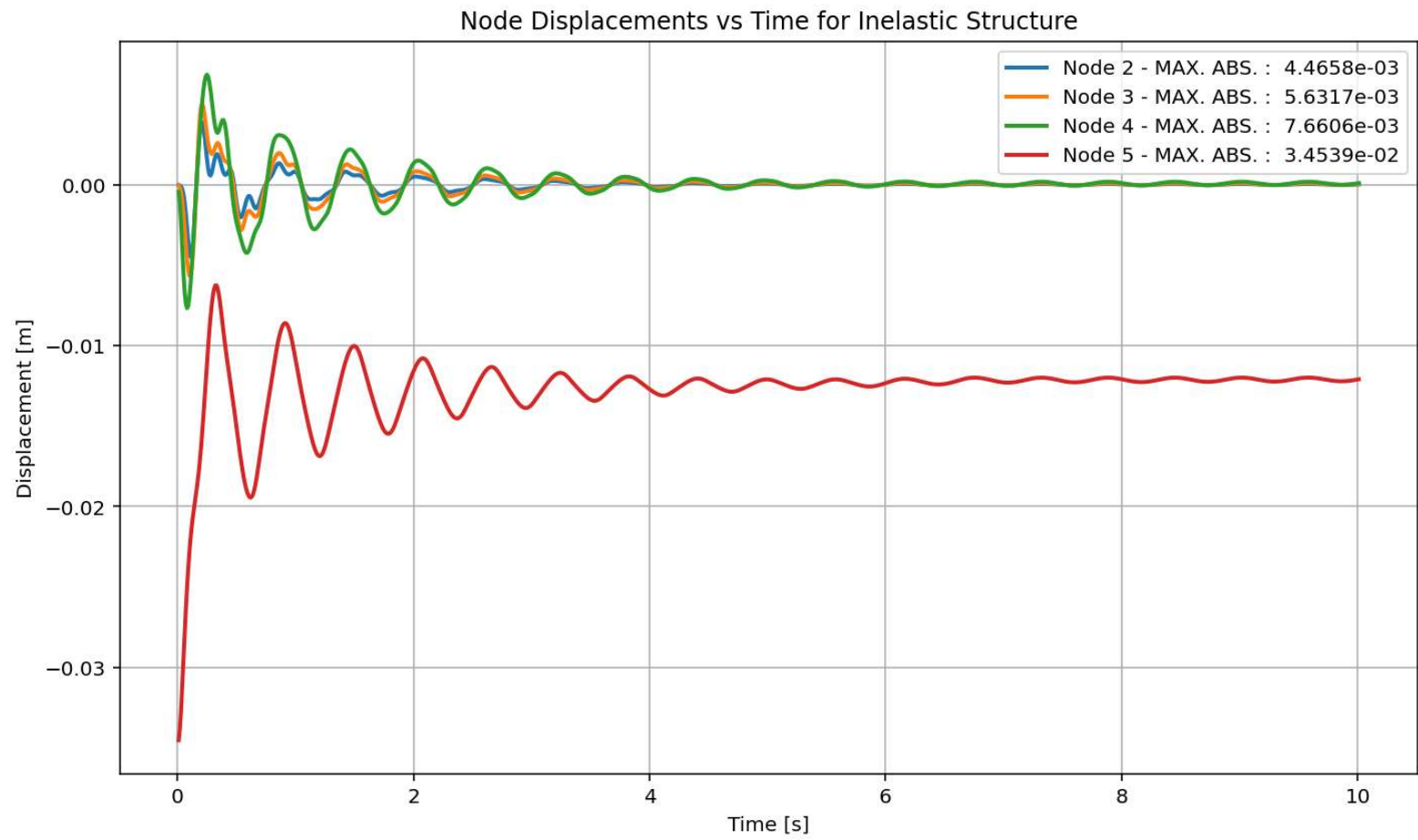


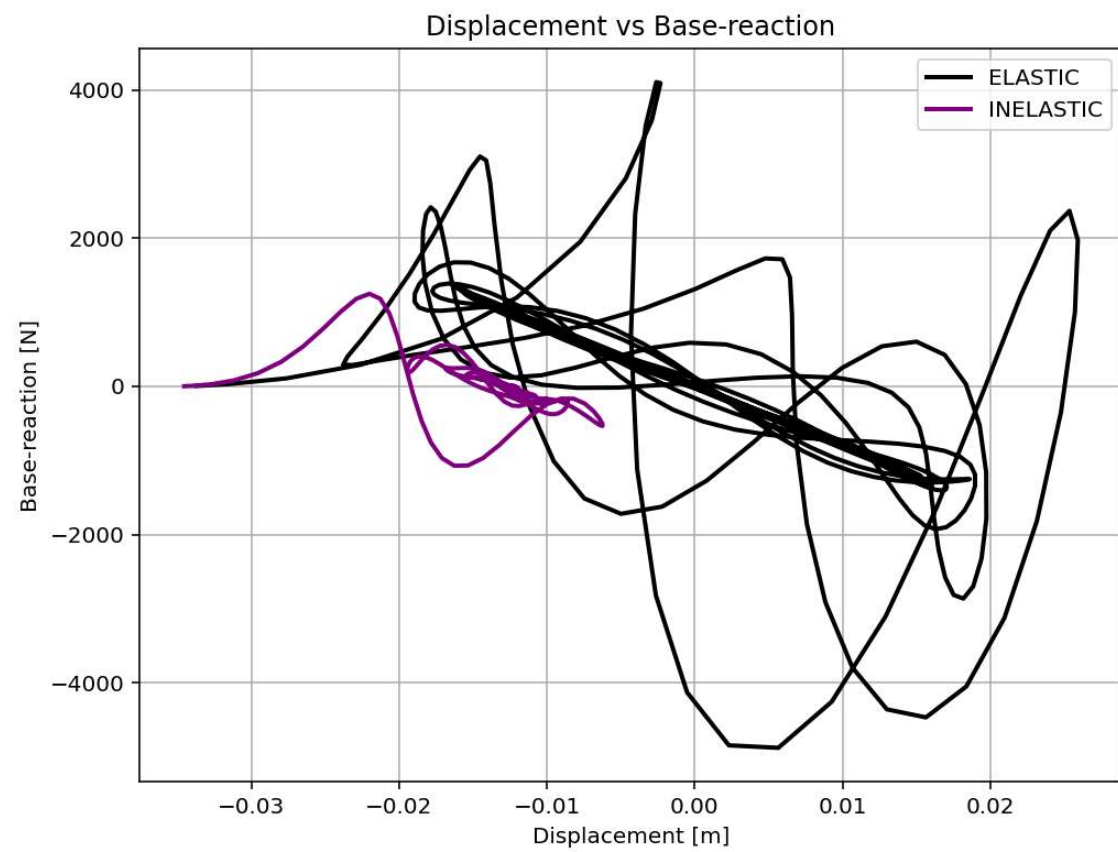




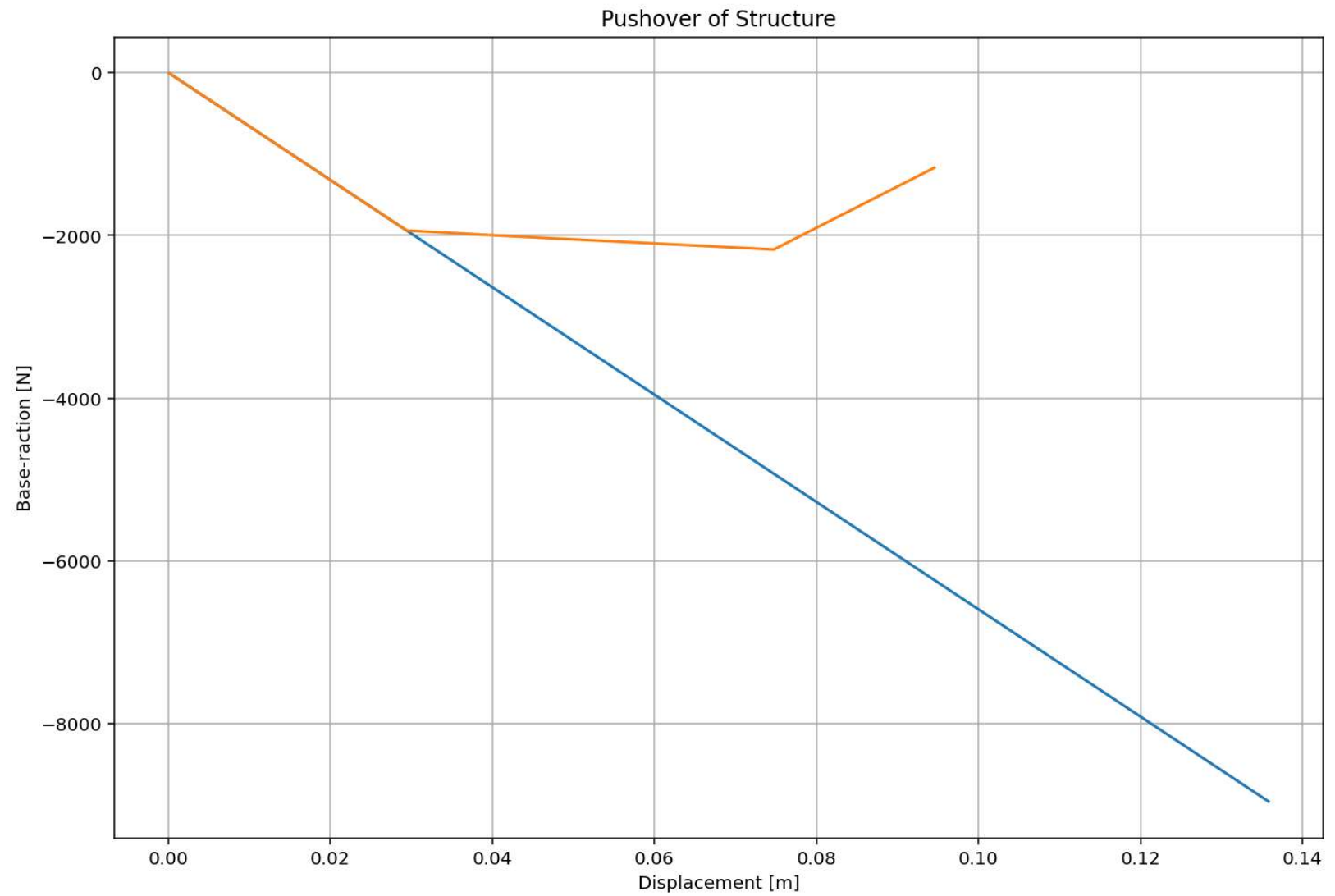
Node Displacements vs Time for Elastic Structure

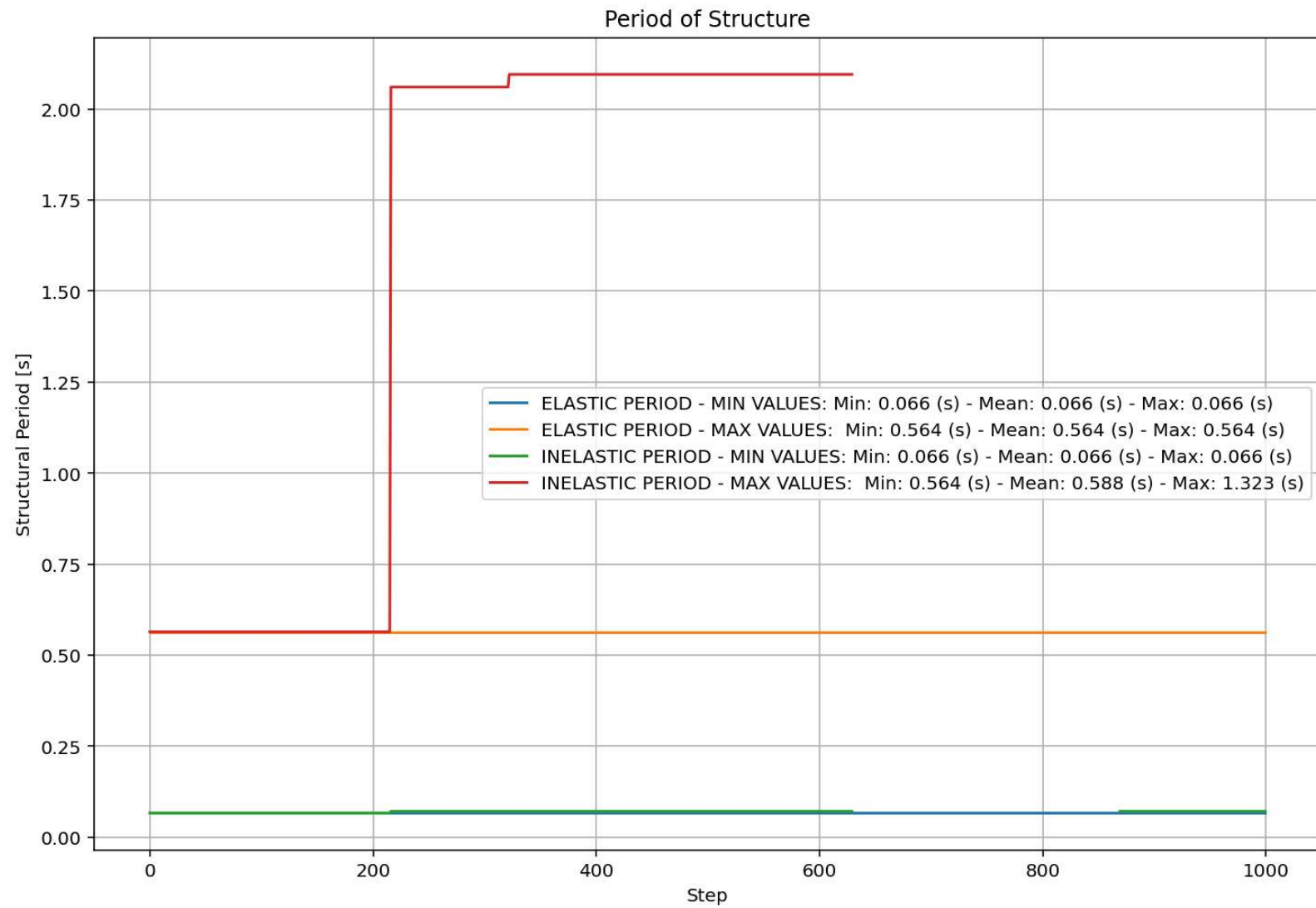






# **PUSHOVER ANALYSIS**





Node Displacements vs Time for Elastic Structure

