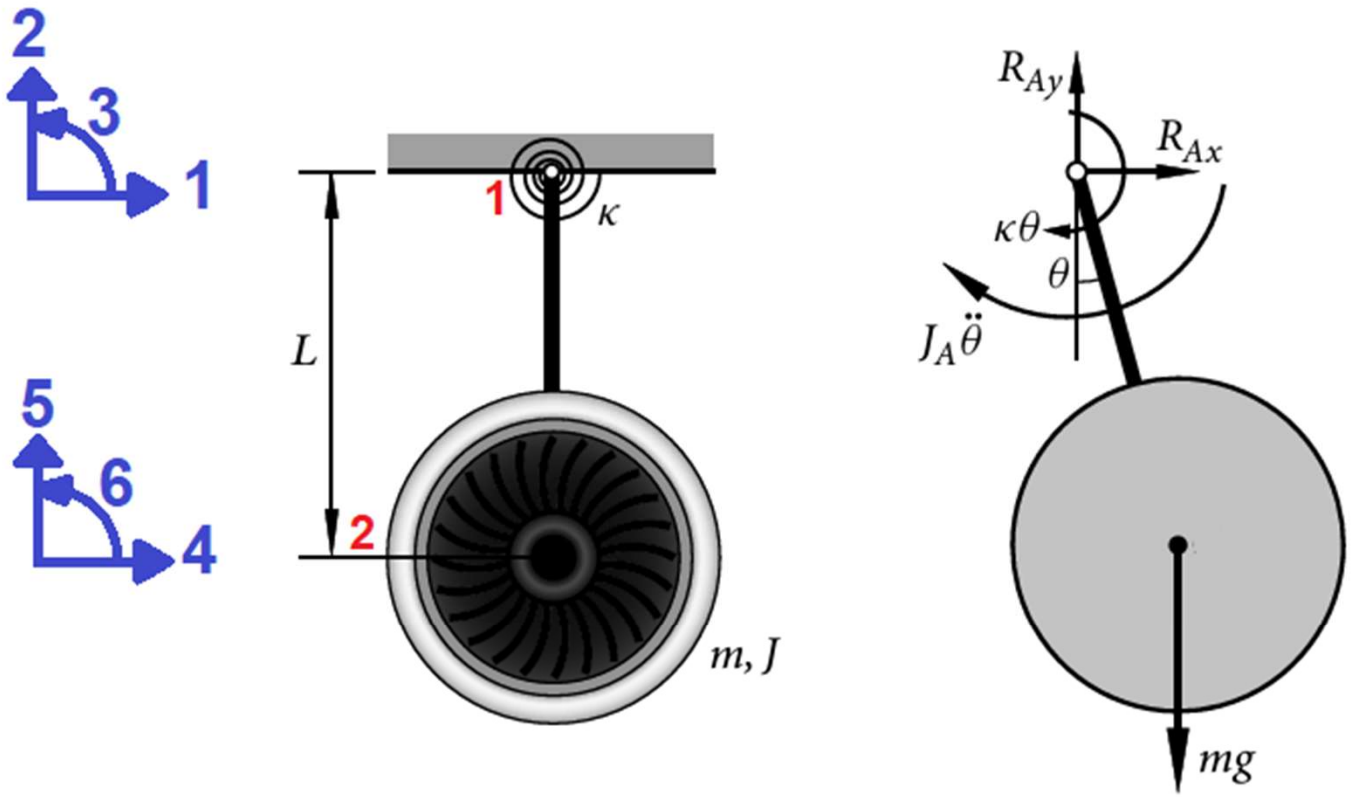
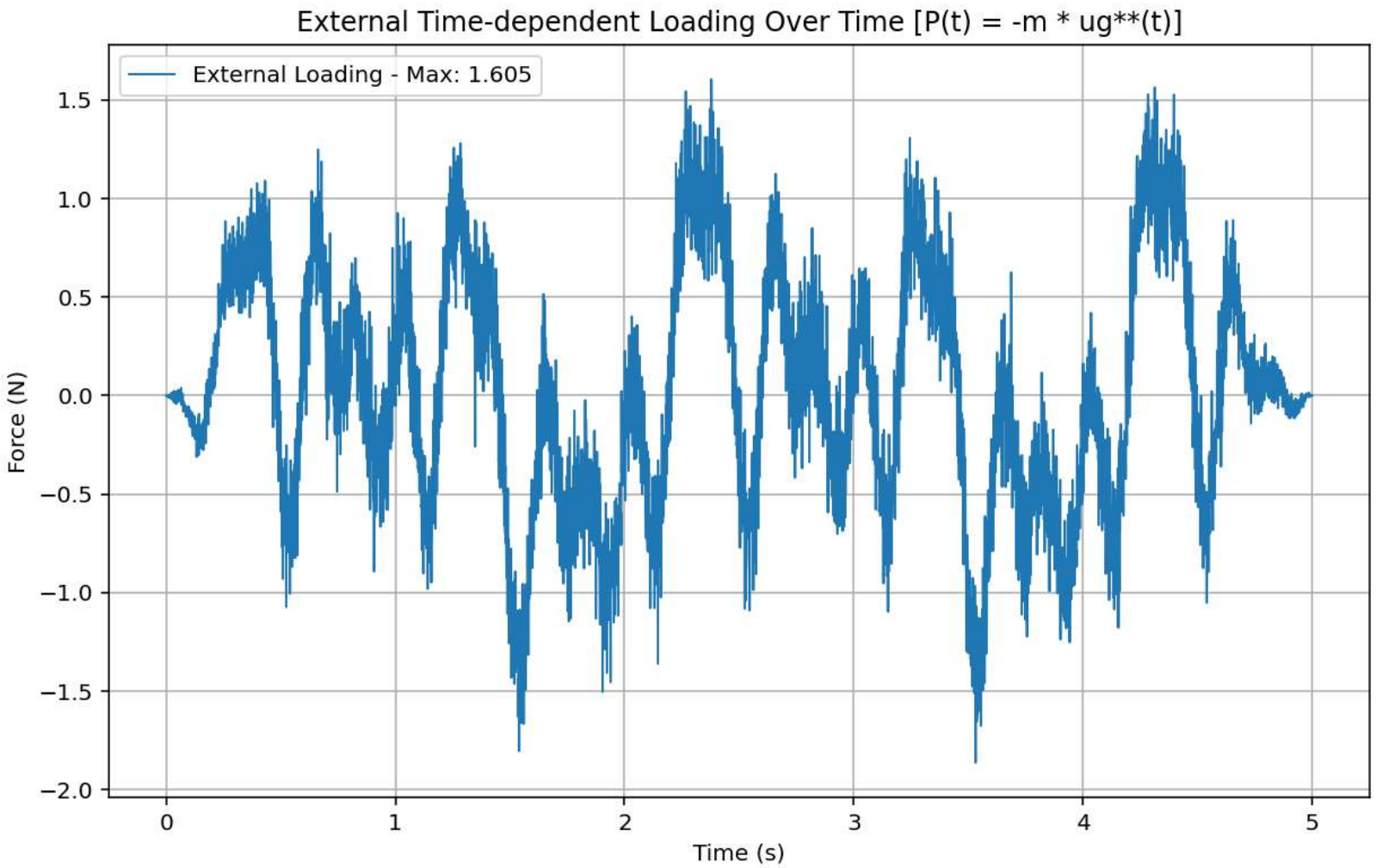
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

MODELING OF PENDULUM MDOF STRUCTURE USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)



Horizontal vibration of a jet engine.


External Time-dependent Loading Over Time [P(t) = -m * ug**(t)]
External Loading - Max: 1.605
Force (N)
Time (s)
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0
1
2
3
4
5

Spyder (Python 3.12)

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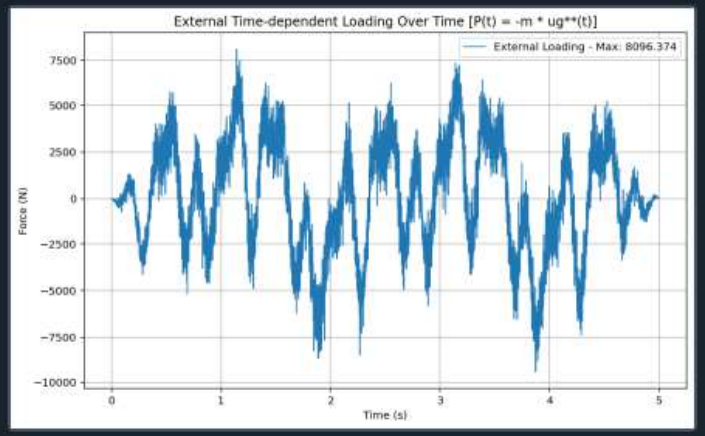
C:\Users\Dell\Desktop\OPENSEES_FILES\SEISMOMETER\MDF_PENDULUM\EXAMPLE_02\MDF_PENDULUM_TWO.py

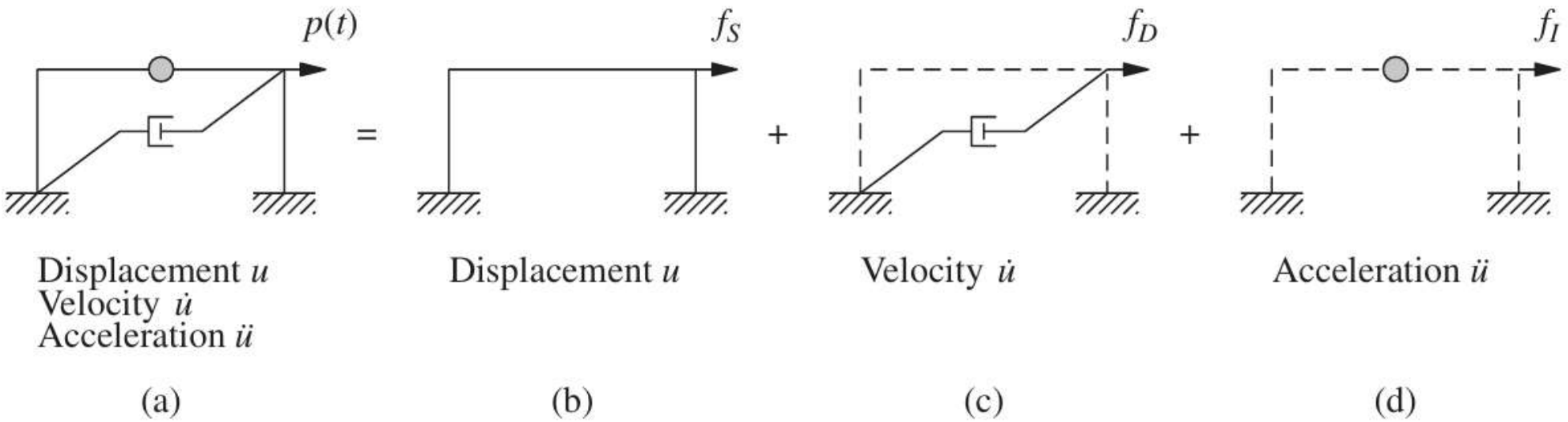
MDF_PENDULUM_TWO.py

```
#############################################################################################
#                          >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
#                                MODELING OF PENDULUM MDOF STRUCTURE USING OPENSEES
#                                          P(t) = -m * ug**(t)
#-------------------------------------------------------------------------------------------
#                    EVALUATION OF DAMPING FORCE (fD), SPRING FORCE (fS) AND INERTIA FORCE (
#-------------------------------------------------------------------------------------------
#                              THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
#                                    EMAIL: salar.d.ghashghaei@gmail.com
#############################################################################################
"""
Performs time-dependent loading 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 time-dependent loading
 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.
-------------------------------------------------------------------------
This code performs a comparative nonlinear dynamic analysis of a multi-degree-of-freedom (M
```

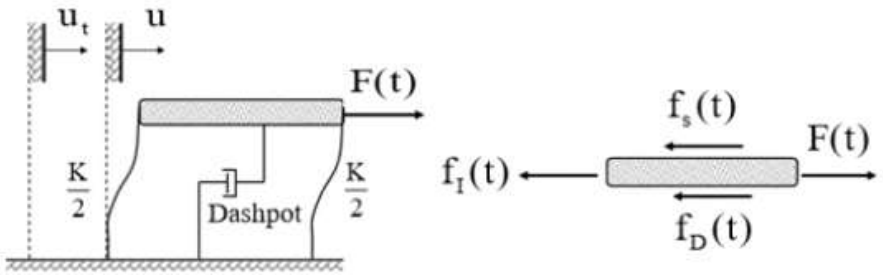


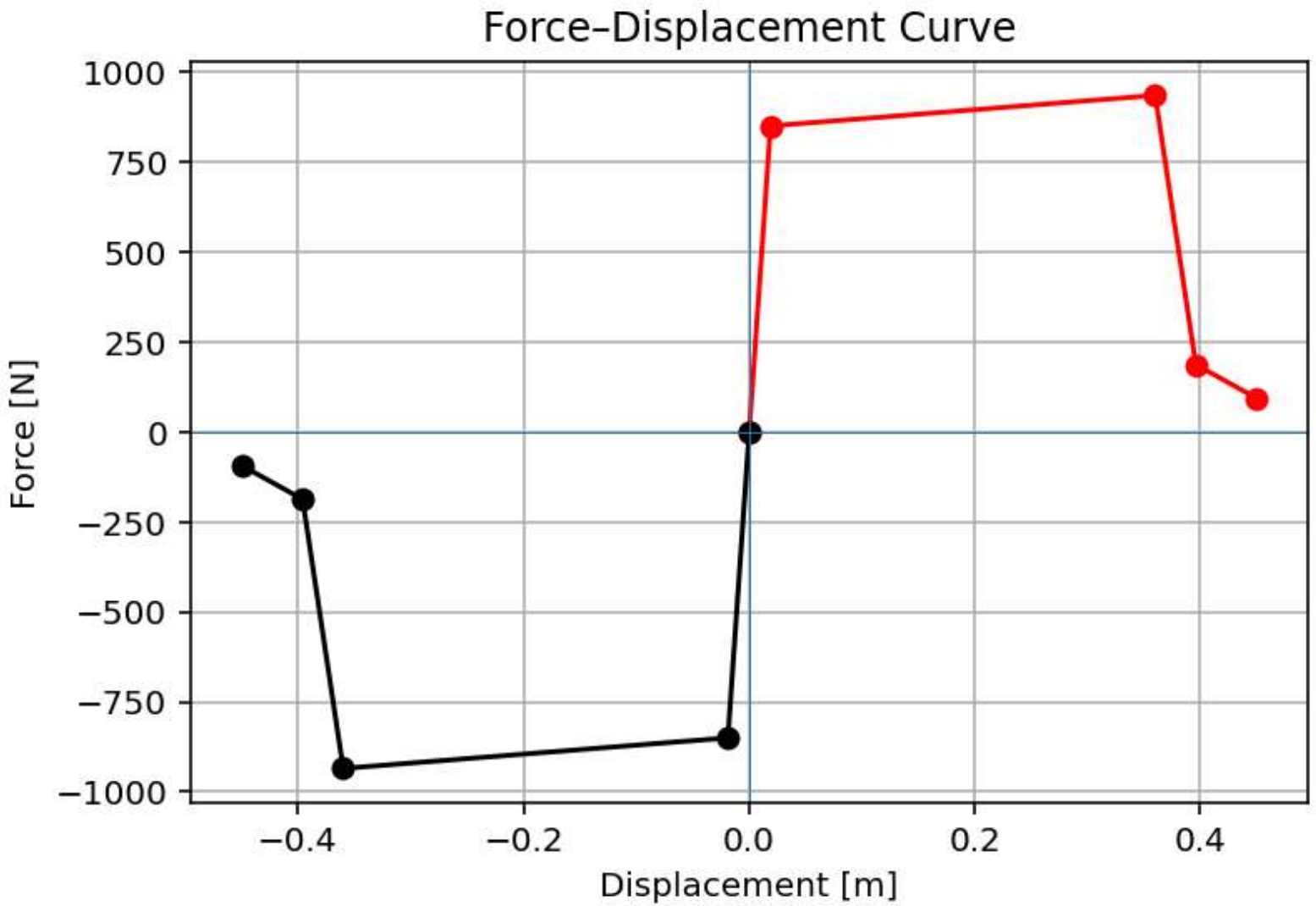
IPython Console | Files | Help | Variable Explorer | Debugger | Plots | History

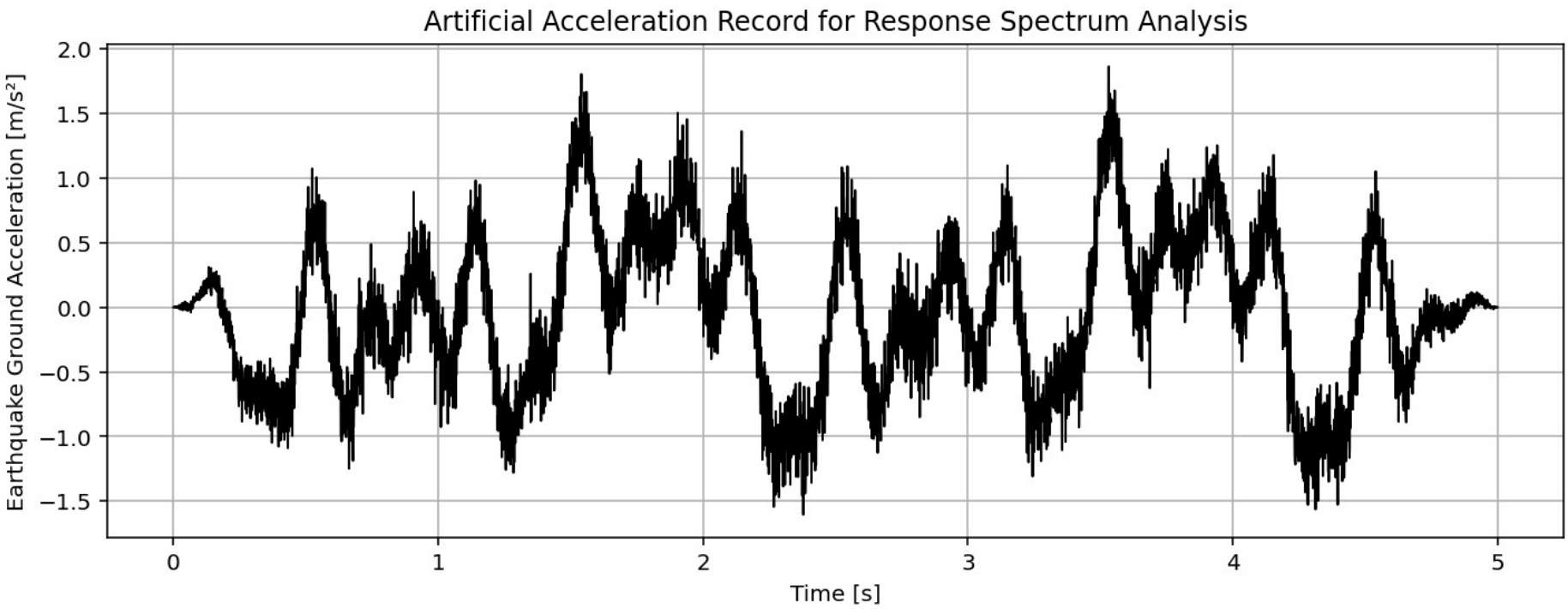
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 356, Col 40 UTF-8 CRLF RW Mem 43%

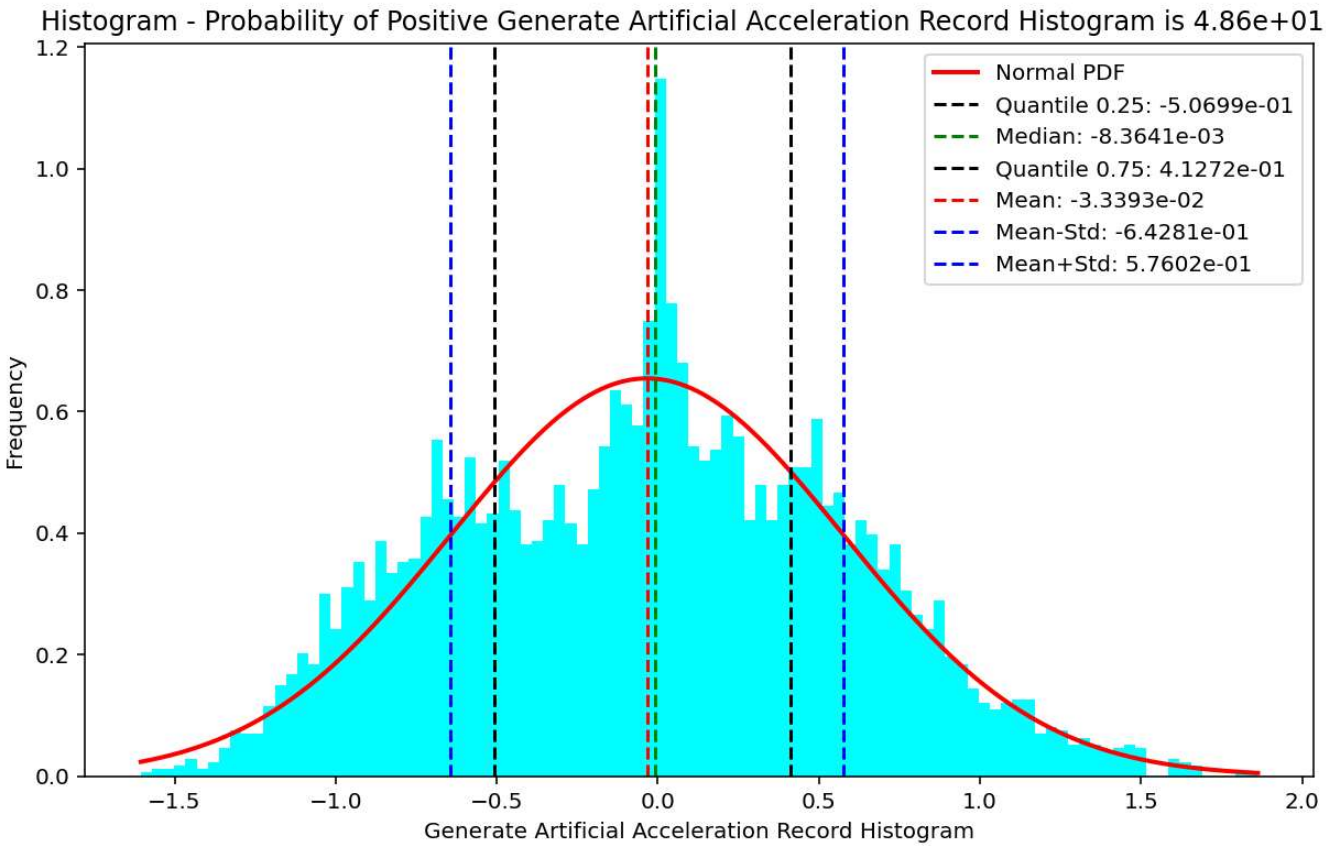


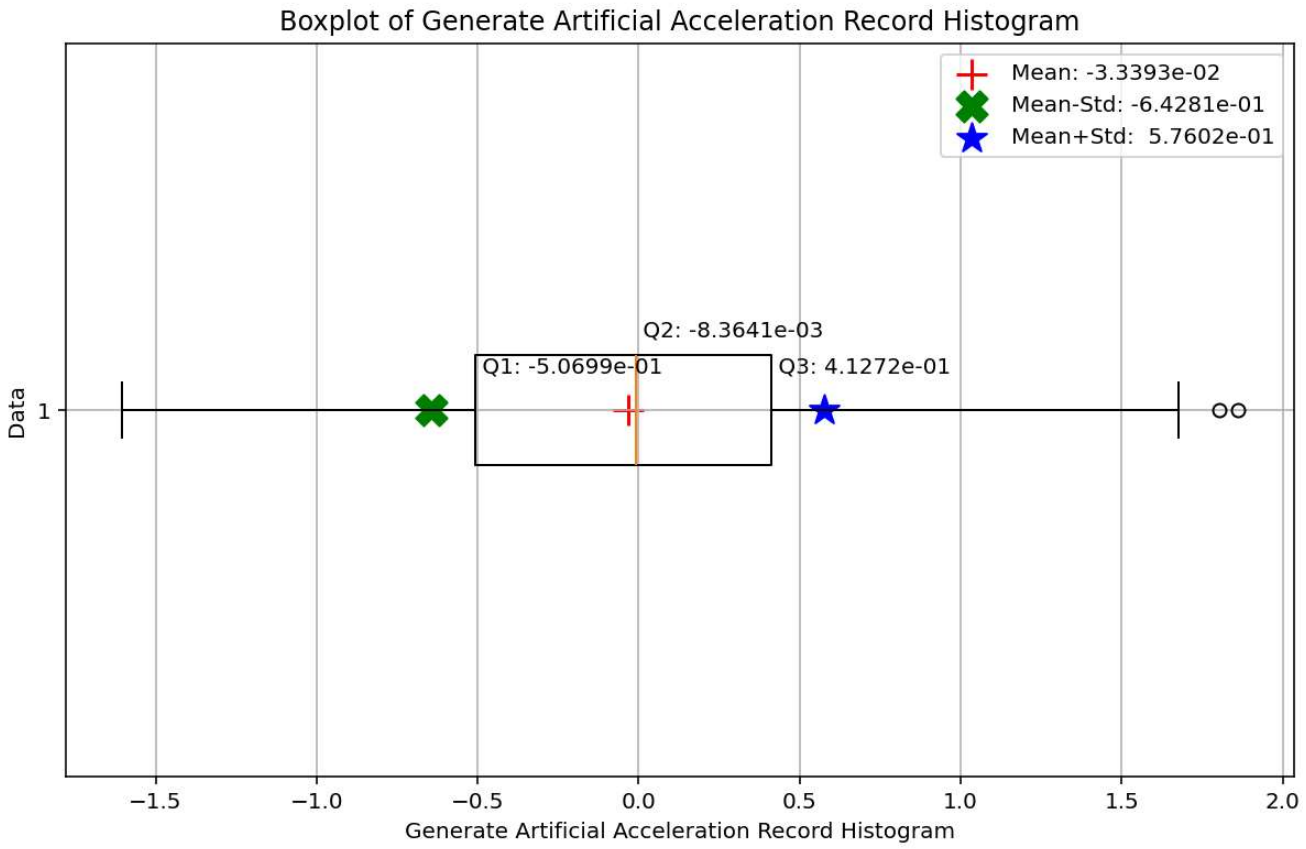
(a) System; (b) stiffness component; (c) damping component; (d) mass component.

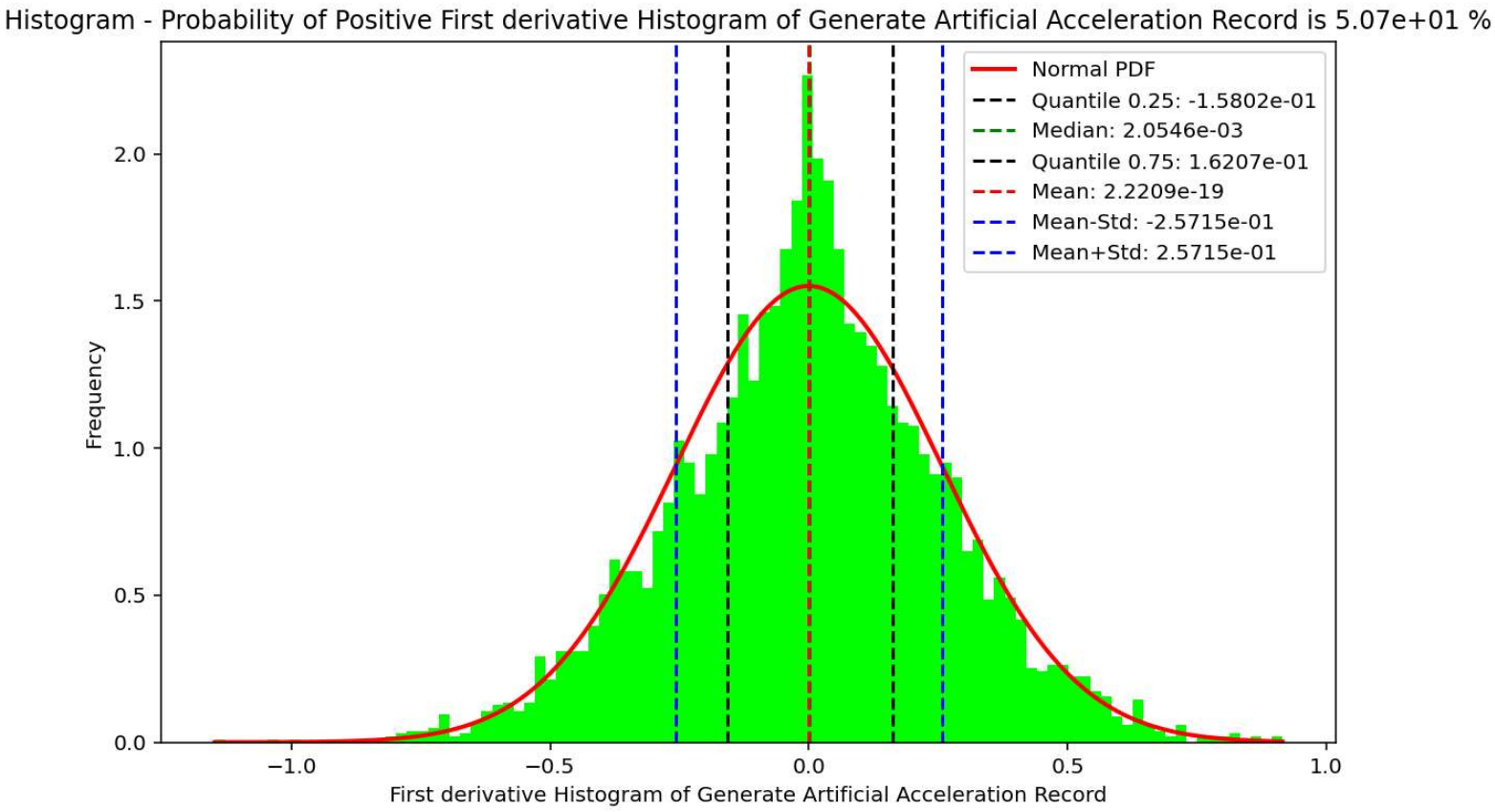


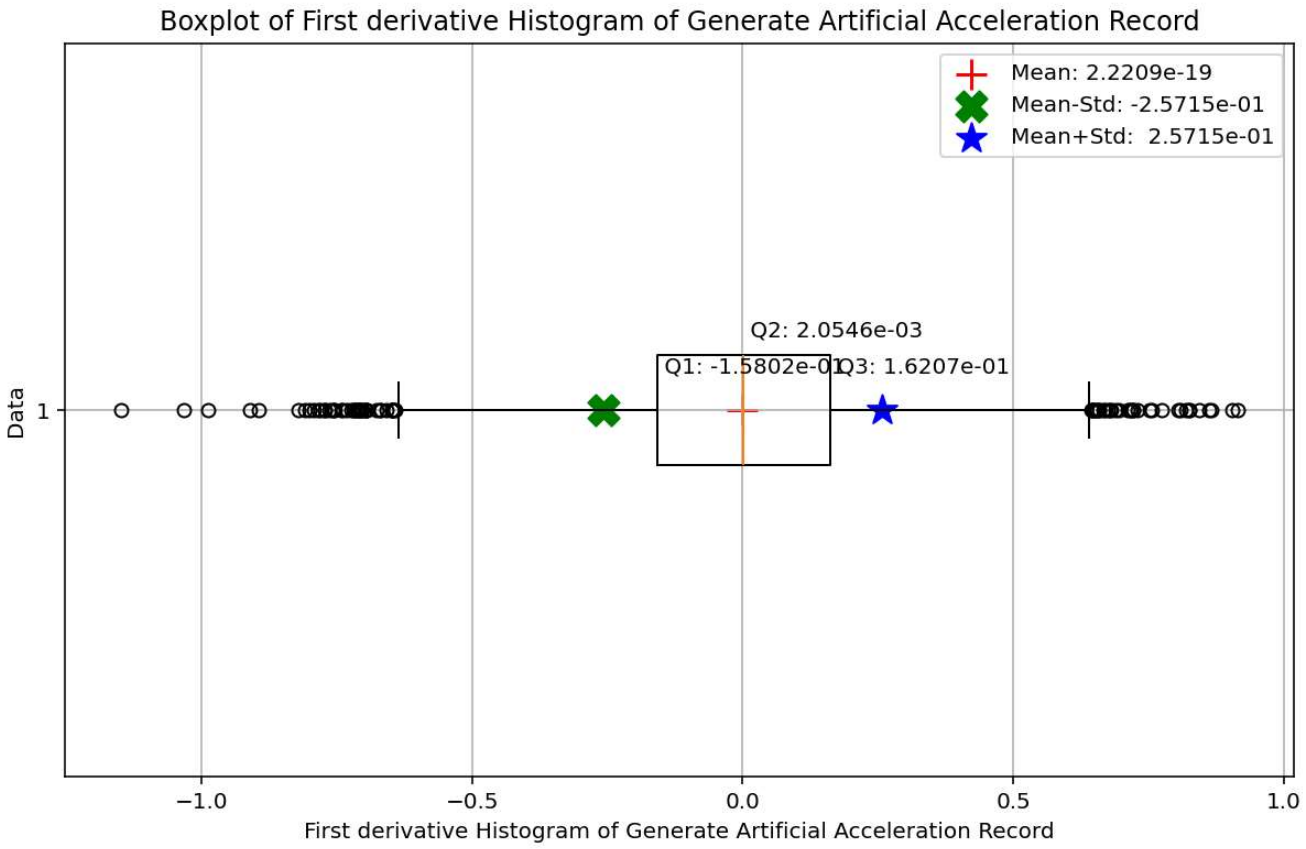

Force–Displacement Curve
1000
750
500
250
0
−250
−500
−750
−1000
Force [N]
−0.4
−0.2
0.0
0.2
0.4
Displacement [m]

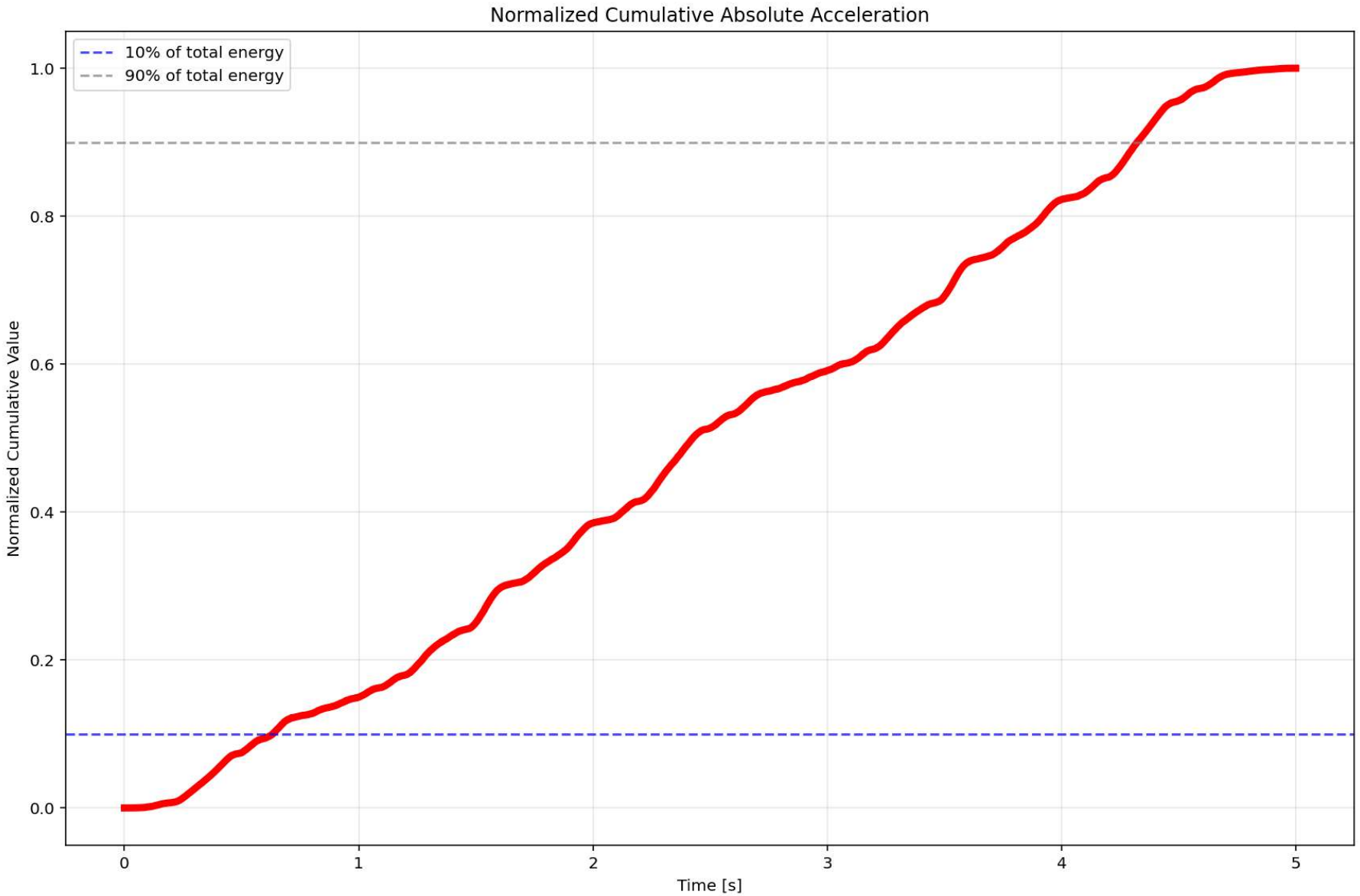

Artificial Acceleration Record for Response Spectrum Analysis
Earthquake Ground Acceleration [m/s²]
Time [s]
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
0
1
2
3
4
5

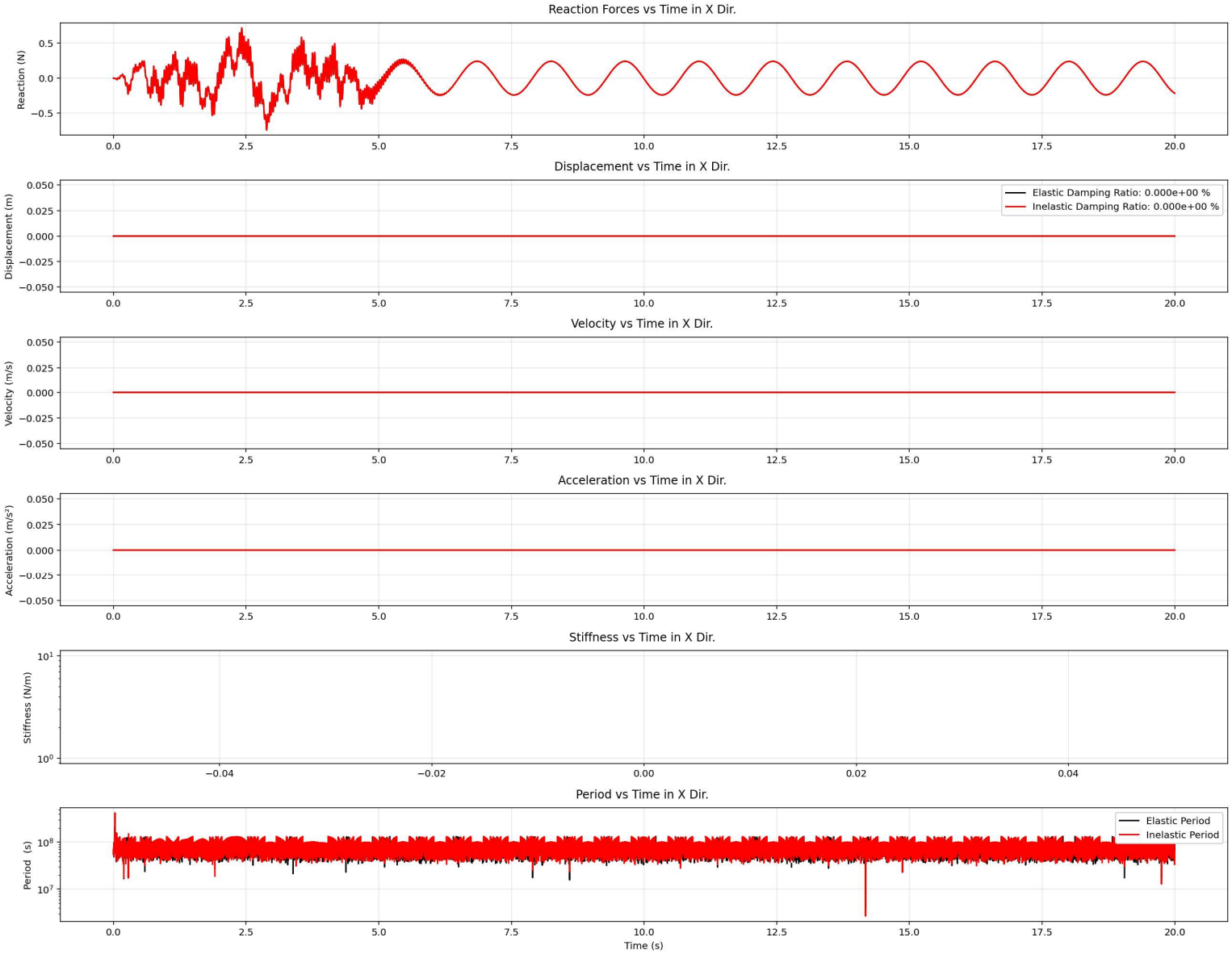

Histogram - Probability of Positive Generate Artificial Acceleration Record Histogram is 4.86e+01 %
Normal PDF
Quantile 0.25: -5.0699e-01
Median: -8.3641e-03
Quantile 0.75: 4.1272e-01
Mean: -3.3393e-02
Mean-Std: -6.4281e-01
Mean+Std: 5.7602e-01
Frequency
Generate Artificial Acceleration Record Histogram
0.0
0.2
0.4
0.6
0.8
1.0
1.2
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0

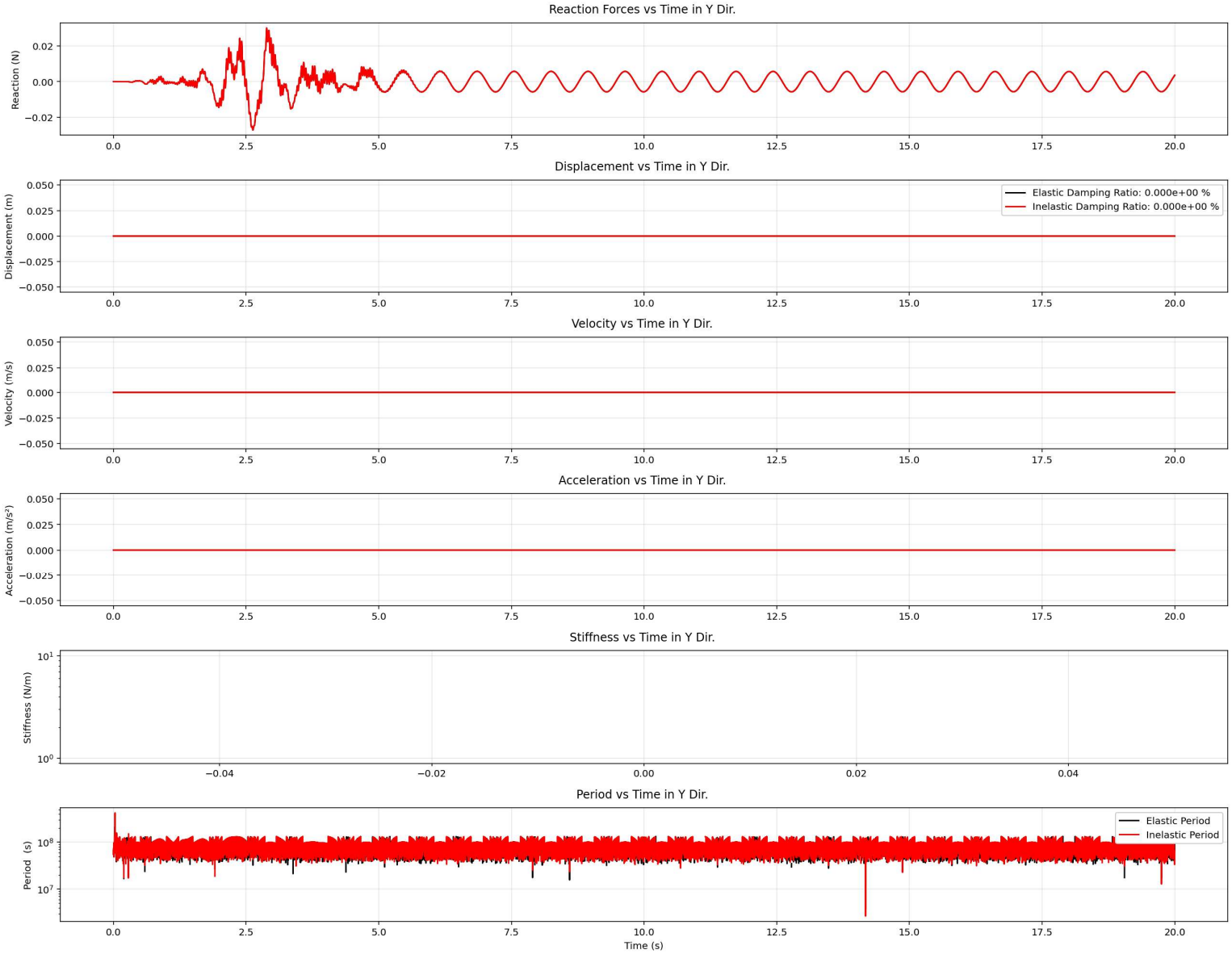

Boxplot of Generate Artificial Acceleration Record Histogram
Mean: -3.3393e-02
Mean-Std: -6.4281e-01
Mean+Std: 5.7602e-01
Q2: -8.3641e-03
Q1: -5.0699e-01
Q3: 4.1272e-01
Data
1
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
Generate Artificial Acceleration Record Histogram

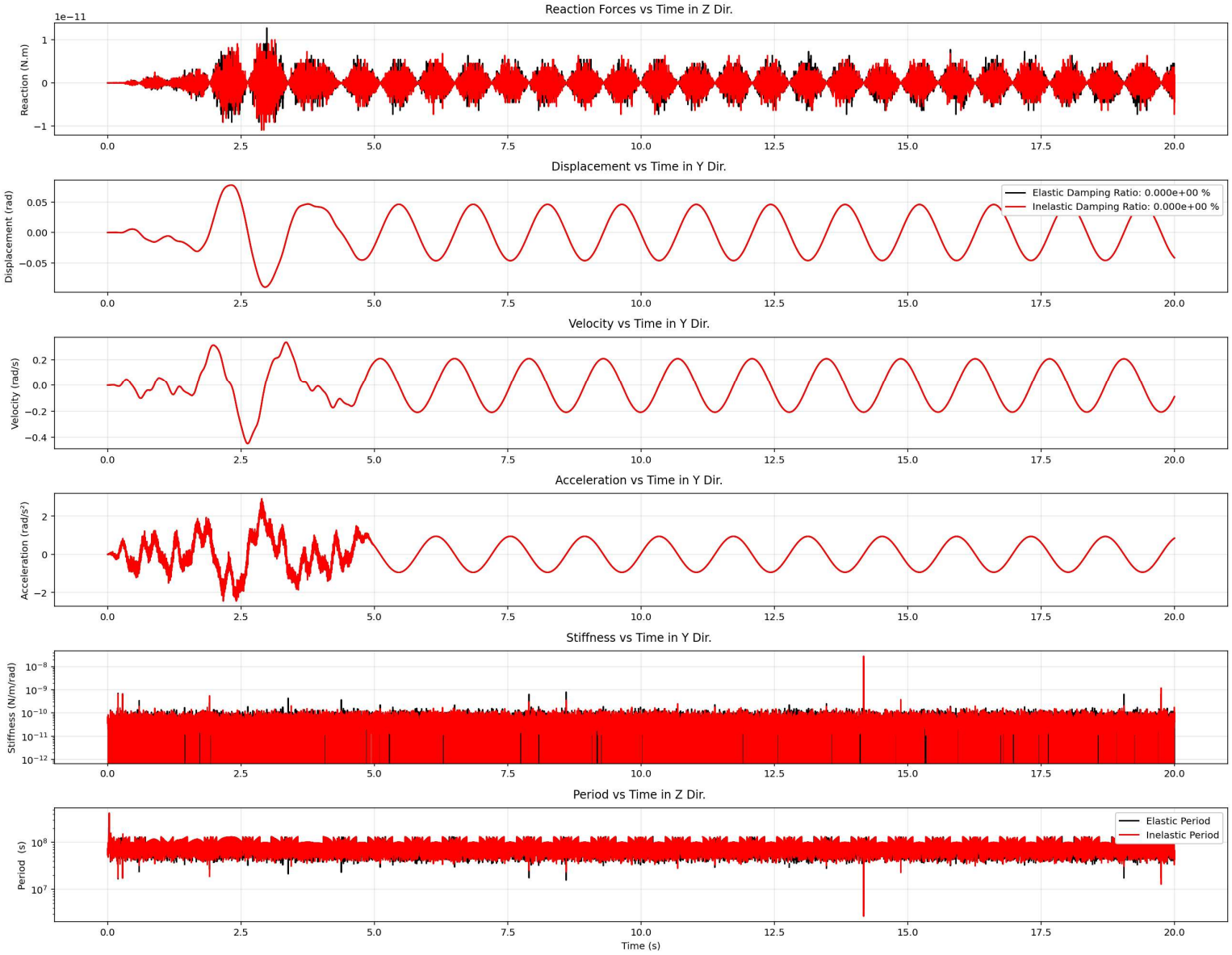

Histogram - Probability of Positive First derivative Histogram of Generate Artificial Acceleration Record is 5.07e+01 %
Normal PDF
Quantile 0.25: -1.5802e-01
Median: 2.0546e-03
Quantile 0.75: 1.6207e-01
Mean: 2.2209e-19
Mean-Std: -2.5715e-01
Mean+Std: 2.5715e-01
Frequency
0.0
0.5
1.0
1.5
2.0
−1.0
−0.5
0.0
0.5
1.0
First derivative Histogram of Generate Artificial Acceleration Record

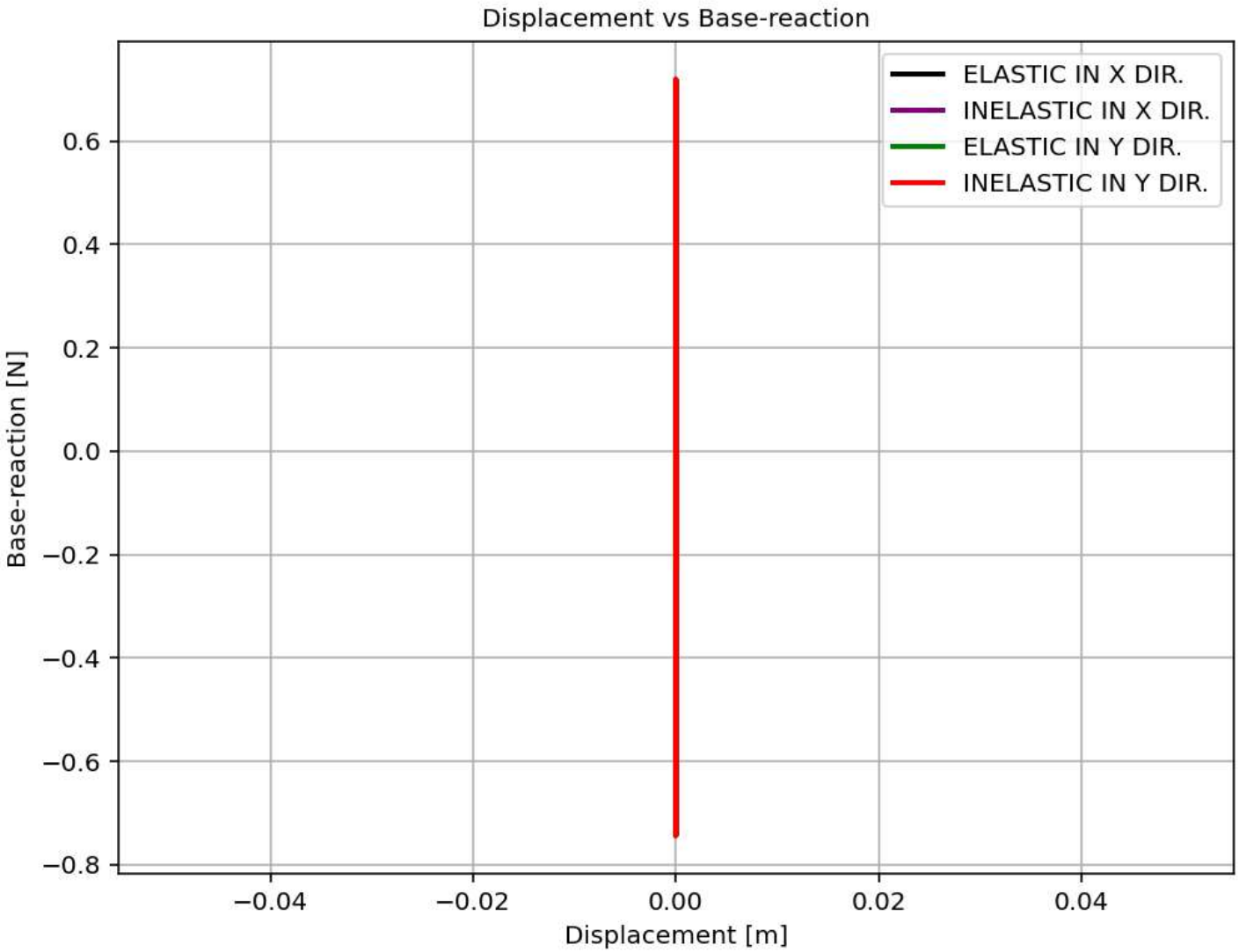

Boxplot of First derivative Histogram of Generate Artificial Acceleration Record
Mean: 2.2209e-19
Mean-Std: -2.5715e-01
Mean+Std: 2.5715e-01
Q2: 2.0546e-03
Q1: -1.5802e-01
Q3: 1.6207e-01
Data
1
−1.0
−0.5
0.0
0.5
1.0
First derivative Histogram of Generate Artificial Acceleration Record

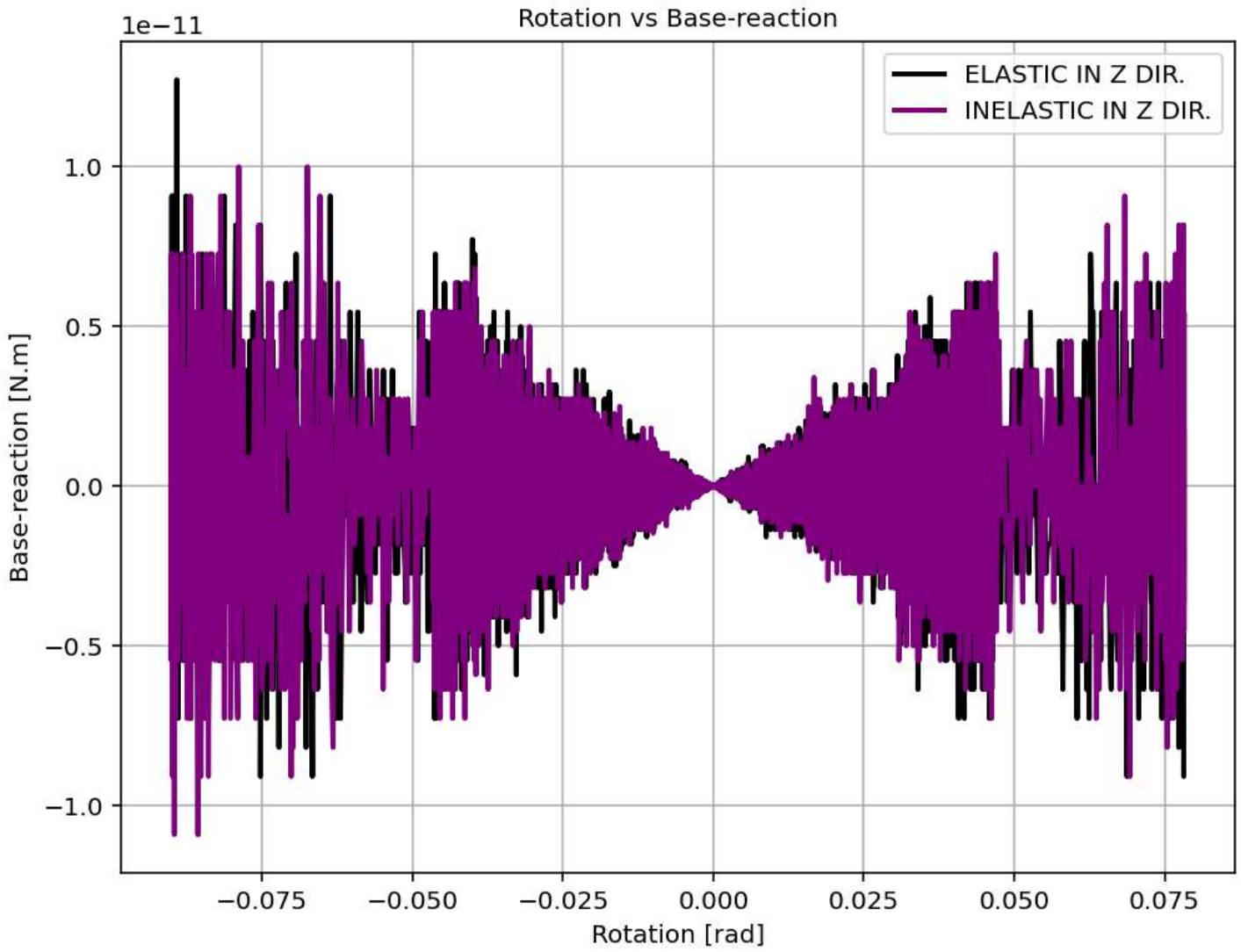

Normalized Cumulative Absolute Acceleration
10% of total energy
90% of total energy
Normalized Cumulative Value
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
Time [s]

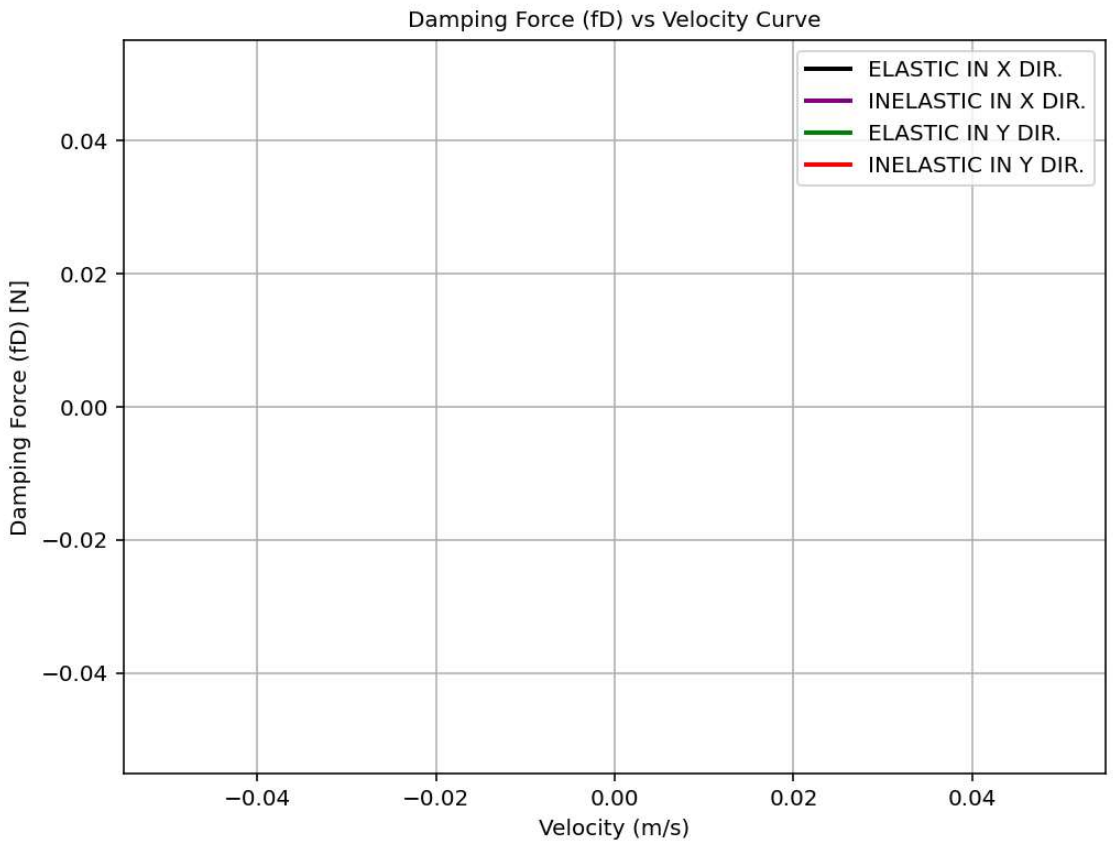

Reaction Forces vs Time in X Dir.
Reaction (N)
Displacement vs Time in X Dir.
Displacement (m)
Elastic Damping Ratio: 0.000e+00 %
Inelastic Damping Ratio: 0.000e+00 %
Velocity vs Time in X Dir.
Velocity (m/s)
Acceleration vs Time in X Dir.
Acceleration (m/s²)
Stiffness vs Time in X Dir.
Stiffness (N/m)
Period vs Time in X Dir.
Period (s)
Elastic Period
Inelastic Period
Time (s)

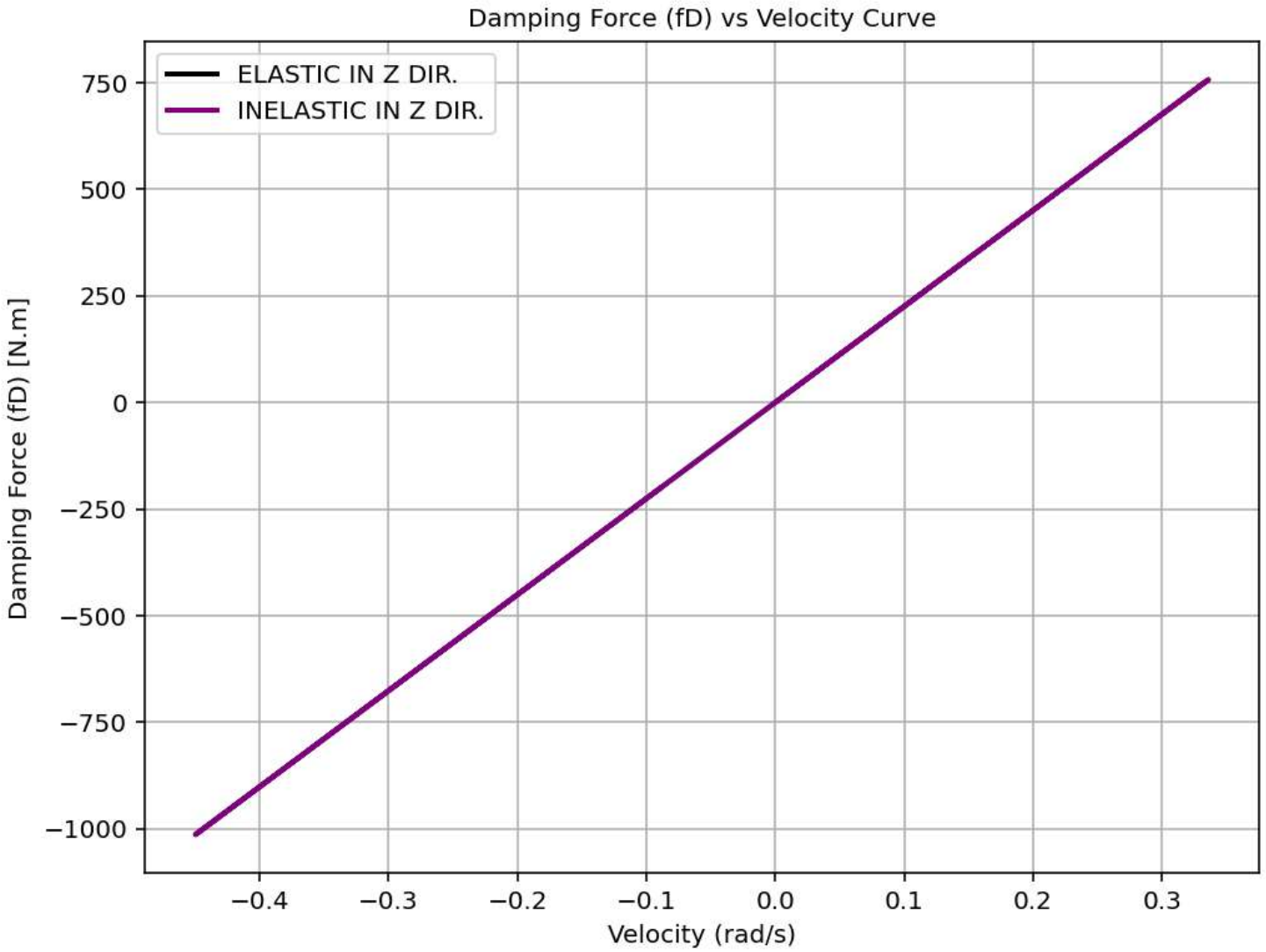

Reaction Forces vs Time in Y Dir.
Reaction (N)
0.02
0.00
−0.02
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Displacement vs Time in Y Dir.
Displacement (m)
0.050
0.025
0.000
−0.025
−0.050
Elastic Damping Ratio: 0.000e+00 %
Inelastic Damping Ratio: 0.000e+00 %
Velocity vs Time in Y Dir.
Velocity (m/s)
Acceleration vs Time in Y Dir.
Acceleration (m/s²)
Stiffness vs Time in Y Dir.
Stiffness (N/m)
10¹
10⁰
−0.04
−0.02
0.00
0.02
0.04
Period vs Time in Y Dir.
Period (s)
10⁸
10⁷
Elastic Period
Inelastic Period
Time (s)

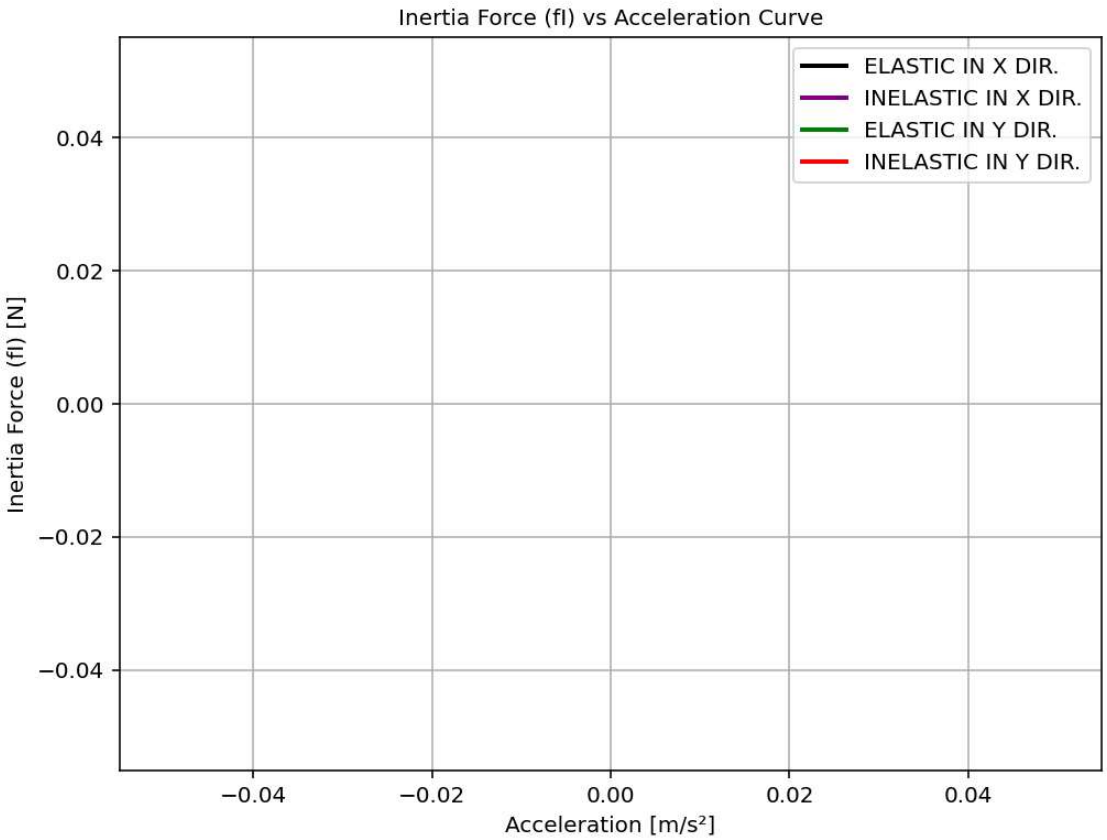

Reaction Forces vs Time in Z Dir.
1e−11
Reaction (N.m)
Displacement vs Time in Y Dir.
Displacement (rad)
Elastic Damping Ratio: 0.000e+00 %
Inelastic Damping Ratio: 0.000e+00 %
Velocity vs Time in Y Dir.
Velocity (rad/s)
Acceleration vs Time in Y Dir.
Acceleration (rad/s²)
Stiffness vs Time in Y Dir.
Stiffness (N/m/rad)
Period vs Time in Z Dir.
Period (s)
Elastic Period
Inelastic Period
Time (s)

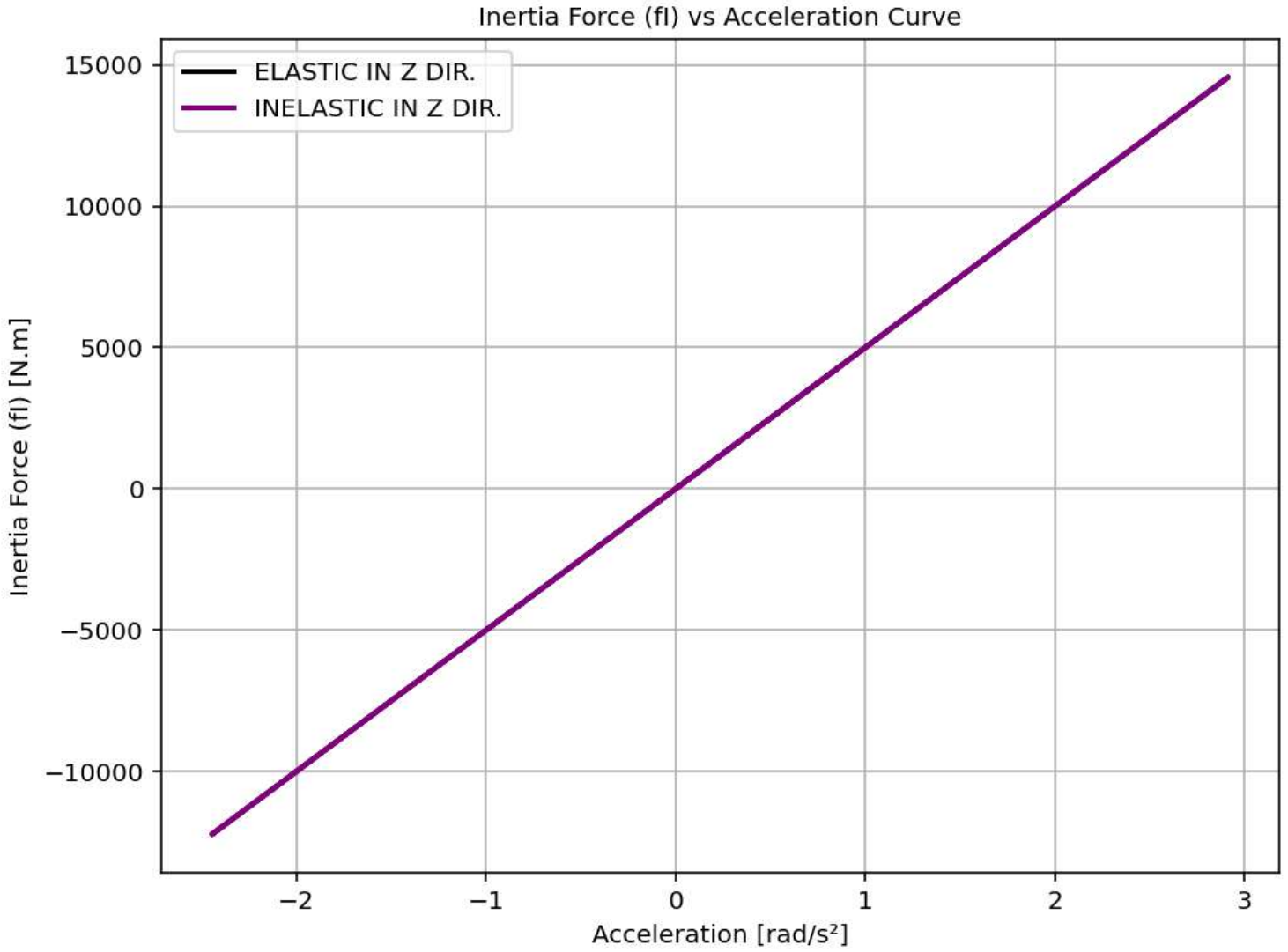

Displacement vs Base-reaction
ELASTIC IN X DIR.
INELASTIC IN X DIR.
ELASTIC IN Y DIR.
INELASTIC IN Y DIR.
Base-reaction [N]
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−0.04
−0.02
0.00
0.02
0.04
Displacement [m]

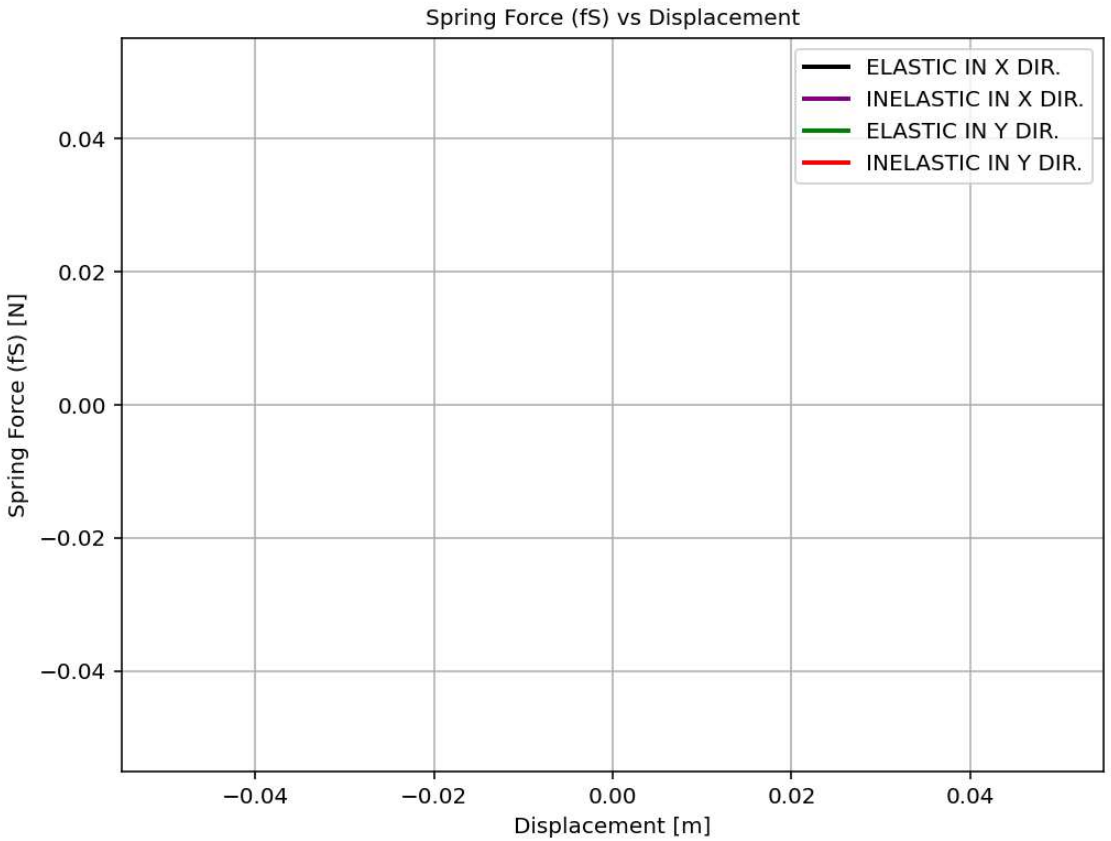

Rotation vs Base-reaction
1e−11
ELASTIC IN Z DIR.
INELASTIC IN Z DIR.
1.0
0.5
0.0
−0.5
−1.0
Base-reaction [N.m]
−0.075
−0.050
−0.025
0.000
0.025
0.050
0.075
Rotation [rad]

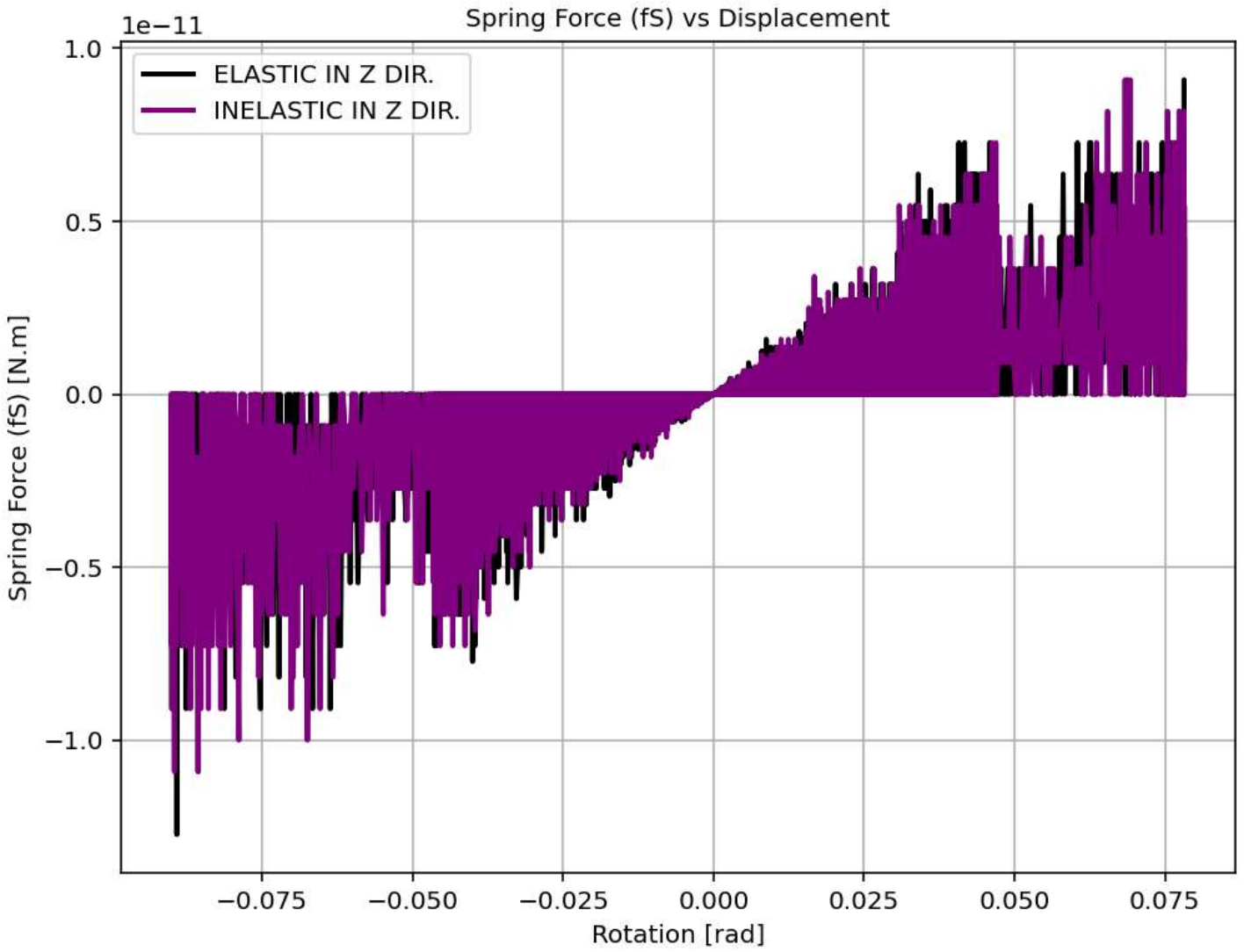

Damping Force (fD) vs Velocity Curve
ELASTIC IN X DIR.
INELASTIC IN X DIR.
ELASTIC IN Y DIR.
INELASTIC IN Y DIR.
Damping Force (fD) [N]
0.04
0.02
0.00
−0.02
−0.04
−0.04
−0.02
0.00
0.02
0.04
Velocity (m/s)

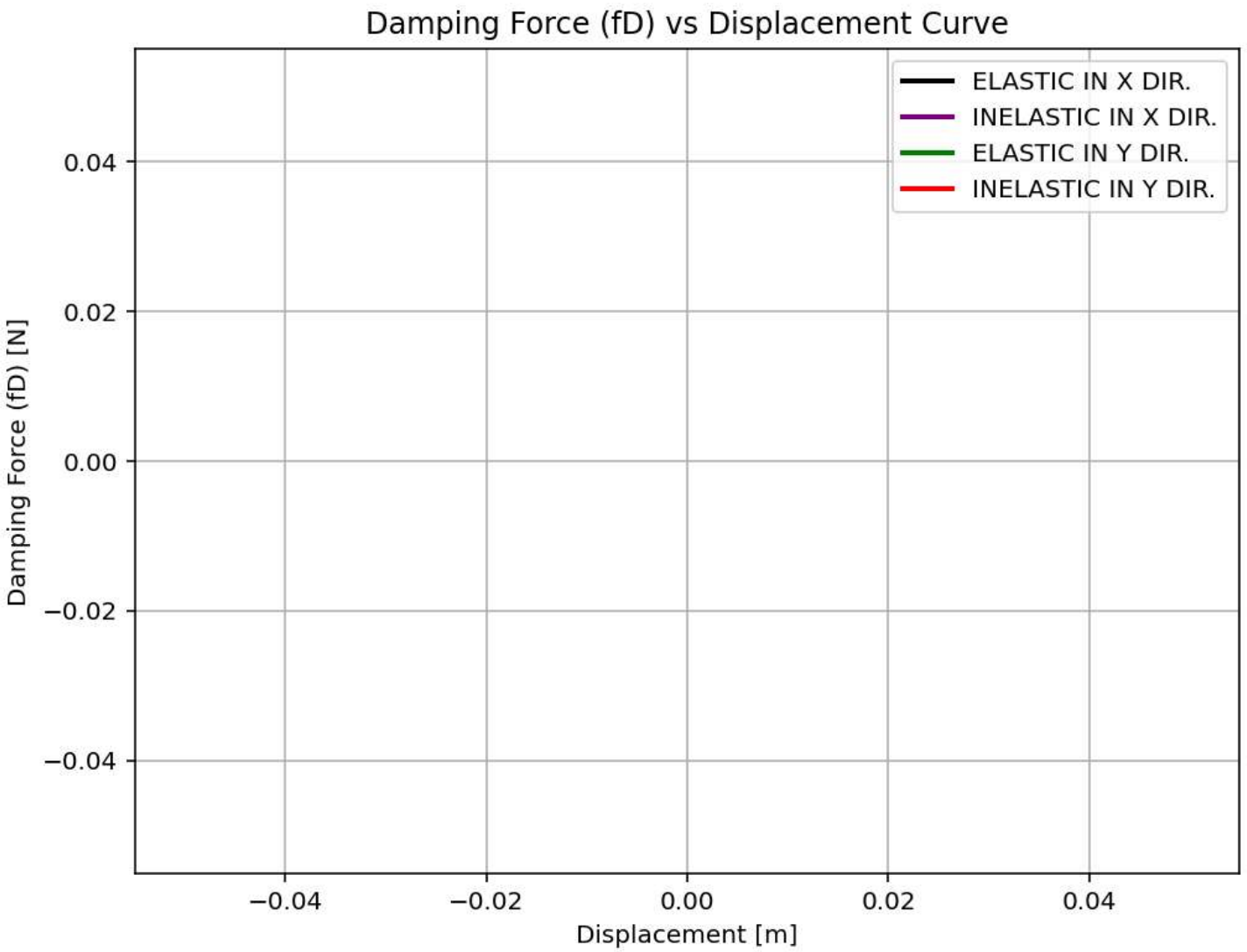

Damping Force (fD) vs Velocity Curve
ELASTIC IN Z DIR.
INELASTIC IN Z DIR.
Damping Force (fD) [N.m]
750
500
250
0
−250
−500
−750
−1000
−0.4
−0.3
−0.2
−0.1
0.0
0.1
0.2
0.3
Velocity (rad/s)

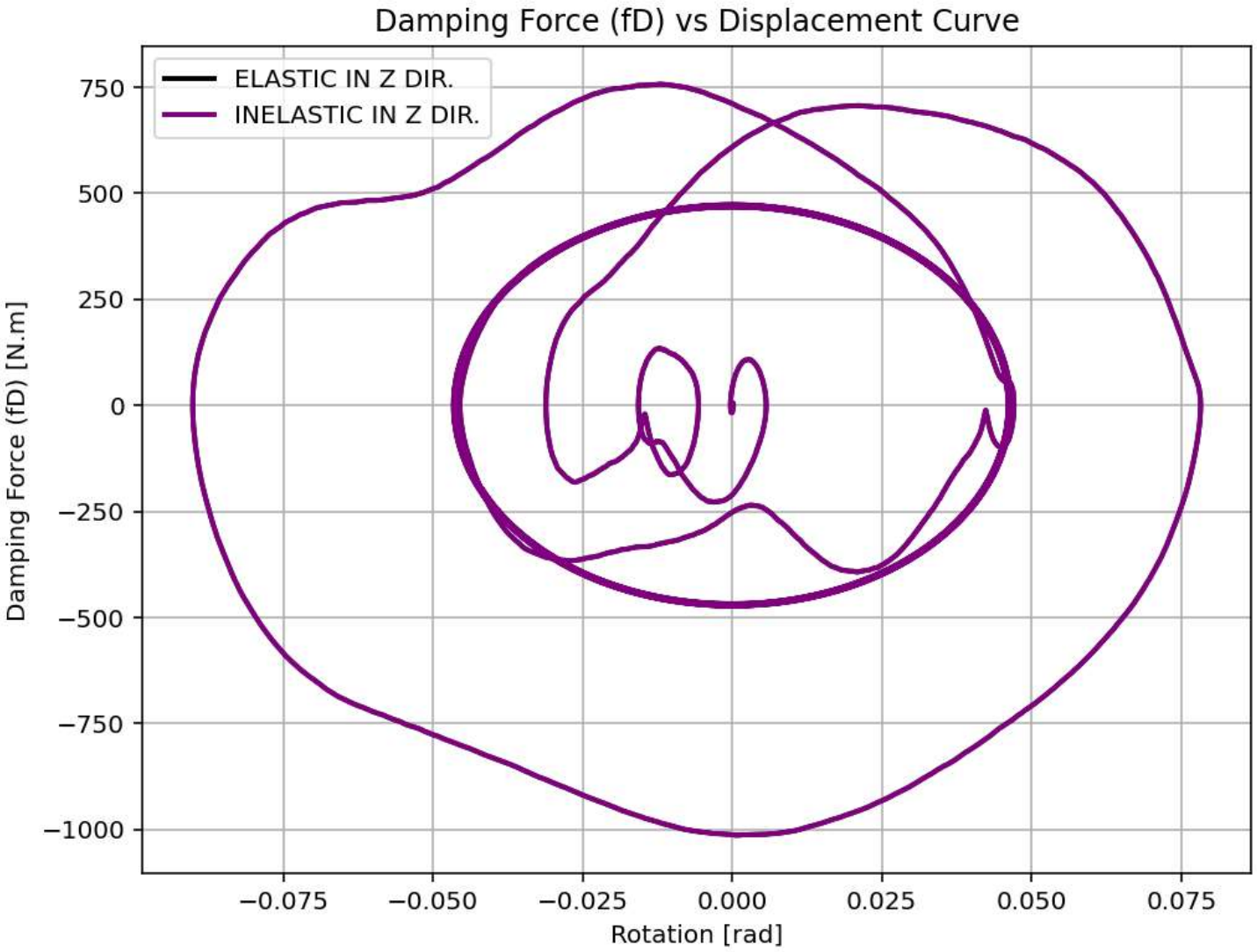

Inertia Force (fI) vs Acceleration Curve
ELASTIC IN X DIR.
INELASTIC IN X DIR.
ELASTIC IN Y DIR.
INELASTIC IN Y DIR.
0.04
0.02
0.00
−0.02
−0.04
Inertia Force (fI) [N]
−0.04
−0.02
0.00
0.02
0.04
Acceleration [m/s²]


Inertia Force (fI) vs Acceleration Curve
ELASTIC IN Z DIR.
INELASTIC IN Z DIR.
15000
10000
5000
0
−5000
−10000
Inertia Force (fI) [N.m]
−2
−1
0
1
2
3
Acceleration [rad/s²]


Spring Force (fS) vs Displacement
ELASTIC IN X DIR.
INELASTIC IN X DIR.
ELASTIC IN Y DIR.
INELASTIC IN Y DIR.
Spring Force (fS) [N]
0.04
0.02
0.00
−0.02
−0.04
−0.04
−0.02
0.00
0.02
0.04
Displacement [m]


Spring Force (fS) vs Displacement
1e−11
1.0
0.5
0.0
−0.5
−1.0
ELASTIC IN Z DIR.
INELASTIC IN Z DIR.
Spring Force (fS) [N.m]
−0.075
−0.050
−0.025
0.000
0.025
0.050
0.075
Rotation [rad]


Damping Force (fD) vs Displacement Curve
ELASTIC IN X DIR.
INELASTIC IN X DIR.
ELASTIC IN Y DIR.
INELASTIC IN Y DIR.
Damping Force (fD) [N]
0.04
0.02
0.00
−0.02
−0.04
−0.04
−0.02
0.00
0.02
0.04
Displacement [m]


Damping Force (fD) vs Displacement Curve
ELASTIC IN Z DIR.
INELASTIC IN Z DIR.
750
500
250
0
−250
−500
−750
−1000
Damping Force (fD) [N.m]
−0.075
−0.050
−0.025
0.000
0.025
0.050
0.075
Rotation [rad]