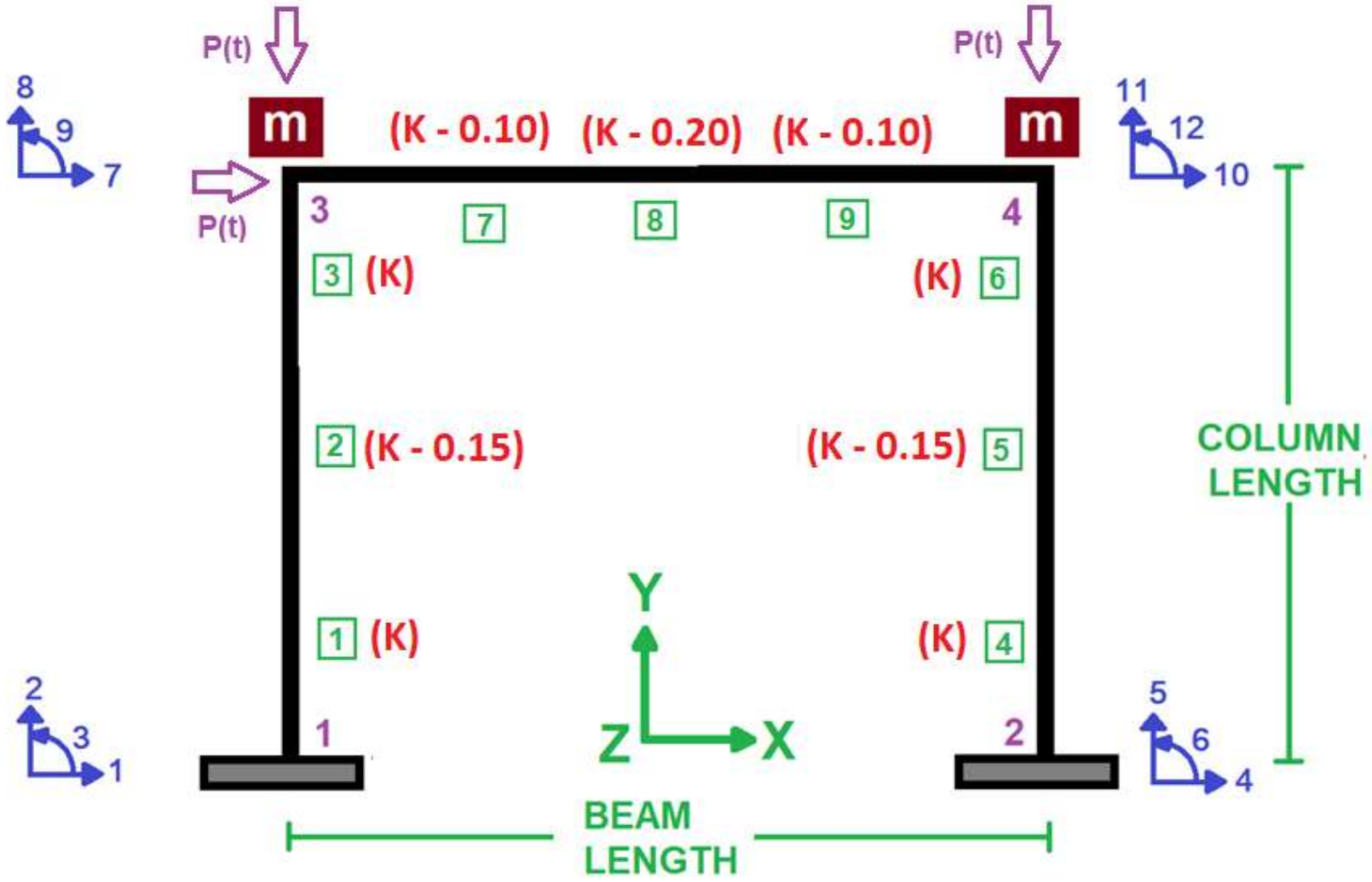
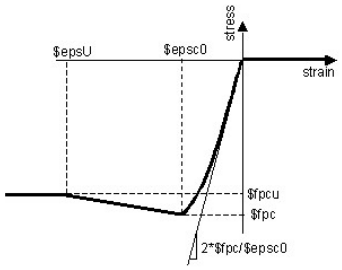
IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL

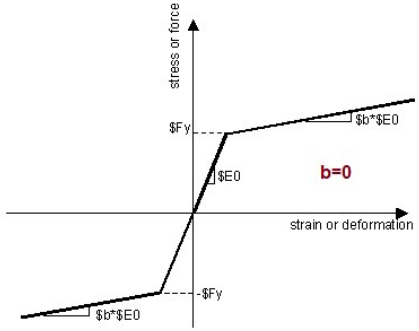
COMPARATIVE STUDY OF ELASTIC AND INELASTIC STRUCTURAL BEHAVIOR THROUGH PUSHOVER DYNAMIC ANALYSIS. HARMONIC IMPACT LOADING ANALYSIS OF CONCRETE FRAME USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)

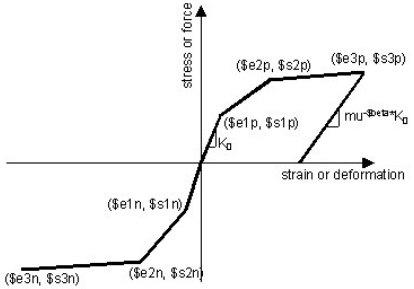

P(t)
P(t)
P(t)
m
m
(K - 0.10)
(K - 0.20)
(K - 0.10)
8
9
7
11
12
10
3
4
7
8
9
3 (K)
(K) 6
2 (K - 0.15)
(K - 0.15) 5
1 (K)
(K) 4
COLUMN LENGTH
Y
Z
X
1
2
2
3
1
5
6
4
BEAM LENGTH



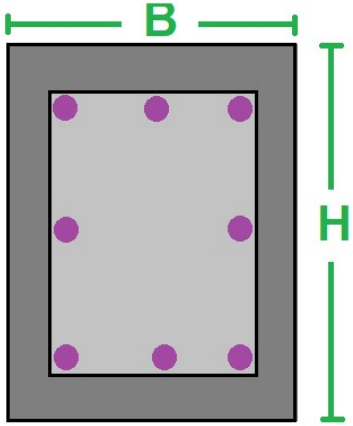
CORE AND COVER CONCRETE RELATION



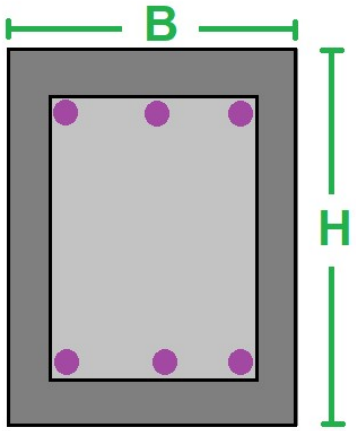
WITHOUT HARDENING AND ULTIMATE STRAIN



WITH HARDENING AND ULTIMATE STRAIN



COLUMN SECTION



BEAM SECTION

Spyder (Python 3.12)

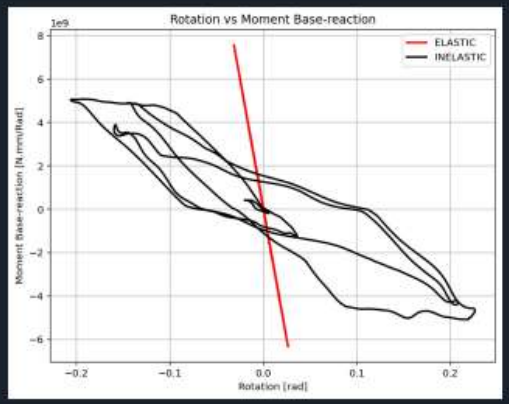
File Edit Search Source Run Debug Consoles Projects Tools View Help

C:\Users\Dell\Desktop\OPENSEES_FILES\CONCRETE_FRA...ONSTANT_ELASTIC_OR_INELASTIC_FRAME_IMPACT_LOAD.py

CONFINEMENT_NONCON...AME_IMPACT_LOAD.py

```
#############################################################################################
#                          >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
#  COMPARATIVE STUDY OF ELASTIC AND INELASTIC STRUCTURAL BEHAVIOR THROUGH PUSHOVER DYNAMIC ANALY
#                                HARMONIC IMPACT LOADING ANALYSIS OF CONCRETE FRAME.
#---------------------------------------------------------------------------------------------
#                             THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
#                                    EMAIL: salar.d.ghashghaei@gmail.com
#############################################################################################
"""
1. The script performs a comparative study of elastic and inelastic structural behavior using pu
2. It models a 2D reinforced concrete frame with columns (500x500mm) and beams (500x300mm) using
3. Material definitions include confined/unconfined concrete (fc=25MPa) and bilinear steel reinf
4. Two analysis types are implemented: static pushover (displacement-controlled) and dynamic tim
5. Rayleigh damping is calculated based on initial modal periods and target damping ratios (5%).
6. The pushover analysis applies incremental displacements up to 675mm, recording base reactions
7. Dynamic analysis uses Newmark integration with ground motion inputs scaled by 0.01g (El Centr
8. Key outputs include force-displacement curves, moment-rotation relationships, and stiffness d
9. Eigenvalue analysis tracks period elongation due to inelasticity during dynamic events.
10. Damage indices are computed for ductility assessment using bilinear curve fitting.
11. Overstrength factors (Ω), ductility ratios (μ), and R-factors are quantified for seismic per
12. Real-time monitoring of base shear, axial forces, and interstory drifts is implemented.
13. The script includes advanced convergence controls (Newton-Raphson, 1e-6 tolerance).
14. Confinement effects are modeled with variable enhancement ratios (Kc=1.25 for columns).
15. Results are exported to Excel, including displacements, forces, stiffness, and period data.
16. Visualization includes deformed shapes, hysteresis loops, and cumulative response envelopes.
17. Damping ratios are estimated from free vibration decay in dynamic analyses.
18. Both geometric nonlinearities (P-Delta/Corotational) and material nonlinearities are conside
19. The code supports parametric studies by varying steel models (with/without hardening) and el
20. Comprehensive plotting functions enable side-by-side comparison of elastic vs. inelastic res

The script demonstrates professional-grade analysis combining FEMA-356 pushover methods with ASC
"""
import openseespy.opensees as ops
import matplotlib.pyplot as plt
```



Help Variable Explorer Debugger Plots Files

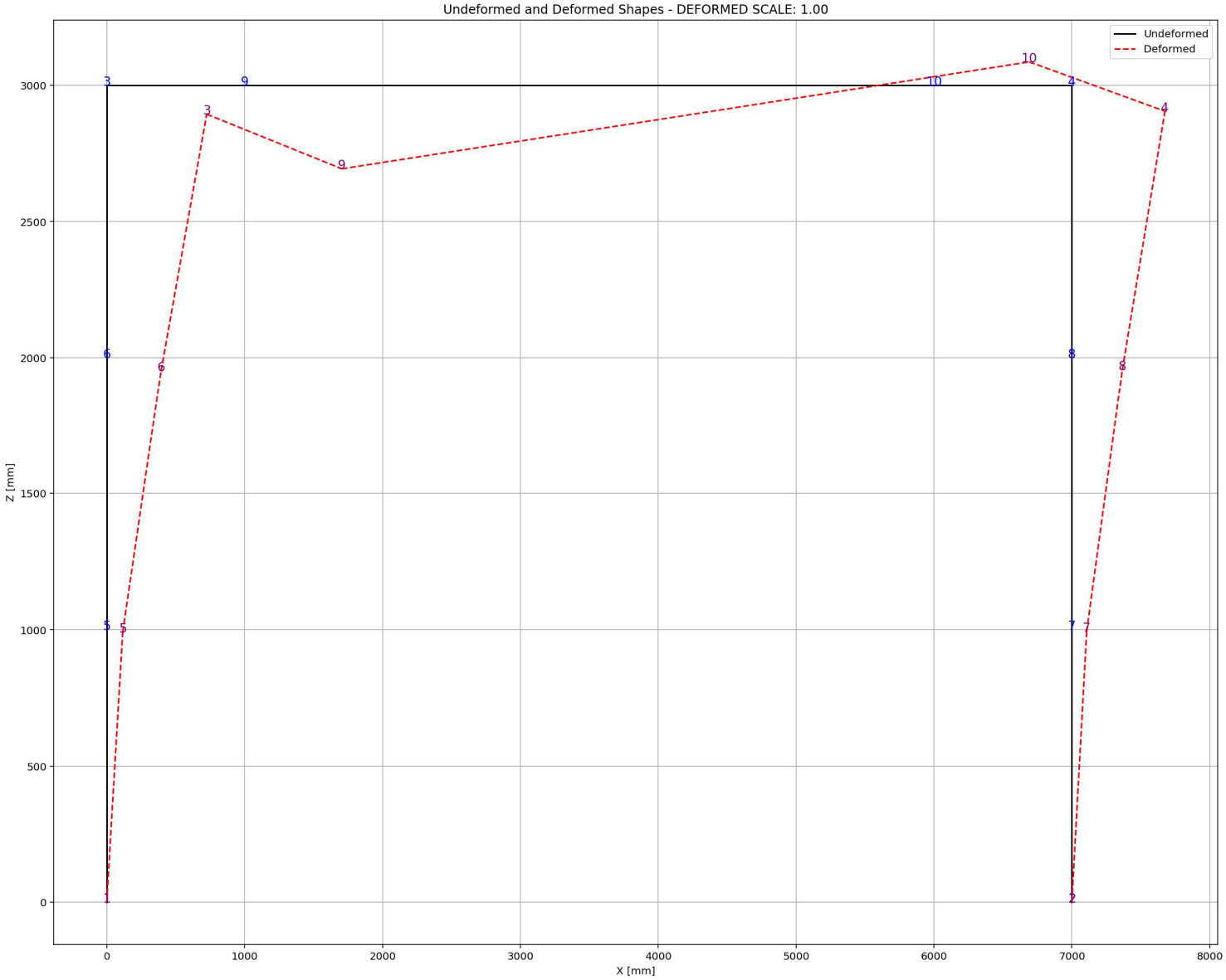
Console 1/A

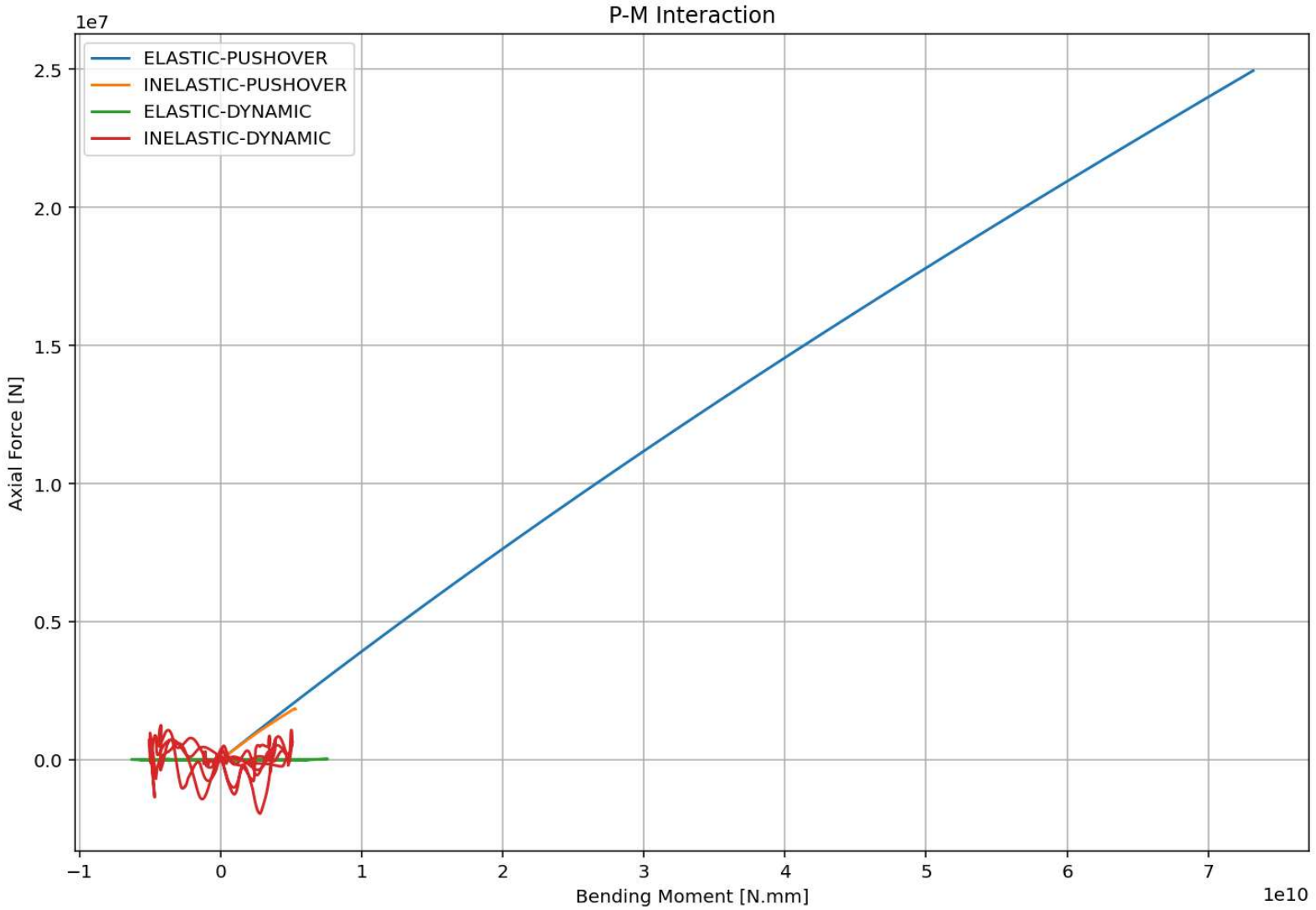
```
+=========================+
=   Analysis curve fitted =
     Disp        Base Shear
---------------------------
[[0.00000000e+00 0.00000000e+00]
 [1.18863557e+02 1.58187702e+06]
 [6.83639813e+02 1.83731549e+06]]
+=========================+
+-----------------------------------------------------+
 Structure Elastic Stiffness :     13308.34
```

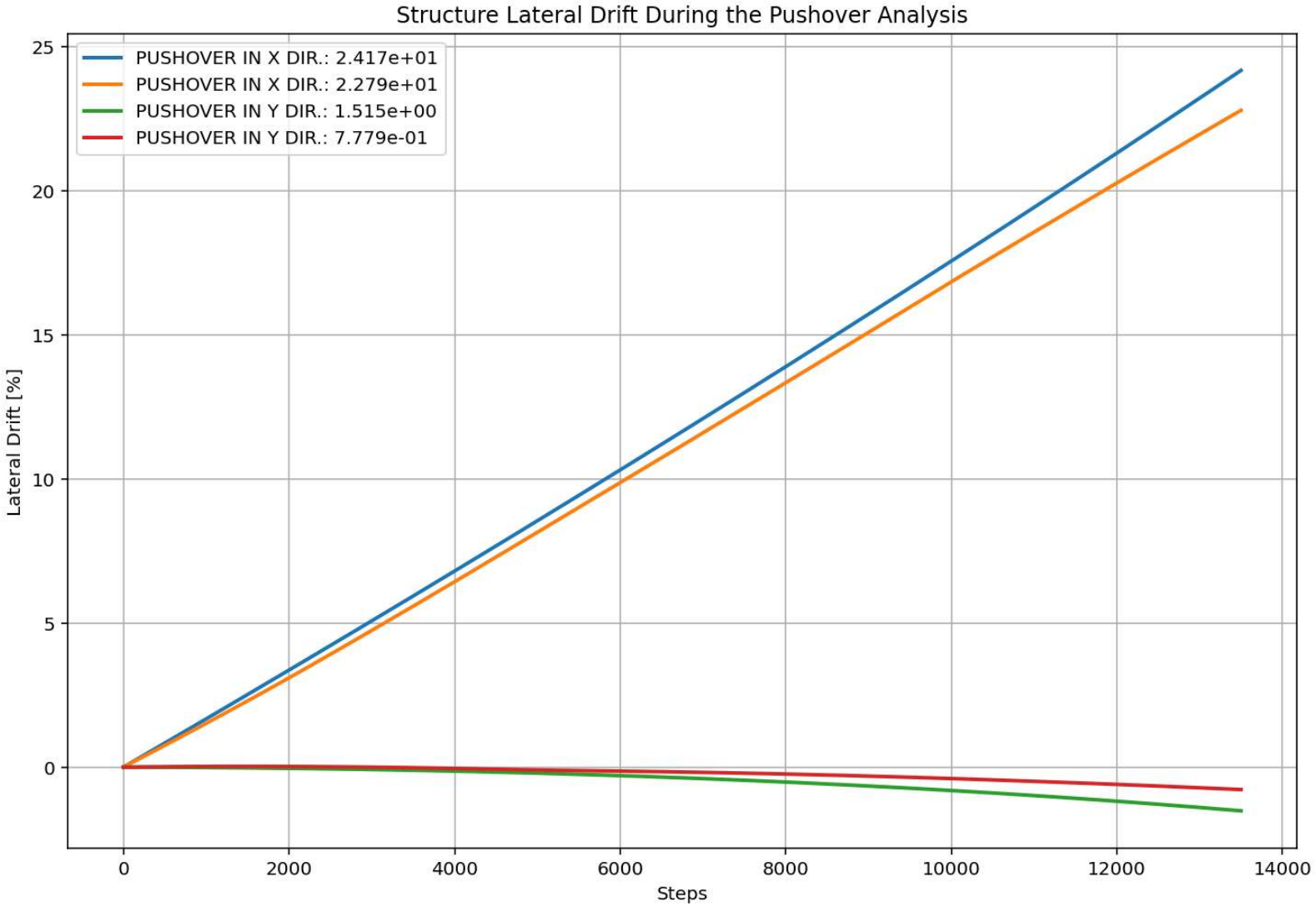
IPython Console History

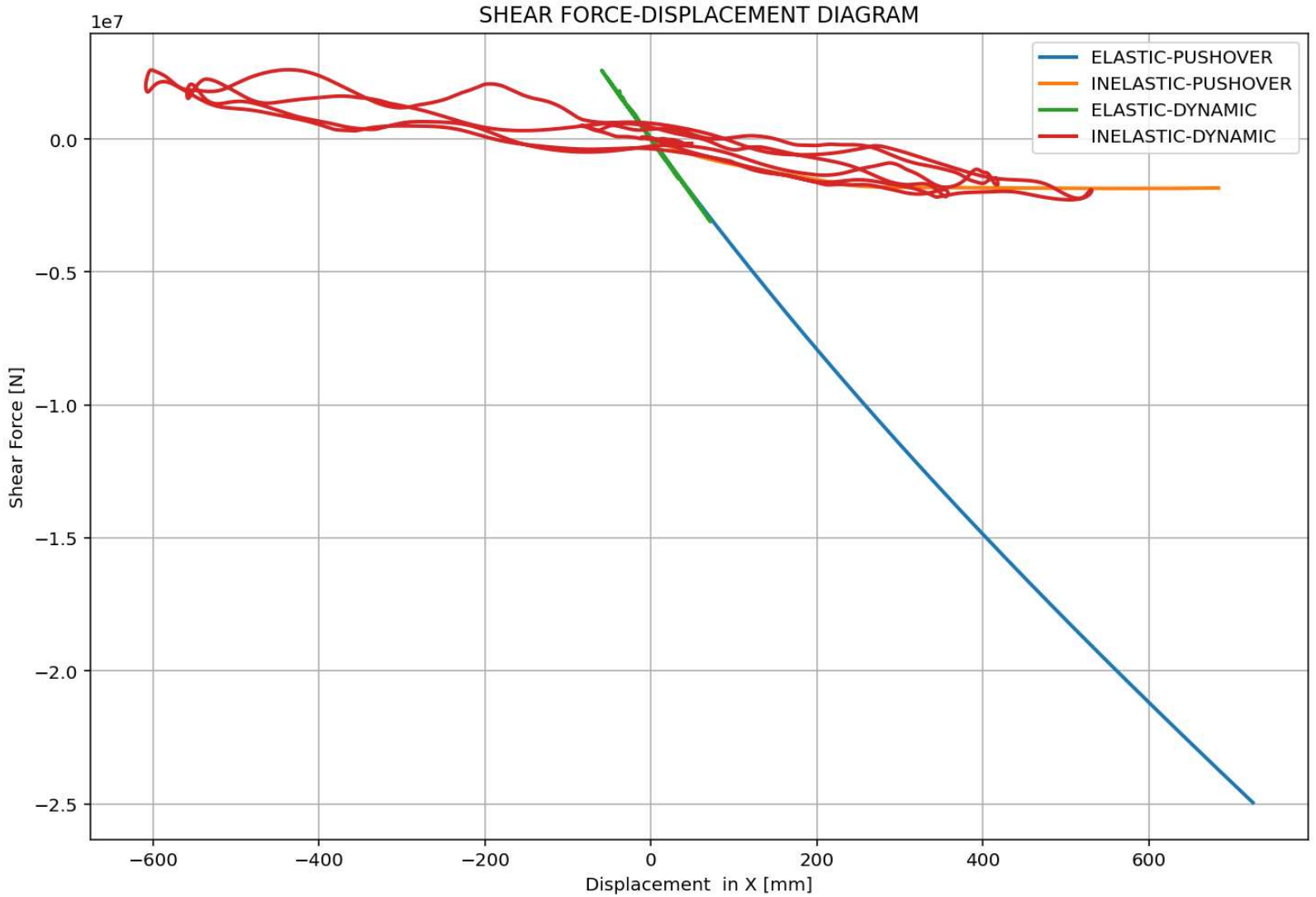
Inline Conda: anaconda3 (Python 3.12.7) LSP: Python Line 268, Col 31 UTF-8 CRLF RW Mem 45%

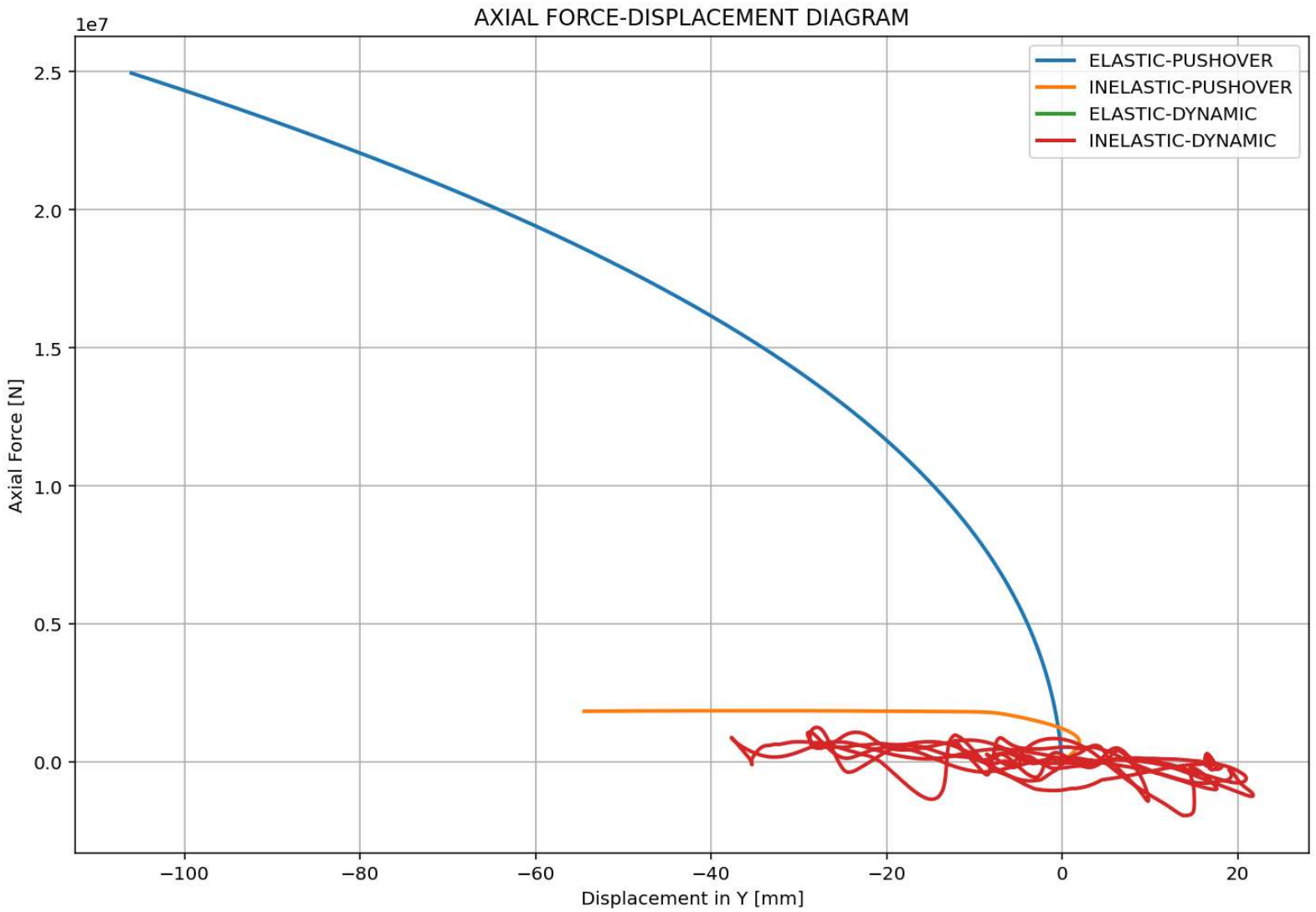
ELASTIC AND INELASTIC STATIC ANALYSIS (PUSHOVER)

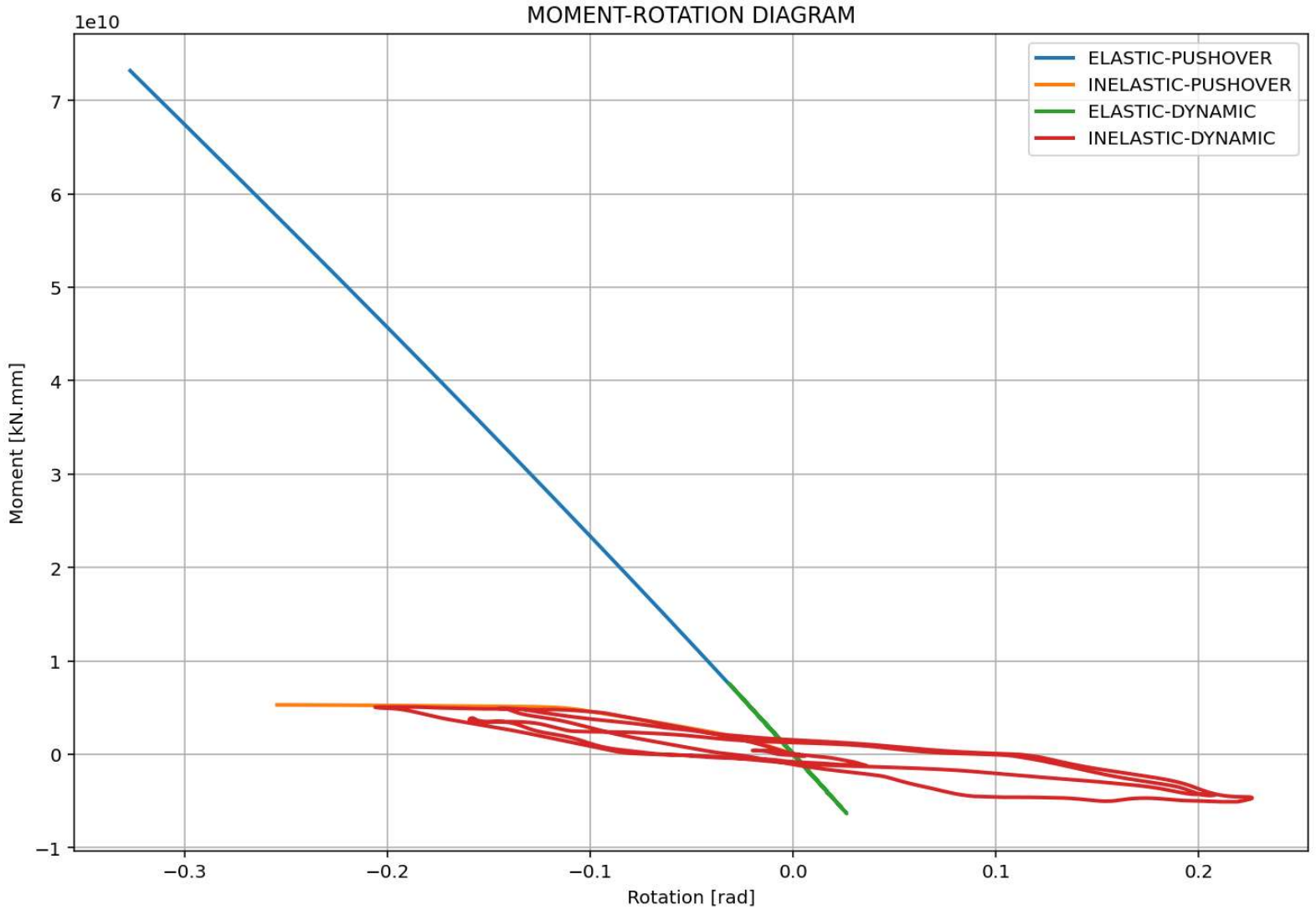

Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000
8000
3
9
10
4
6
8
5
7
1
2

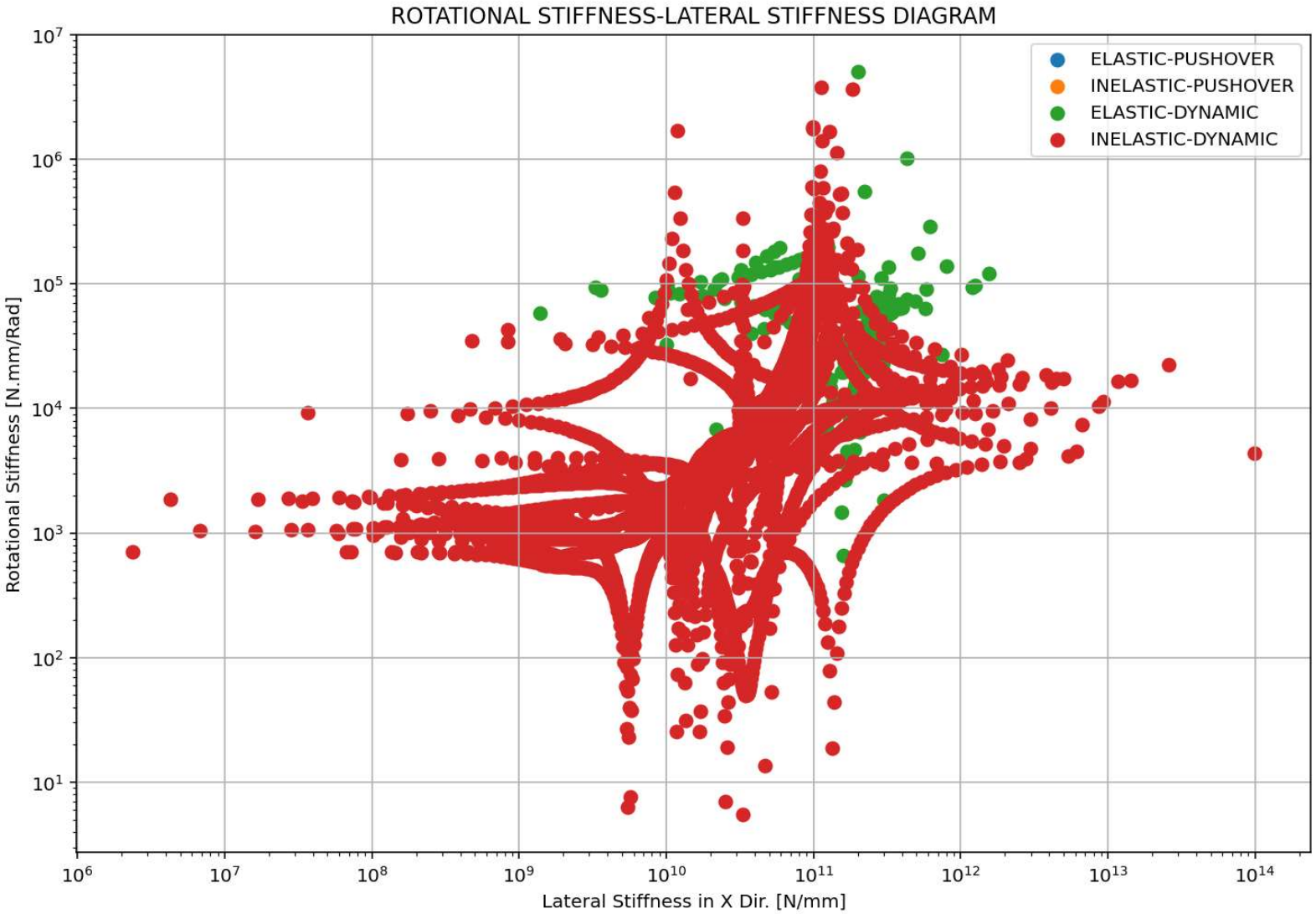

P-M Interaction
1e7
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC
Axial Force [N]
2.5
2.0
1.5
1.0
0.5
0.0
−1
0
1
2
3
4
5
6
7
Bending Moment [N.mm]
1e10

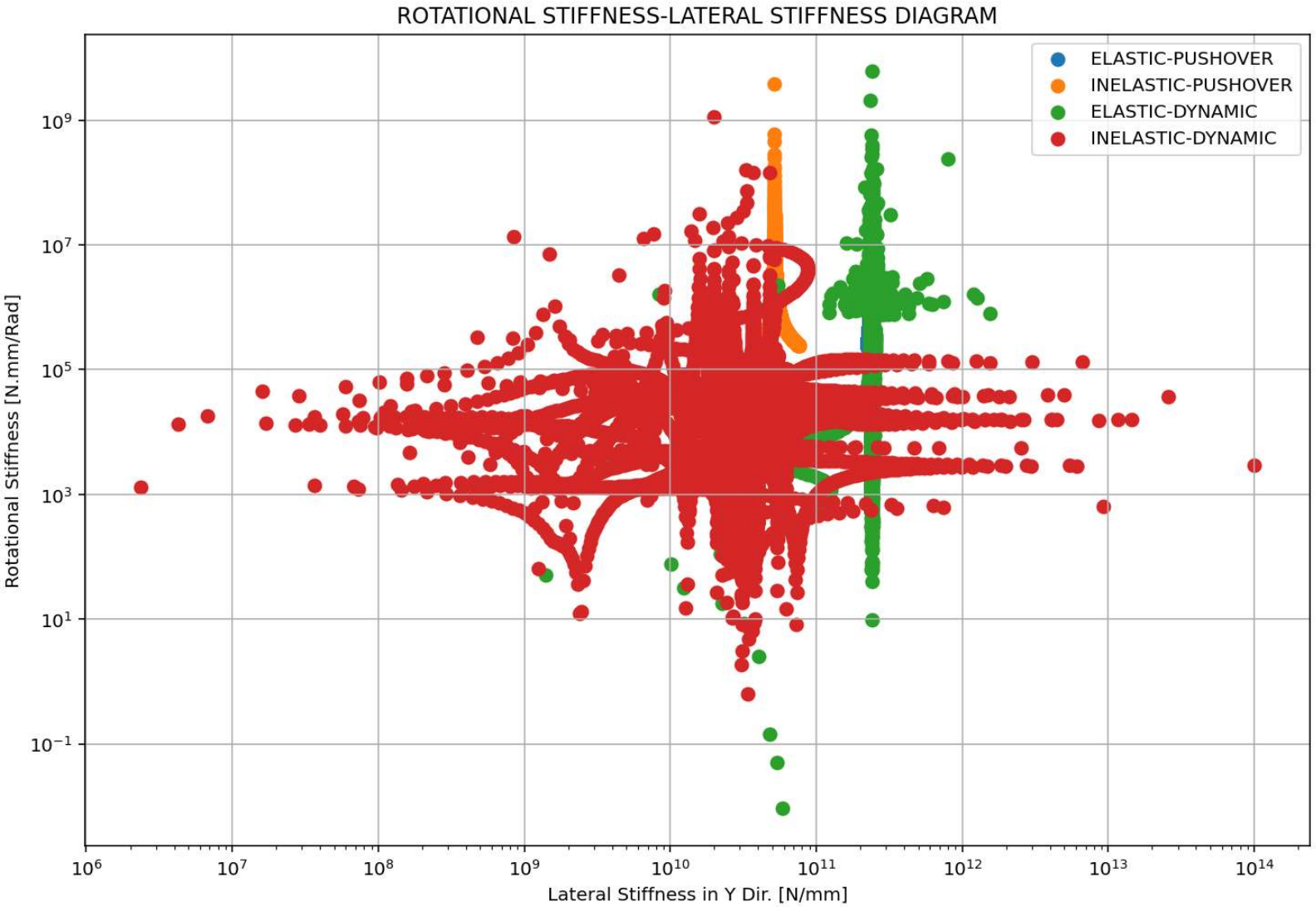

Structure Lateral Drift During the Pushover Analysis
PUSHOVER IN X DIR.: 2.417e+01
PUSHOVER IN X DIR.: 2.279e+01
PUSHOVER IN Y DIR.: 1.515e+00
PUSHOVER IN Y DIR.: 7.779e-01
Lateral Drift [%]
Steps
25
20
15
10
5
0
0
2000
4000
6000
8000
10000
12000
14000

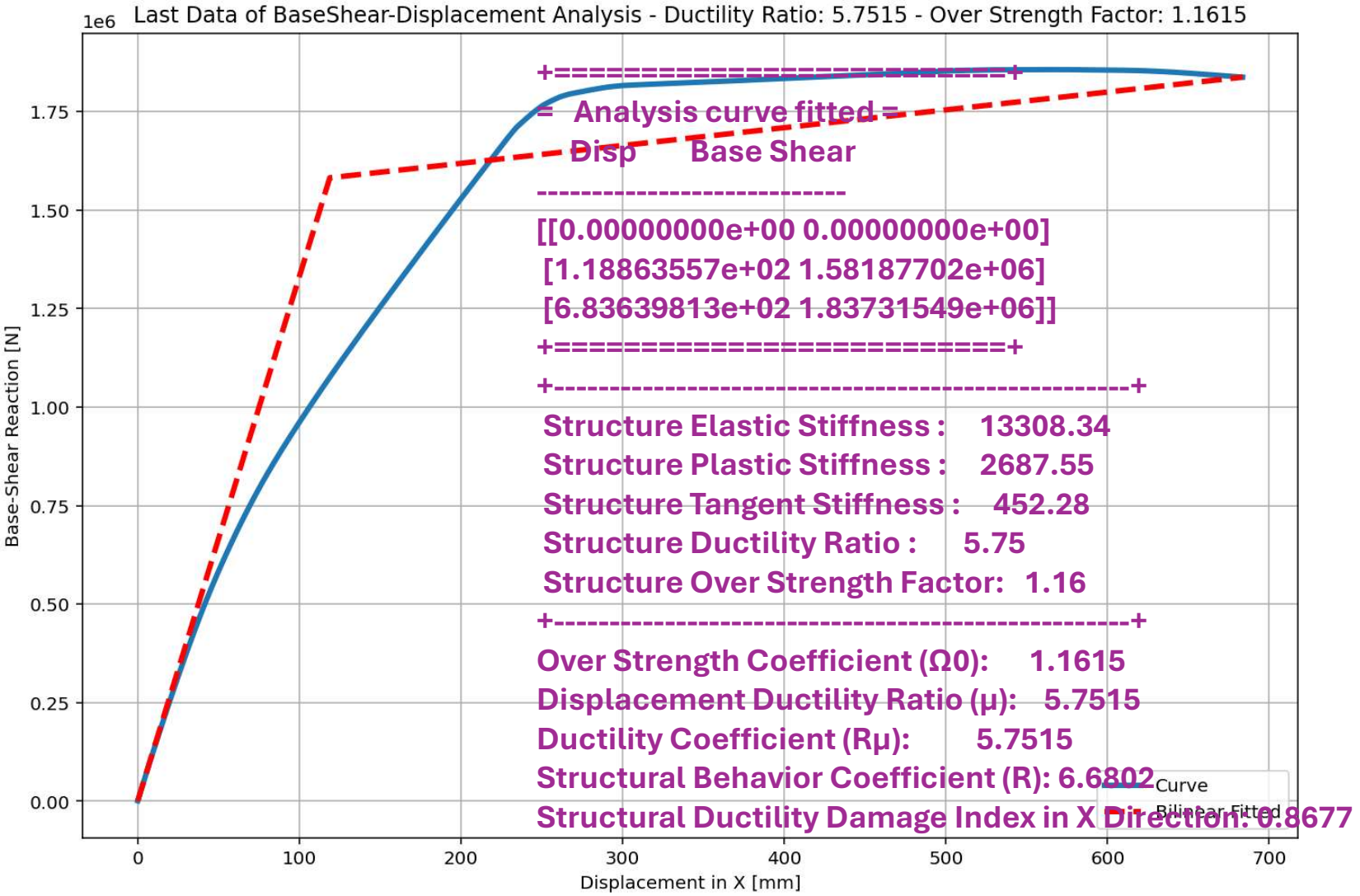

SHEAR FORCE-DISPLACEMENT DIAGRAM
1e7
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
Shear Force [N]
−600
−400
−200
0
200
400
600
Displacement in X [mm]
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC


AXIAL FORCE-DISPLACEMENT DIAGRAM
1e7
2.5
2.0
1.5
1.0
0.5
0.0
Axial Force [N]
−100
−80
−60
−40
−20
0
20
Displacement in Y [mm]
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC

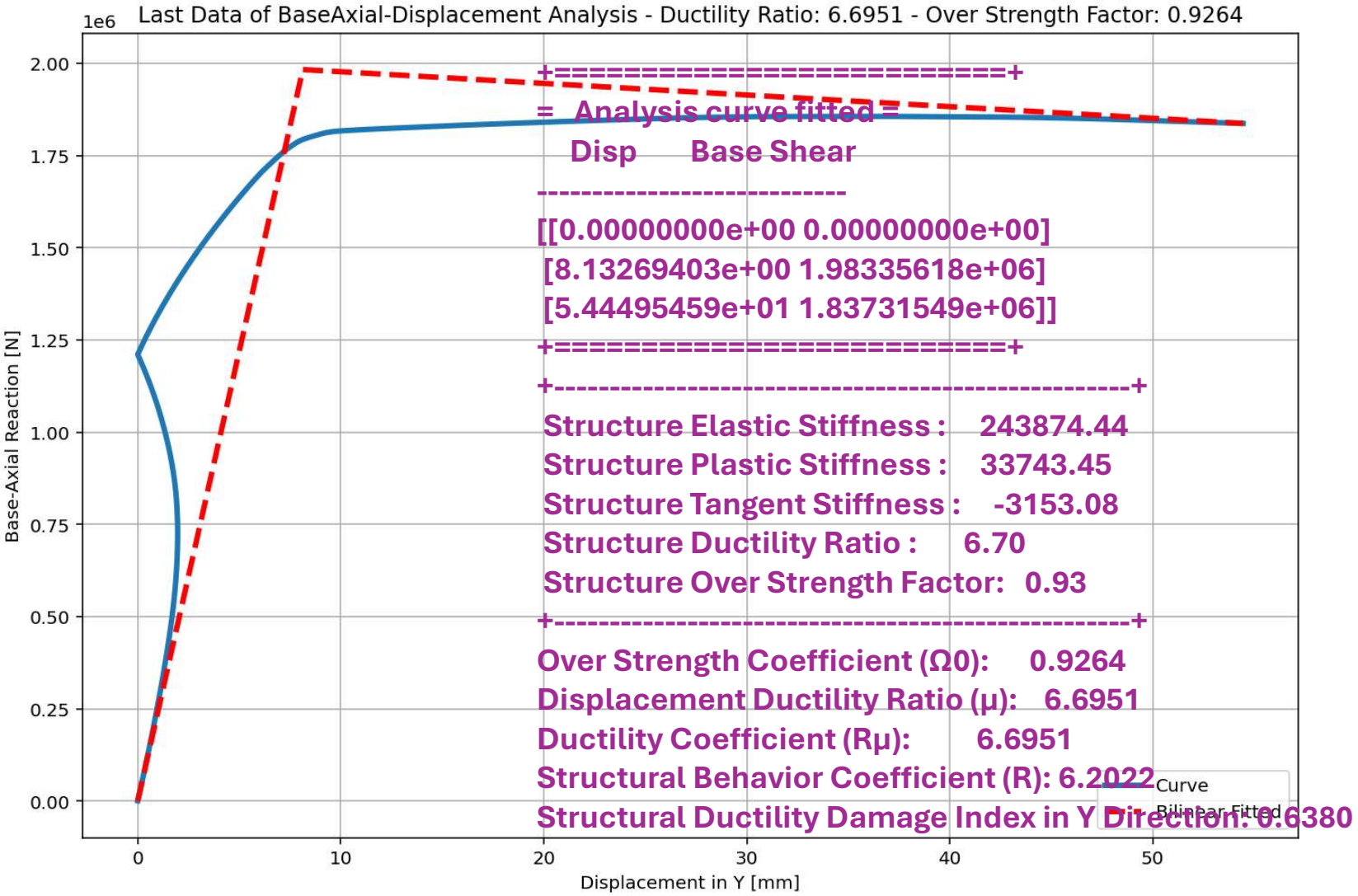

MOMENT-ROTATION DIAGRAM
1e10
Moment [kN.mm]
Rotation [rad]
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC
7
6
5
4
3
2
1
0
−1
−0.3
−0.2
−0.1
0.0
0.1
0.2


ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in X Dir. [N/mm]
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
10^{6}
10^{7}
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}


ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in Y Dir. [N/mm]
10^{9}
10^{7}
10^{5}
10^{3}
10^{1}
10^{-1}
10^{6}
10^{7}
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}

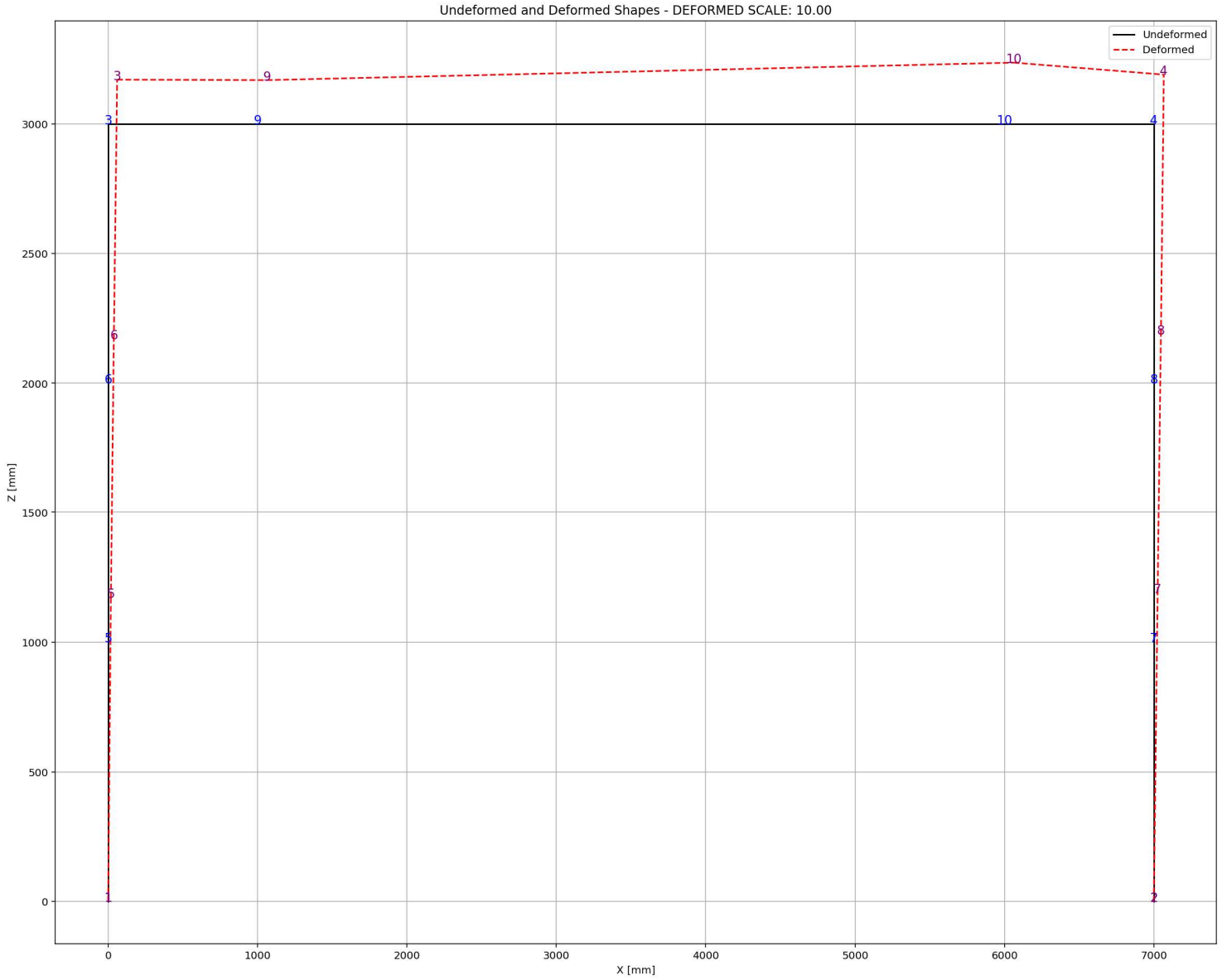

Last Data of BaseShear-Displacement Analysis - Ductility Ratio: 5.7515 - Over Strength Factor: 1.1615
1e6
Base-Shear Reaction [N]
Displacement in X [mm]
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
0
100
200
300
400
500
600
700
+============================+
= Analysis curve fitted =
Disp Base Shear

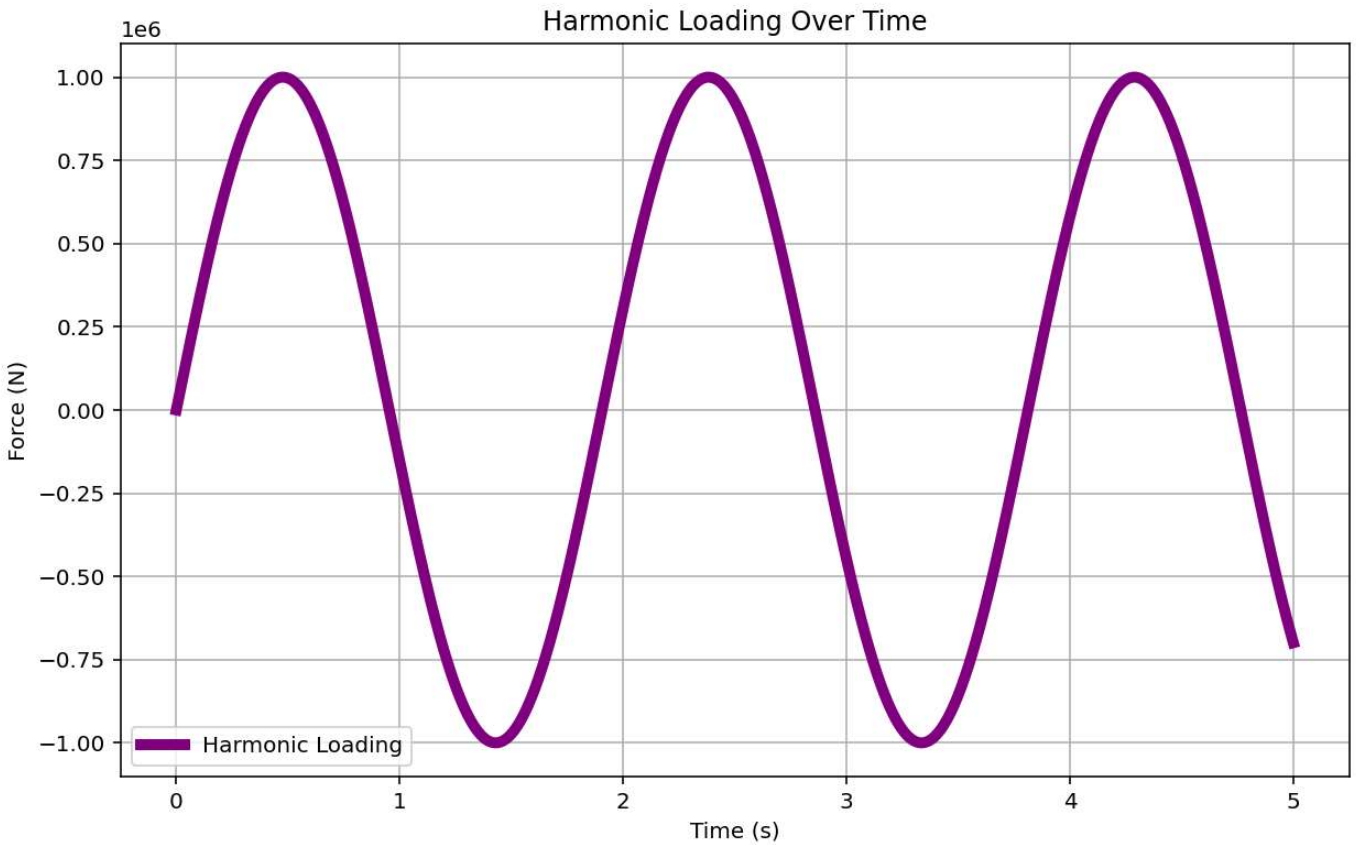
[[0.00000000e+00 0.00000000e+00]
[1.18863557e+02 1.58187702e+06]
[6.83639813e+02 1.83731549e+06]]
+============================+
+--+
Structure Elastic Stiffness : 13308.34
Structure Plastic Stiffness : 2687.55
Structure Tangent Stiffness : 452.28
Structure Ductility Ratio : 5.75
Structure Over Strength Factor: 1.16
+--+
Over Strength Coefficient (Ω0): 1.1615
Displacement Ductility Ratio (μ): 5.7515
Ductility Coefficient (Rμ): 5.7515
Structural Behavior Coefficient (R): 6.6802
Structural Ductility Damage Index in X Direction: 0.8677
Curve
Bilinear Fitted

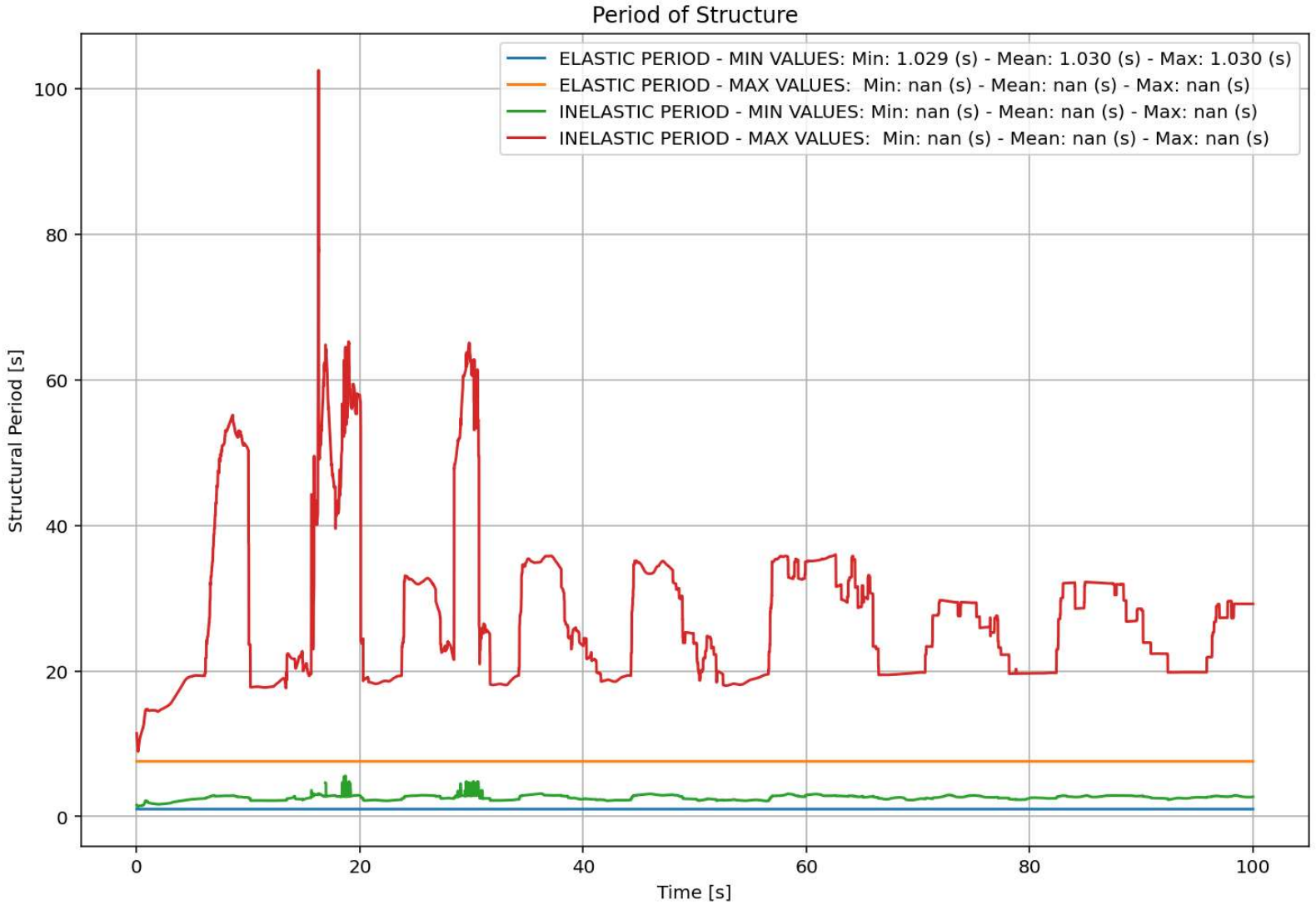

Last Data of BaseAxial-Displacement Analysis - Ductility Ratio: 6.6951 - Over Strength Factor: 0.9264
1e6
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Base-Axial Reaction [N]
0
10
20
30
40
50
Displacement in Y [mm]
+============================+
= Analysis curve fitted =
Disp Base Shear

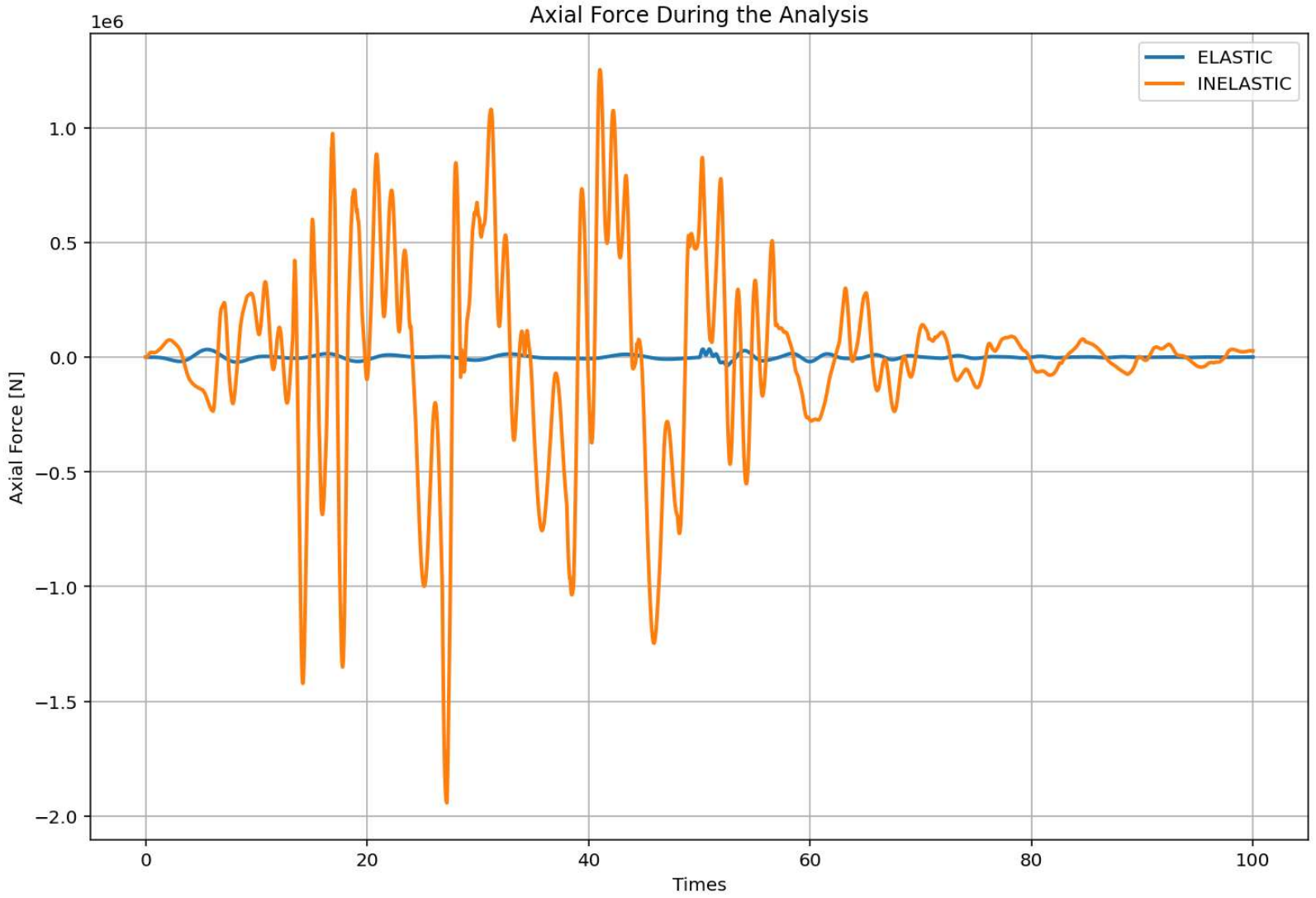
[[0.00000000e+00 0.00000000e+00]
[8.13269403e+00 1.98335618e+06]
[5.44495459e+01 1.83731549e+06]]
+============================+
+--+
Structure Elastic Stiffness : 243874.44
Structure Plastic Stiffness : 33743.45
Structure Tangent Stiffness : -3153.08
Structure Ductility Ratio : 6.70
Structure Over Strength Factor: 0.93
+--+
Over Strength Coefficient (Ω0): 0.9264
Displacement Ductility Ratio (μ): 6.6951
Ductility Coefficient (Rμ): 6.6951
Structural Behavior Coefficient (R): 6.2022
Structural Ductility Damage Index in Y Direction: 0.6380
Curve
Bilinear Fitted

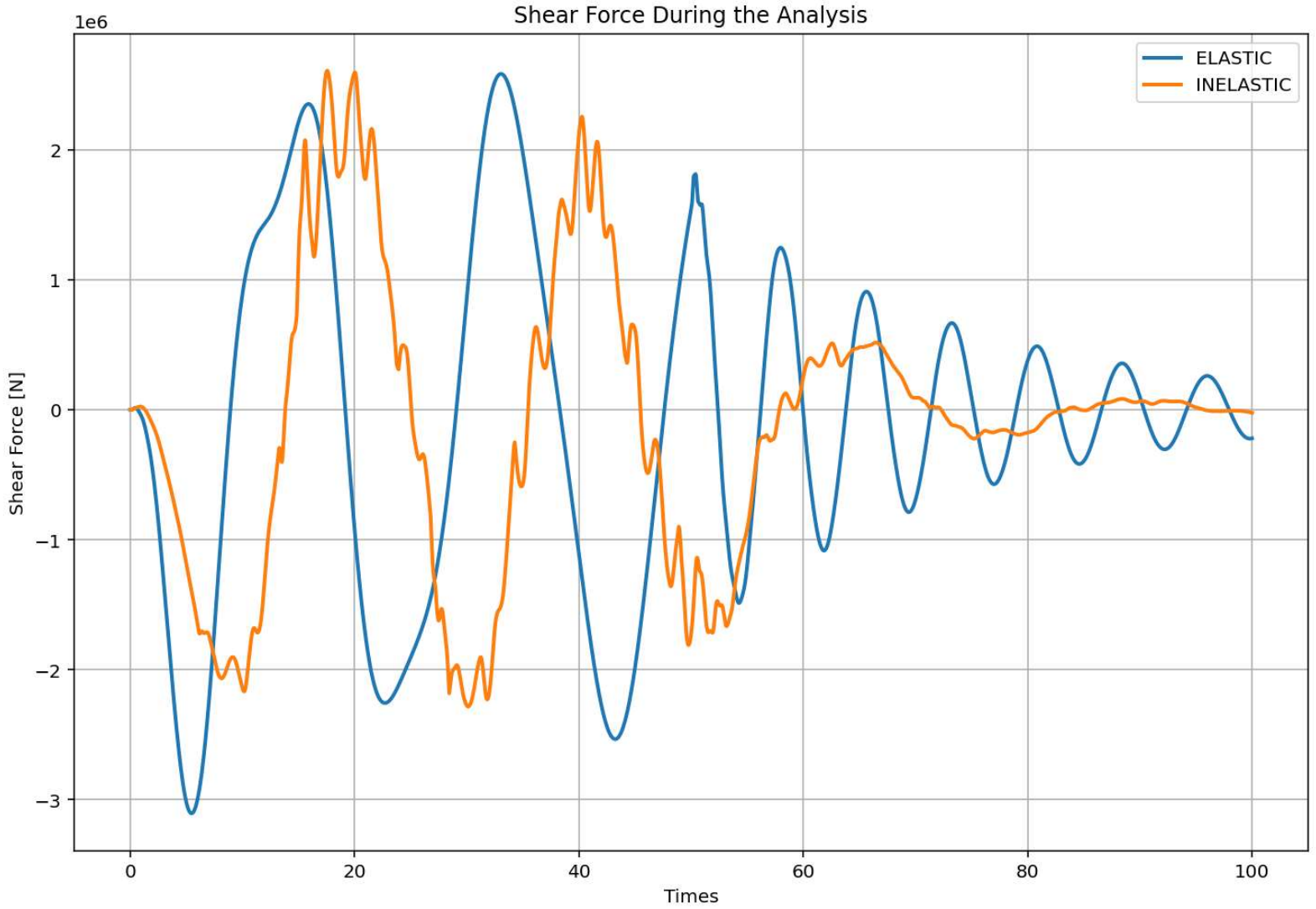
ELASTIC AND INELASTIC DYNAMIC ANALYSIS

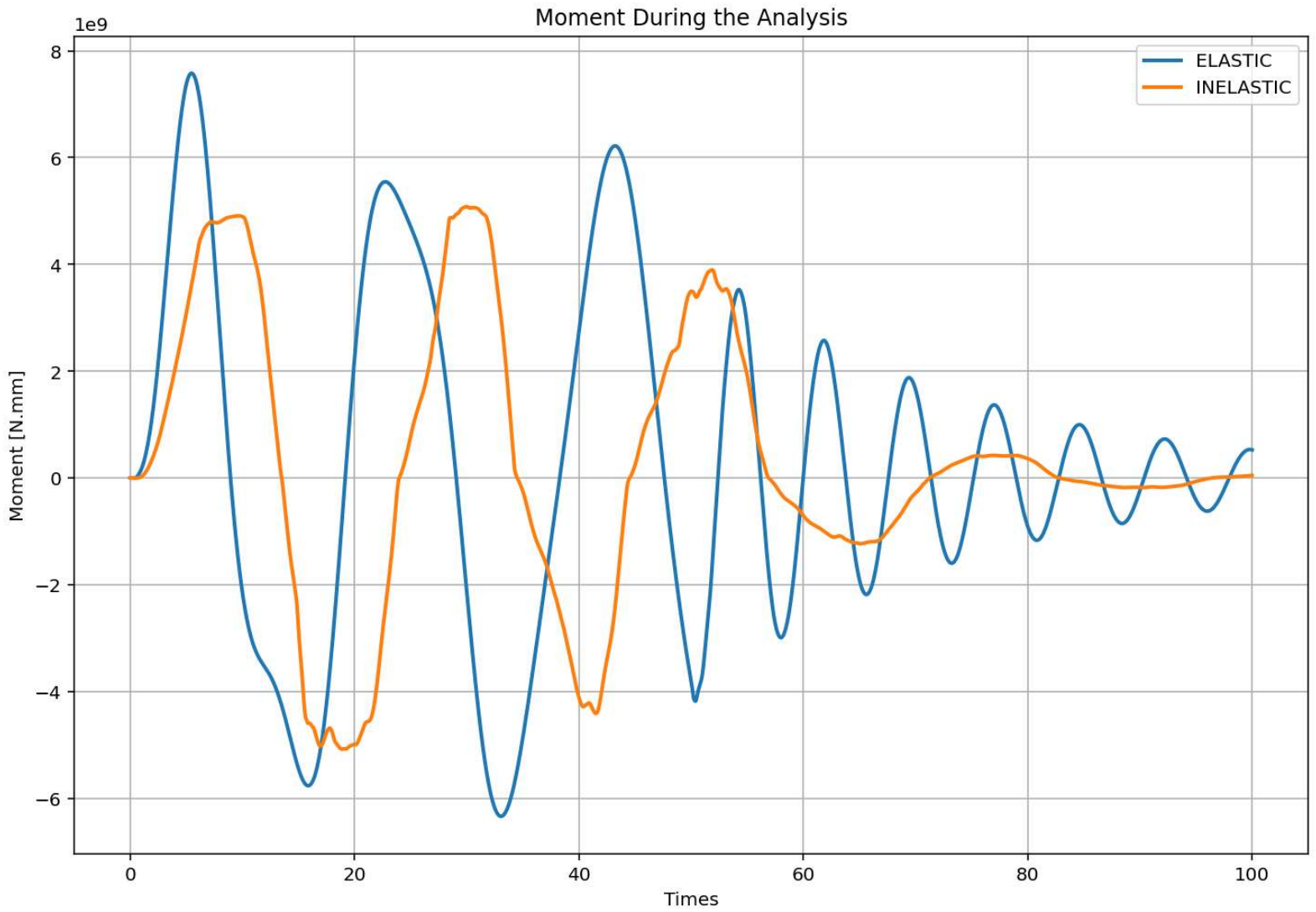

Undeformed and Deformed Shapes - DEFORMED SCALE: 10.00
Undeformed
Deformed
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000
1
2
3
4
5
6
7
8
9
10

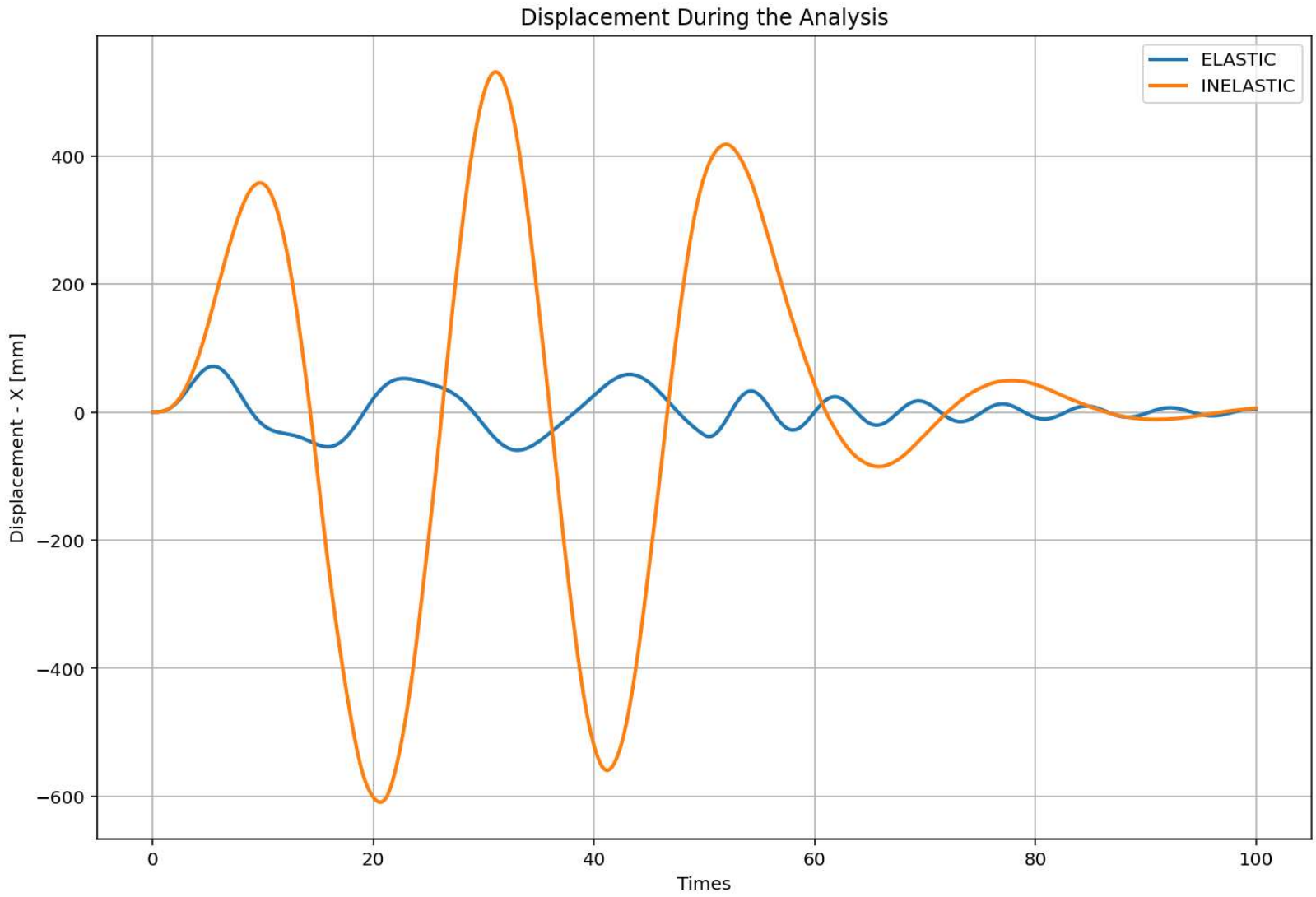

Harmonic Loading Over Time
1e6
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
Force (N)
0
1
2
3
4
5
Time (s)
Harmonic Loading

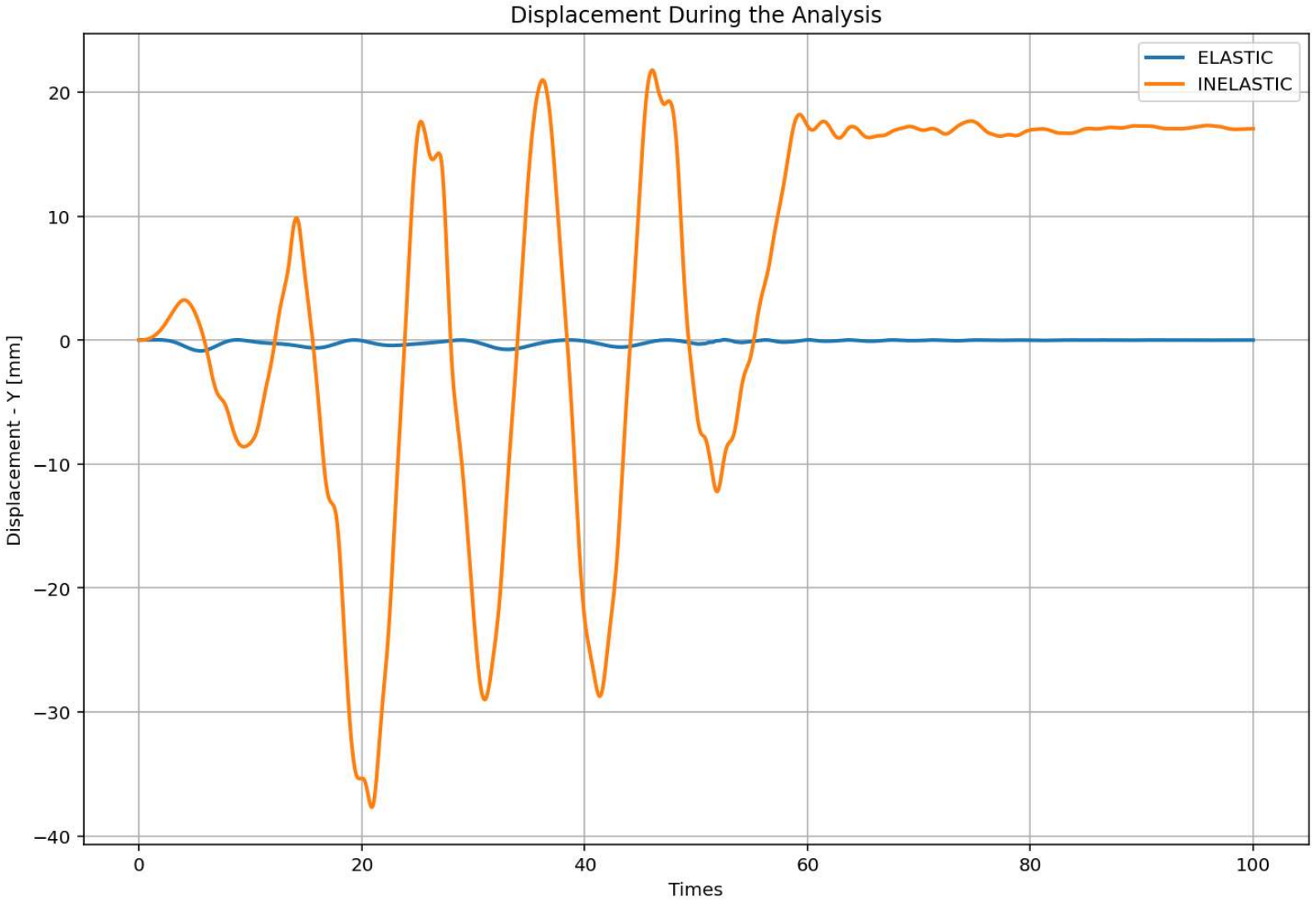

Period of Structure
ELASTIC PERIOD - MIN VALUES: Min: 1.029 (s) - Mean: 1.030 (s) - Max: 1.030 (s)
ELASTIC PERIOD - MAX VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
INELASTIC PERIOD - MIN VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
INELASTIC PERIOD - MAX VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
Structural Period [s]
Time [s]
0
20
40
60
80
100

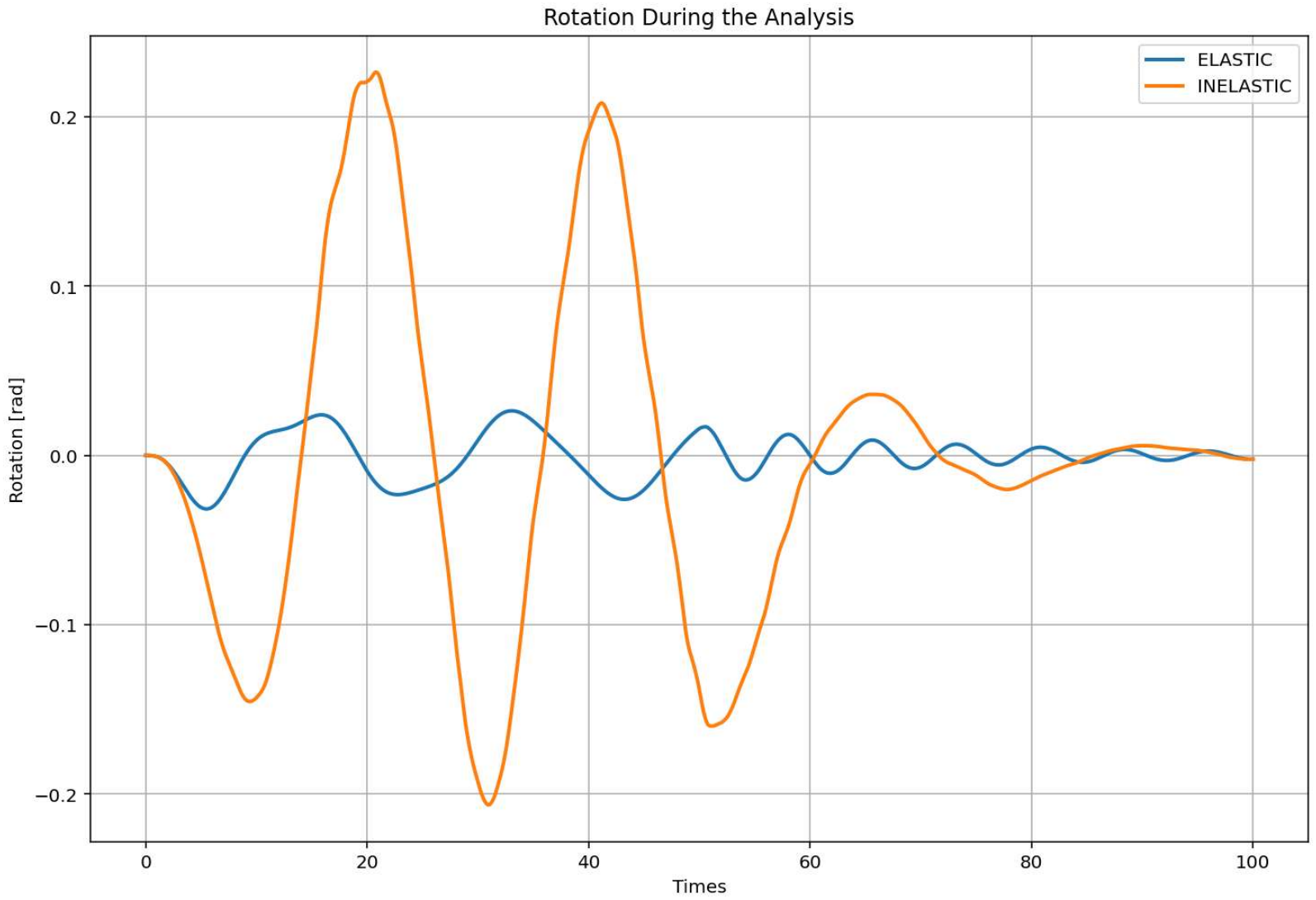

Axial Force During the Analysis
1e6
ELASTIC
INELASTIC
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
Axial Force [N]
0
20
40
60
80
100
Times

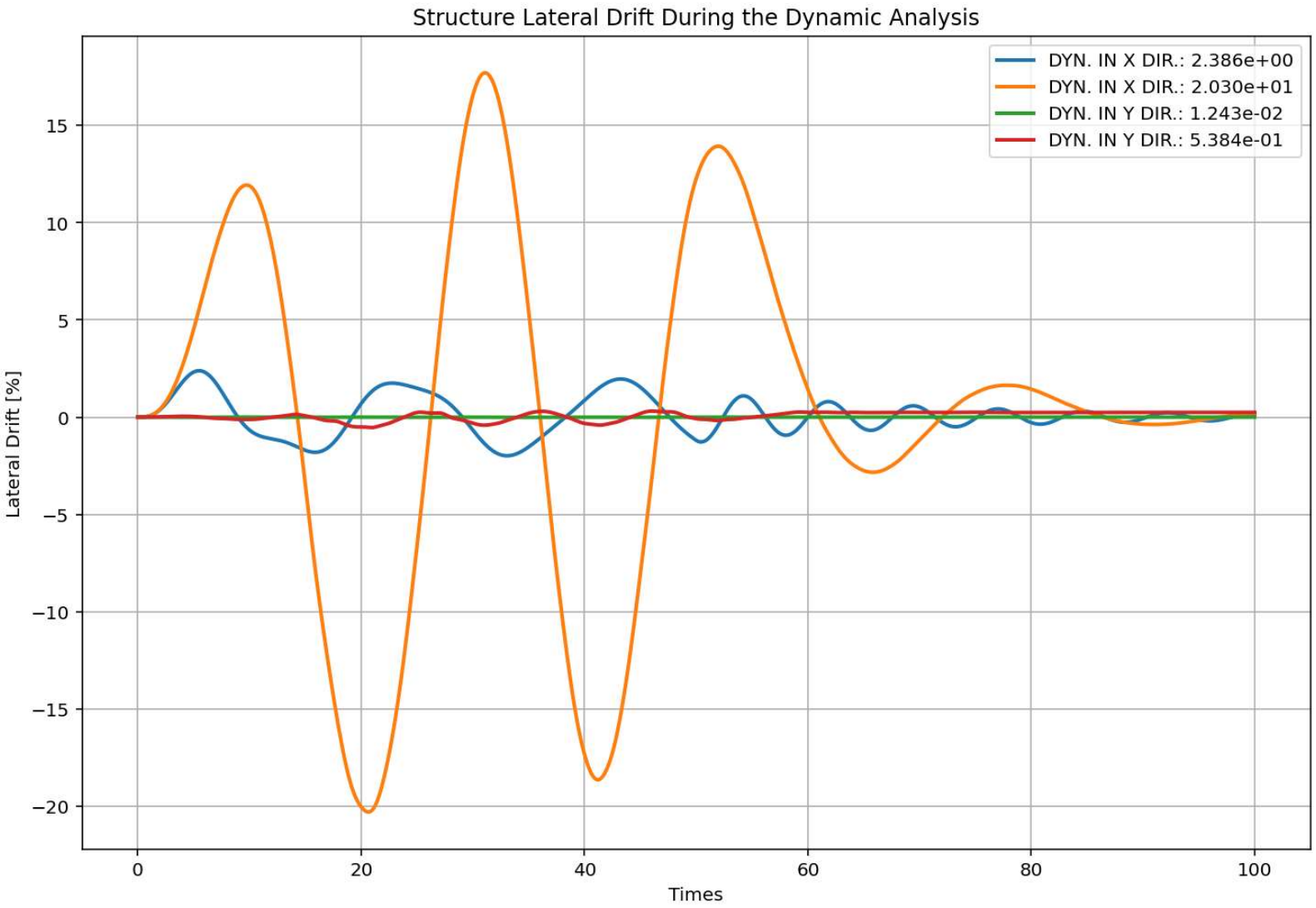

Shear Force During the Analysis
1e6
ELASTIC
INELASTIC
Shear Force [N]
2
1
0
−1
−2
−3
0
20
40
60
80
100
Times

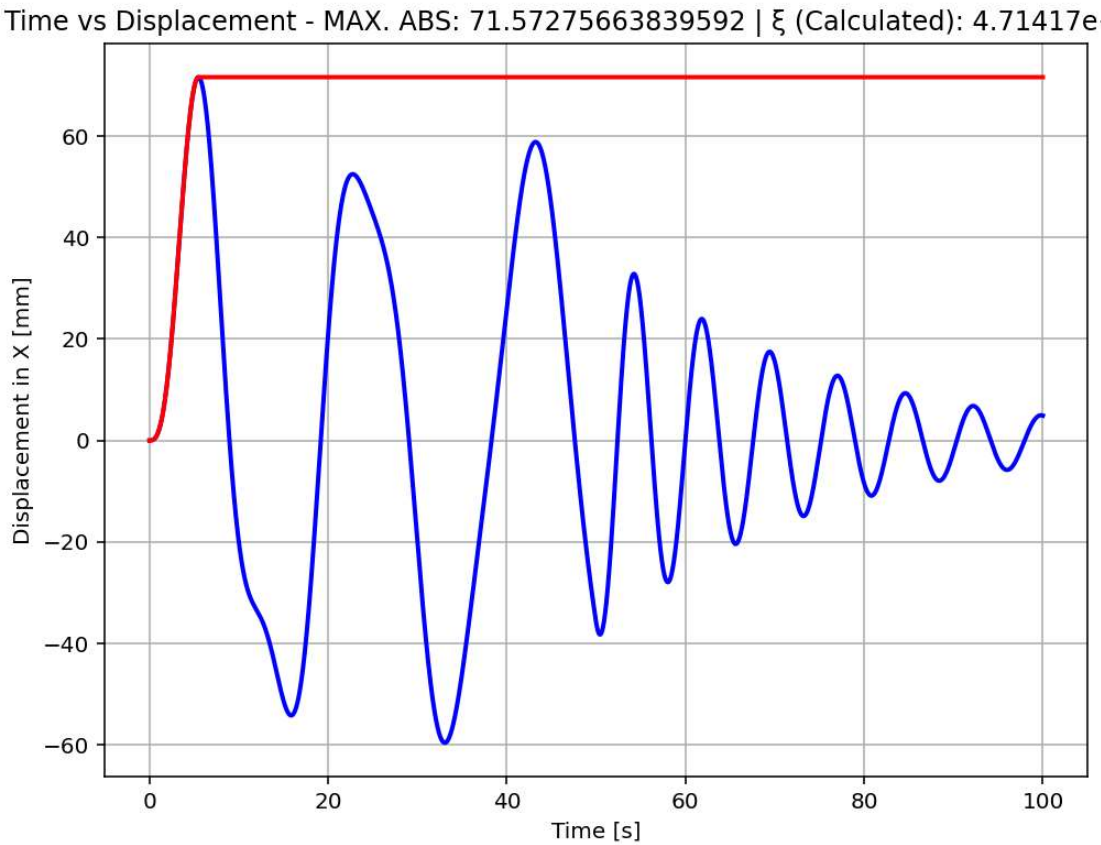

Moment During the Analysis
1e9
8
6
4
2
0
−2
−4
−6
Moment [N.mm]
0
20
40
60
80
100
Times
ELASTIC
INELASTIC

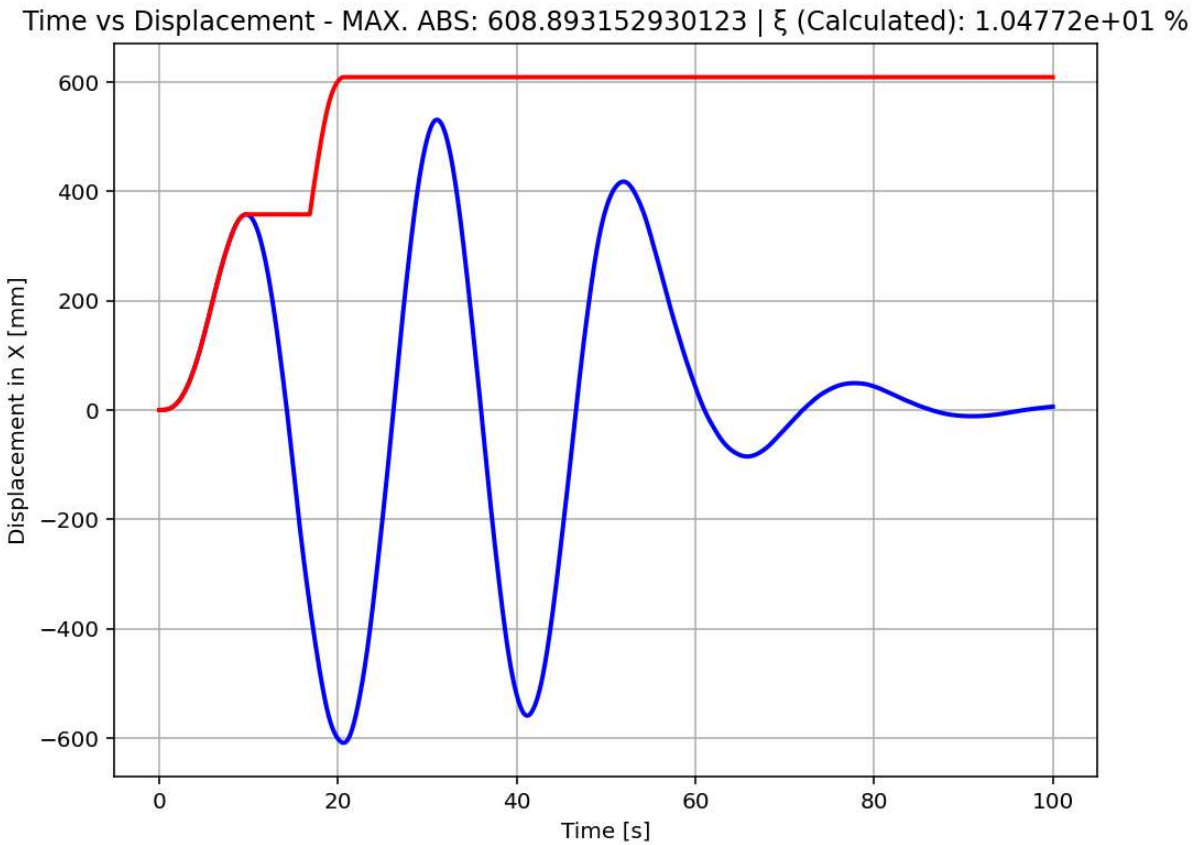

Displacement During the Analysis
ELASTIC
INELASTIC
400
200
0
−200
−400
−600
Displacement - X [mm]
0
20
40
60
80
100
Times

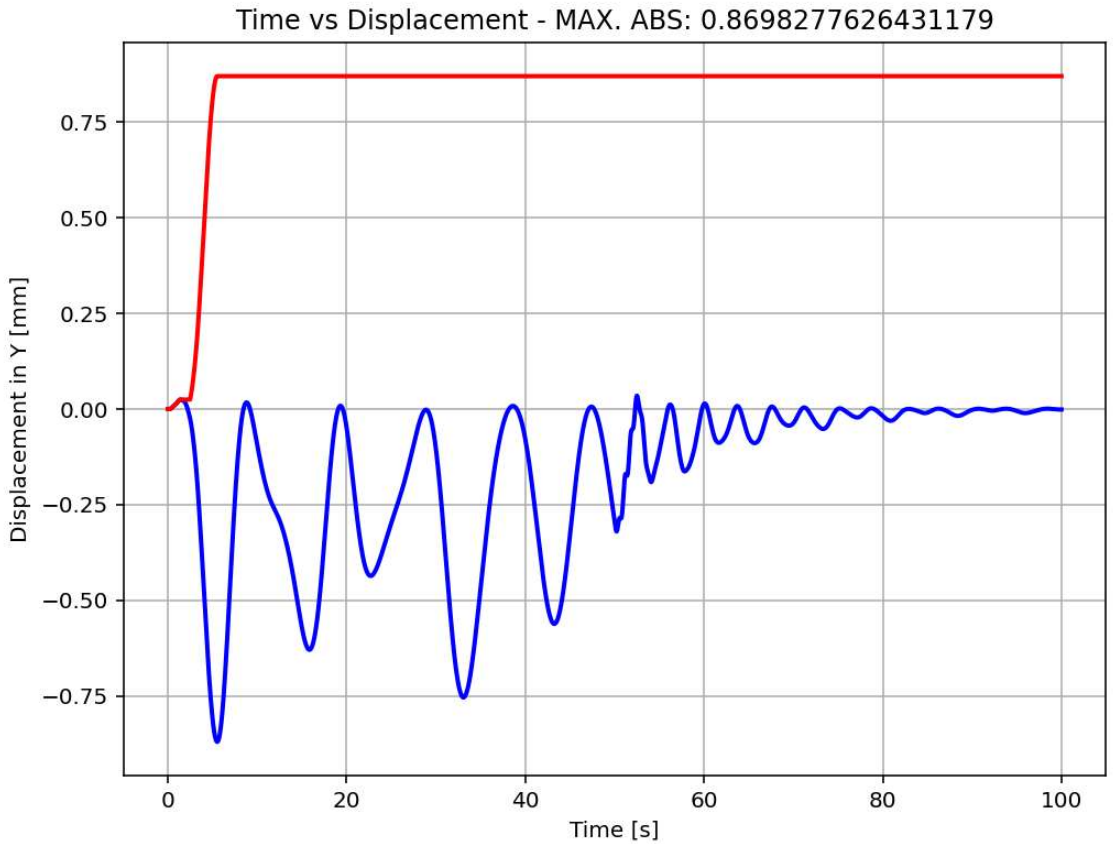

Displacement During the Analysis
ELASTIC
INELASTIC
Displacement - Y [mm]
20
10
0
−10
−20
−30
−40
0
20
40
60
80
100
Times

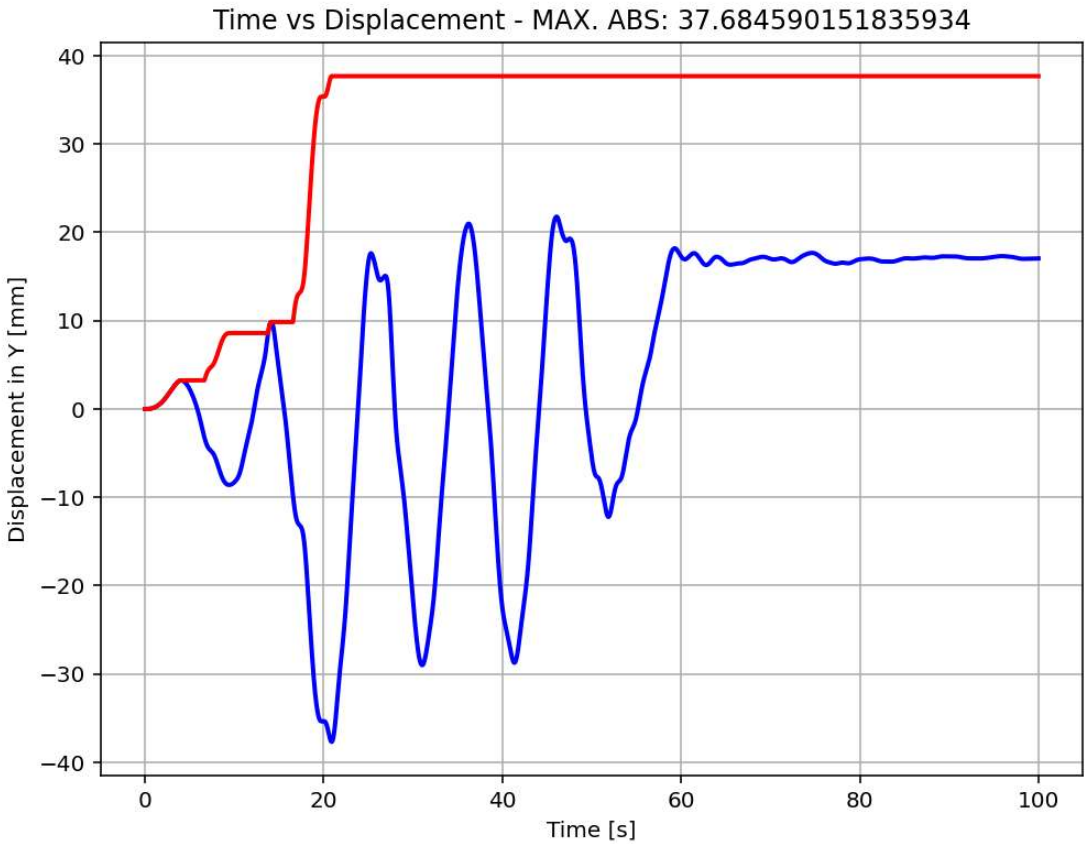

Rotation During the Analysis
ELASTIC
INELASTIC
Rotation [rad]
0.2
0.1
0.0
−0.1
−0.2
0
20
40
60
80
100
Times

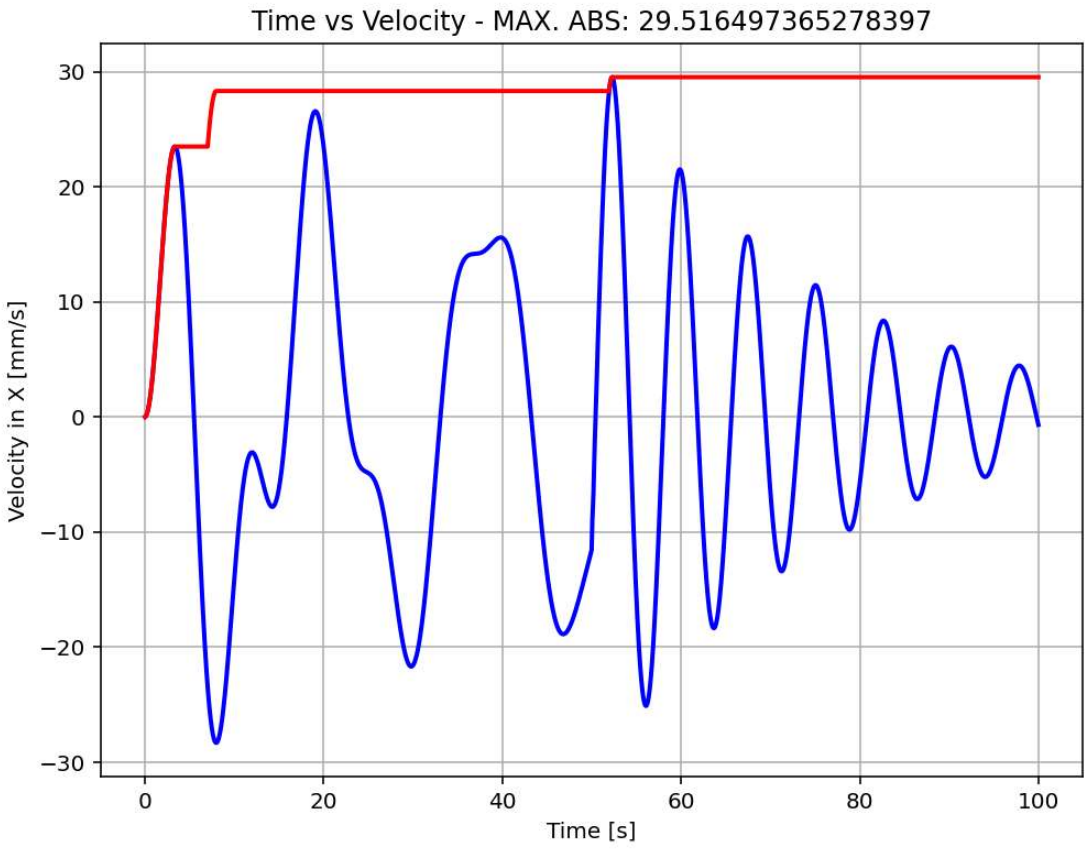

Structure Lateral Drift During the Dynamic Analysis
DYN. IN X DIR.: 2.386e+00
DYN. IN X DIR.: 2.030e+01
DYN. IN Y DIR.: 1.243e-02
DYN. IN Y DIR.: 5.384e-01
Lateral Drift [%]
15
10
5
0
−5
−10
−15
−20
0
20
40
60
80
100
Times

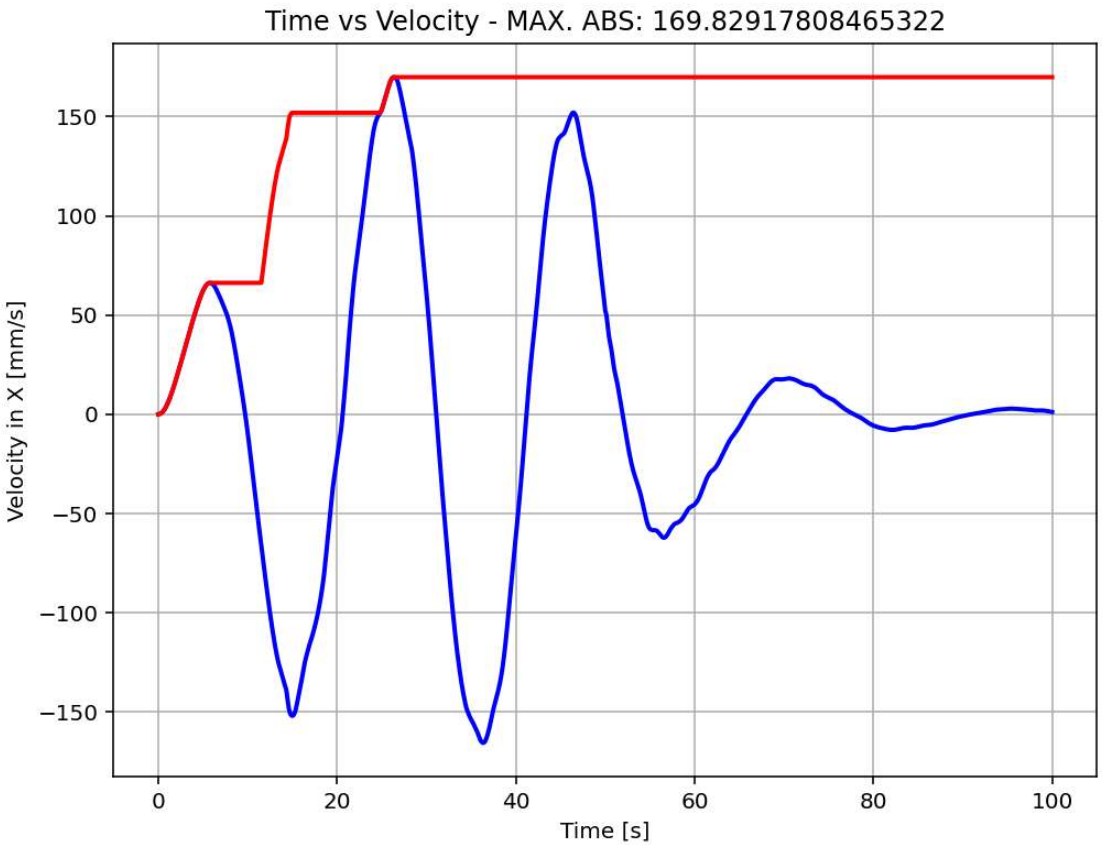

Time vs Displacement - MAX. ABS: 71.57275663839592 | ξ (Calculated): 4.71417e+00 %
Displacement in X [mm]
Time [s]
60
40
20
0
−20
−40
−60
0
20
40
60
80
100

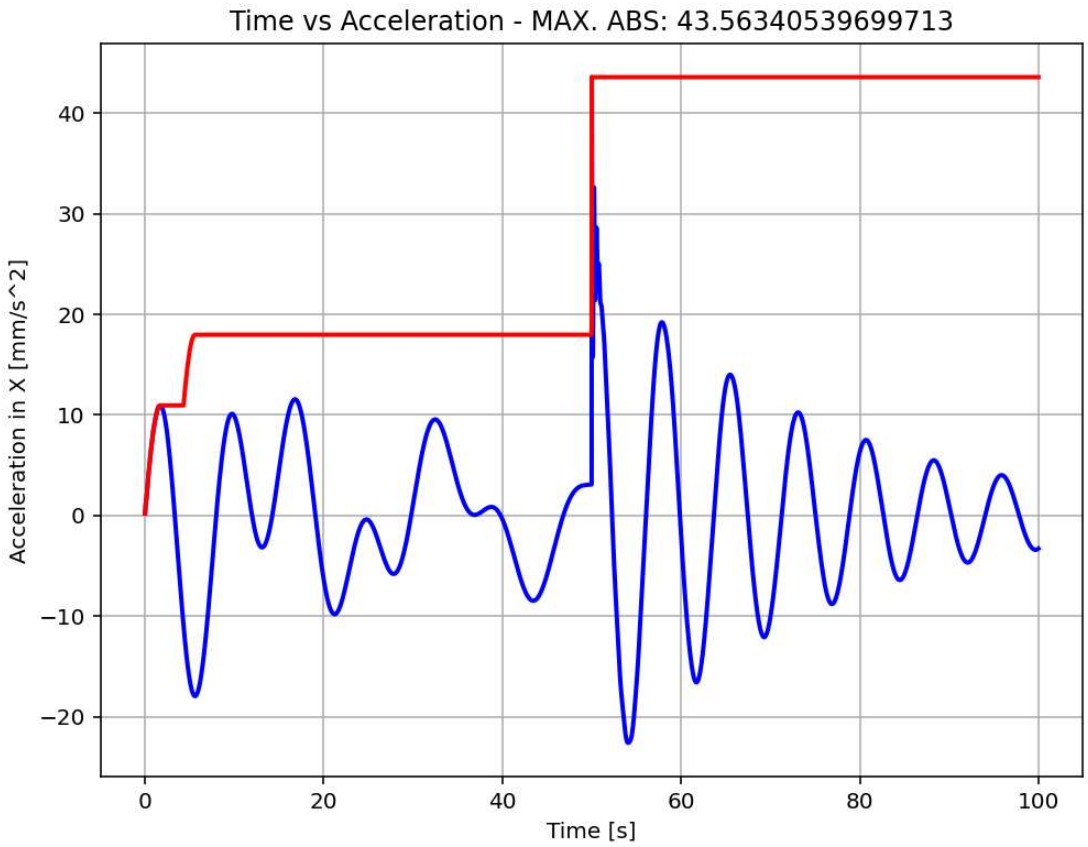

Time vs Displacement - MAX. ABS: 608.893152930123 | ξ (Calculated): 1.04772e+01 %
Displacement in X [mm]
Time [s]
600
400
200
0
−200
−400
−600
0
20
40
60
80
100

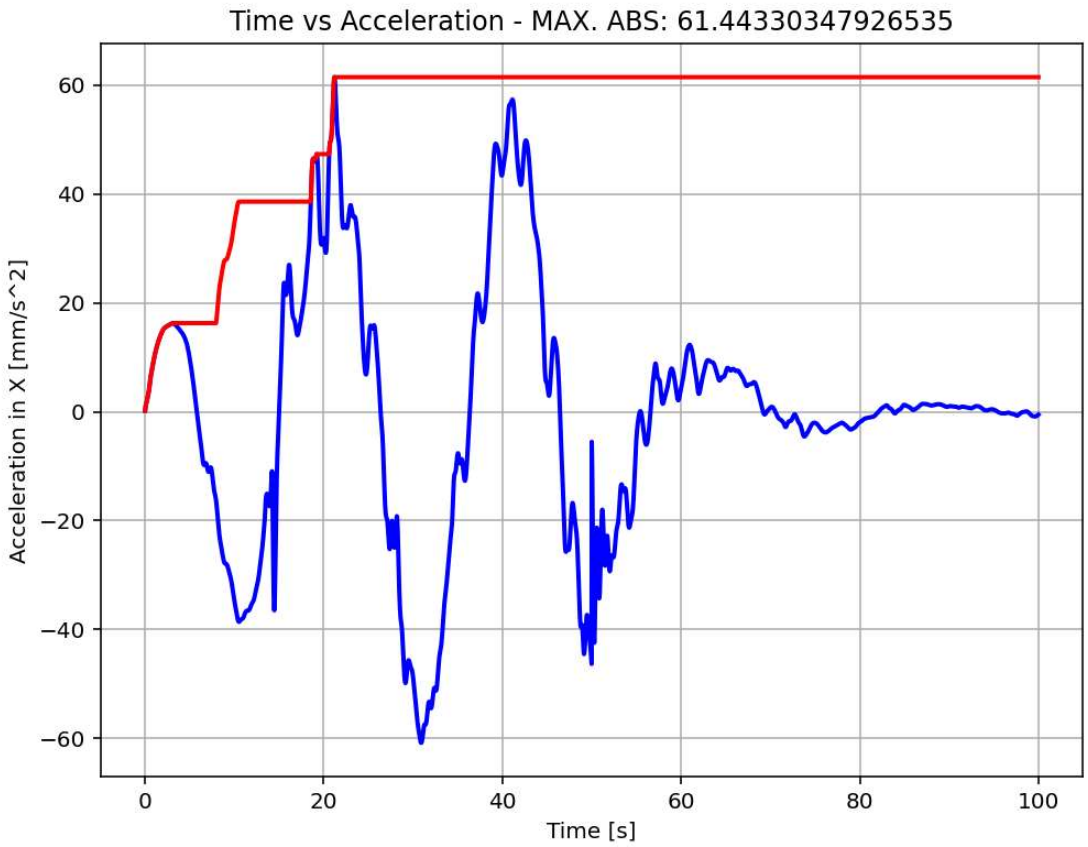

Time vs Displacement - MAX. ABS: 0.8698277626431179
Displacement in Y [mm]
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
0
20
40
60
80
100
Time [s]

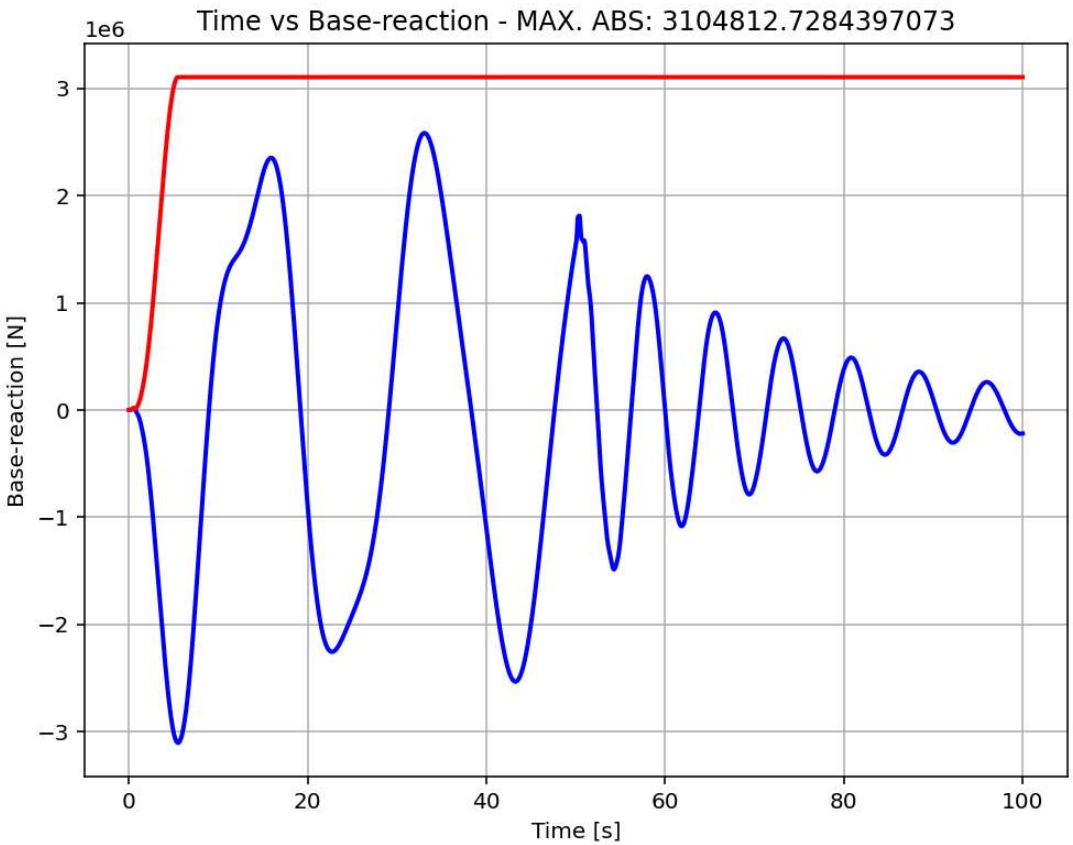

Time vs Displacement - MAX. ABS: 37.684590151835934
Displacement in Y [mm]
Time [s]
40
30
20
10
0
−10
−20
−30
−40
0
20
40
60
80
100

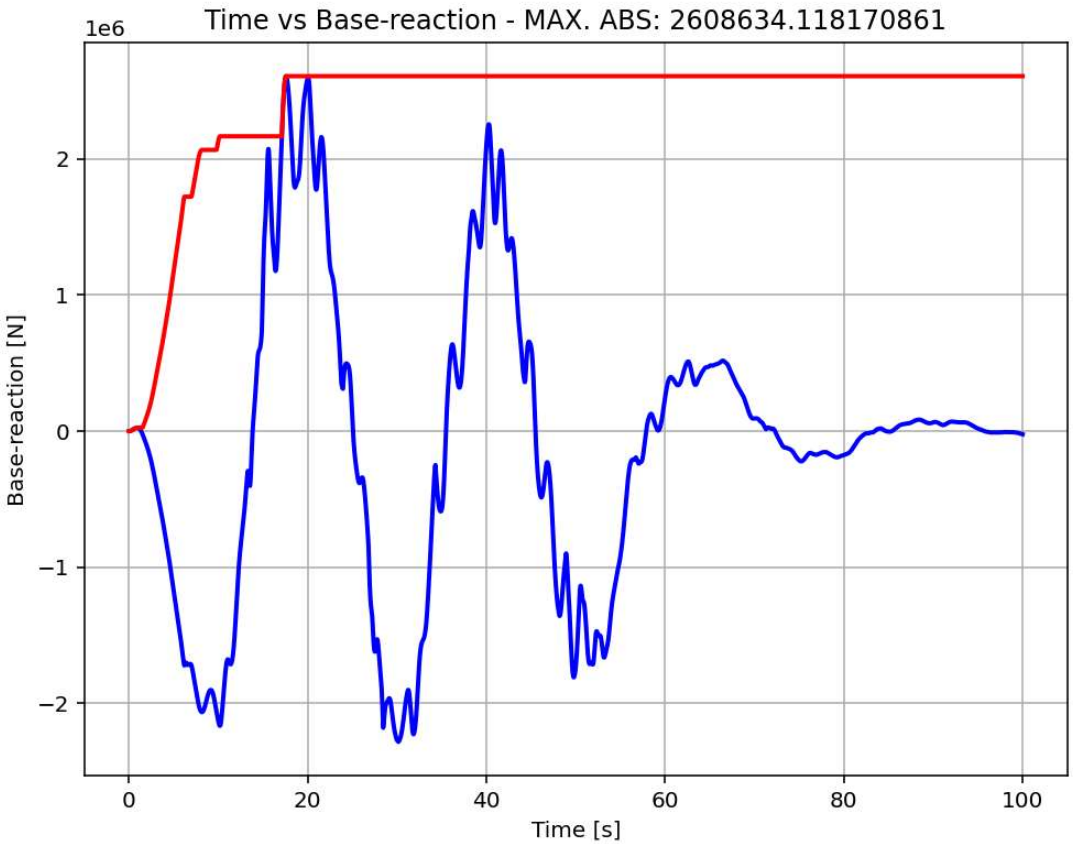

Time vs Velocity - MAX. ABS: 29.516497365278397
Velocity in X [mm/s]
Time [s]
30
20
10
0
−10
−20
−30
0
20
40
60
80
100

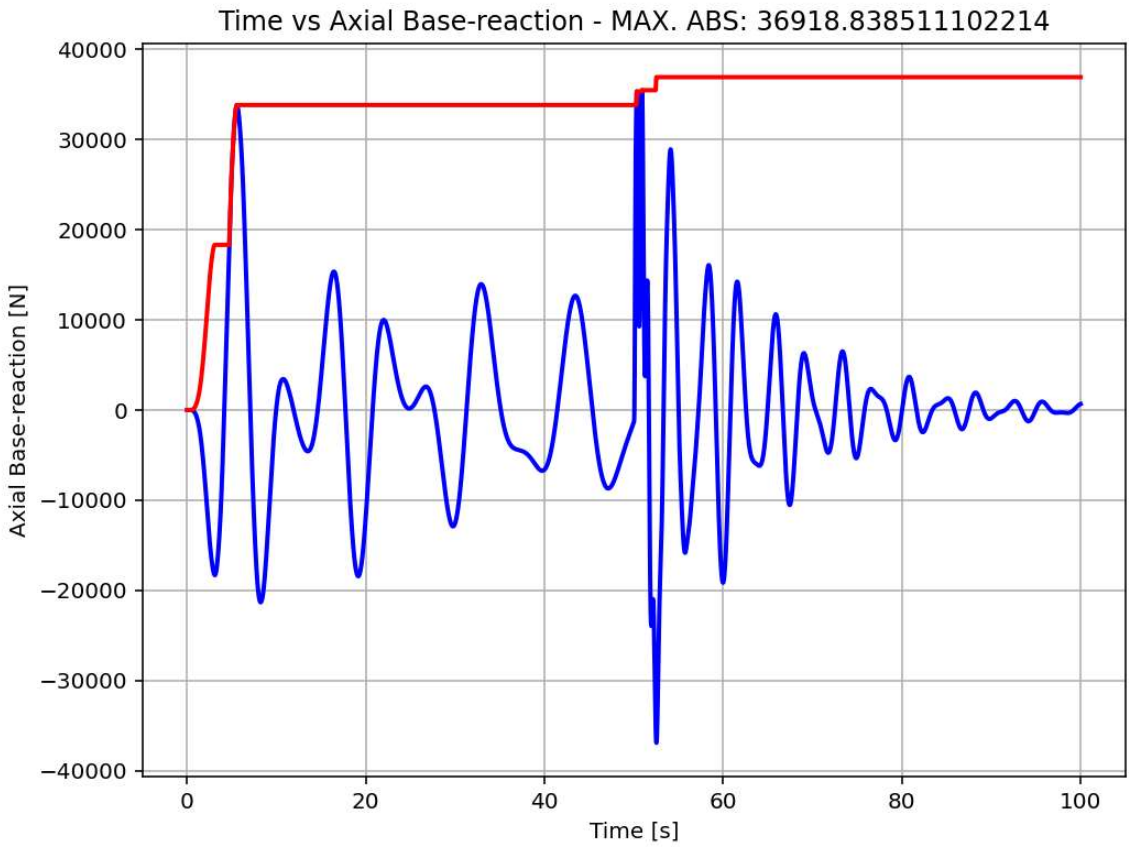

Time vs Velocity - MAX. ABS: 169.82917808465322
Velocity in X [mm/s]
Time [s]
150
100
50
0
−50
−100
−150
0
20
40
60
80
100

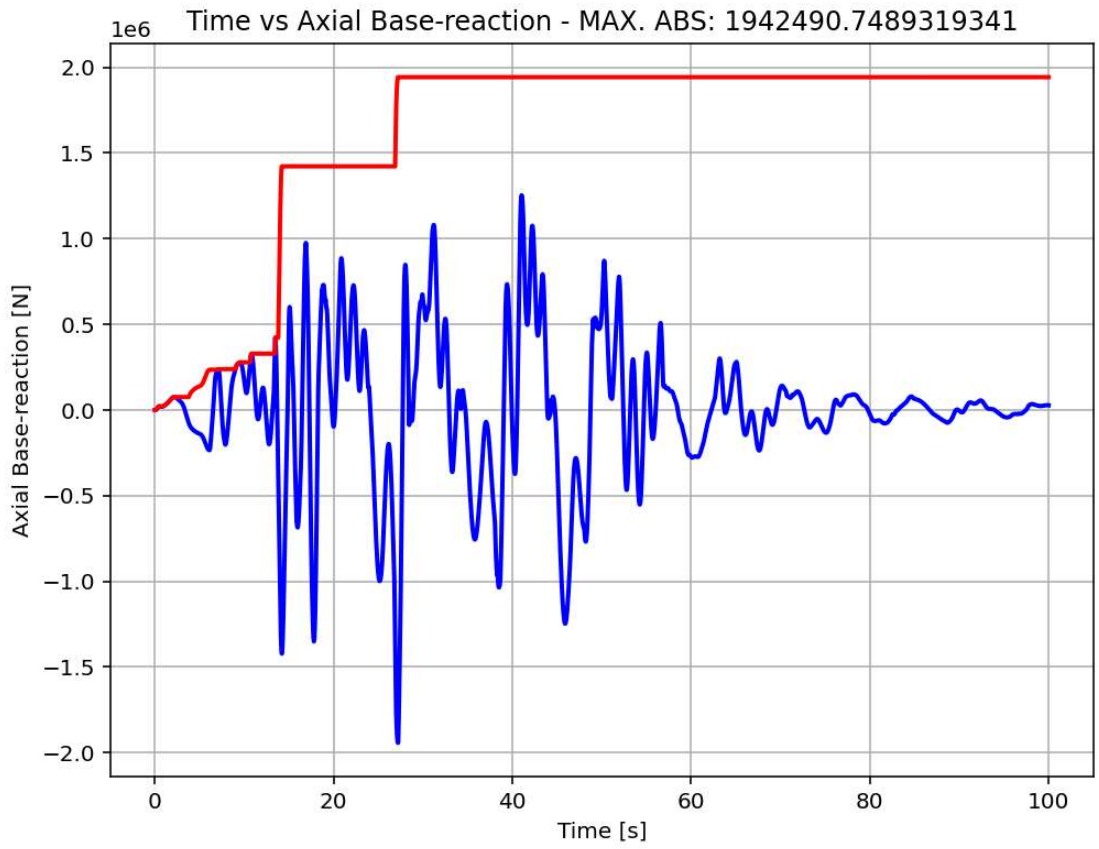

Time vs Acceleration - MAX. ABS: 43.56340539699713
Acceleration in X [mm/s^2]
Time [s]
40
30
20
10
0
−10
−20
0
20
40
60
80
100

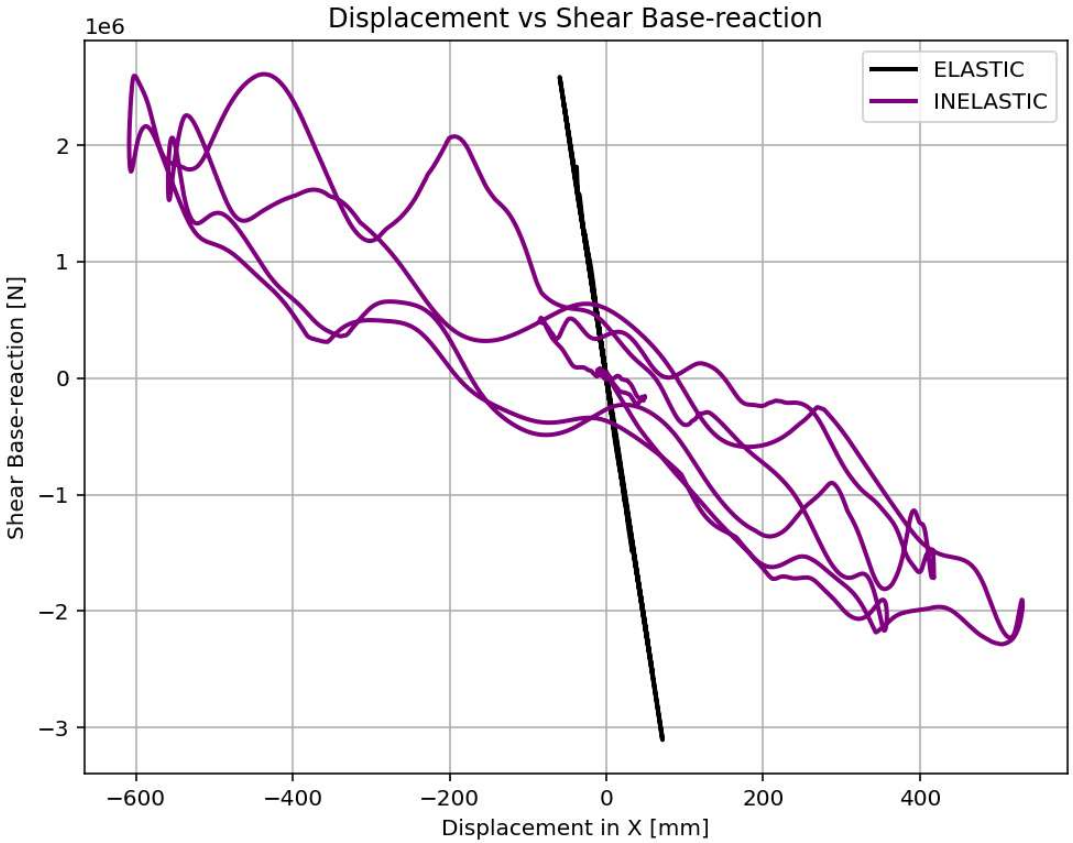

Time vs Acceleration - MAX. ABS: 61.44330347926535
Acceleration in X [mm/s^2]
Time [s]
60
40
20
0
−20
−40
−60
0
20
40
60
80
100

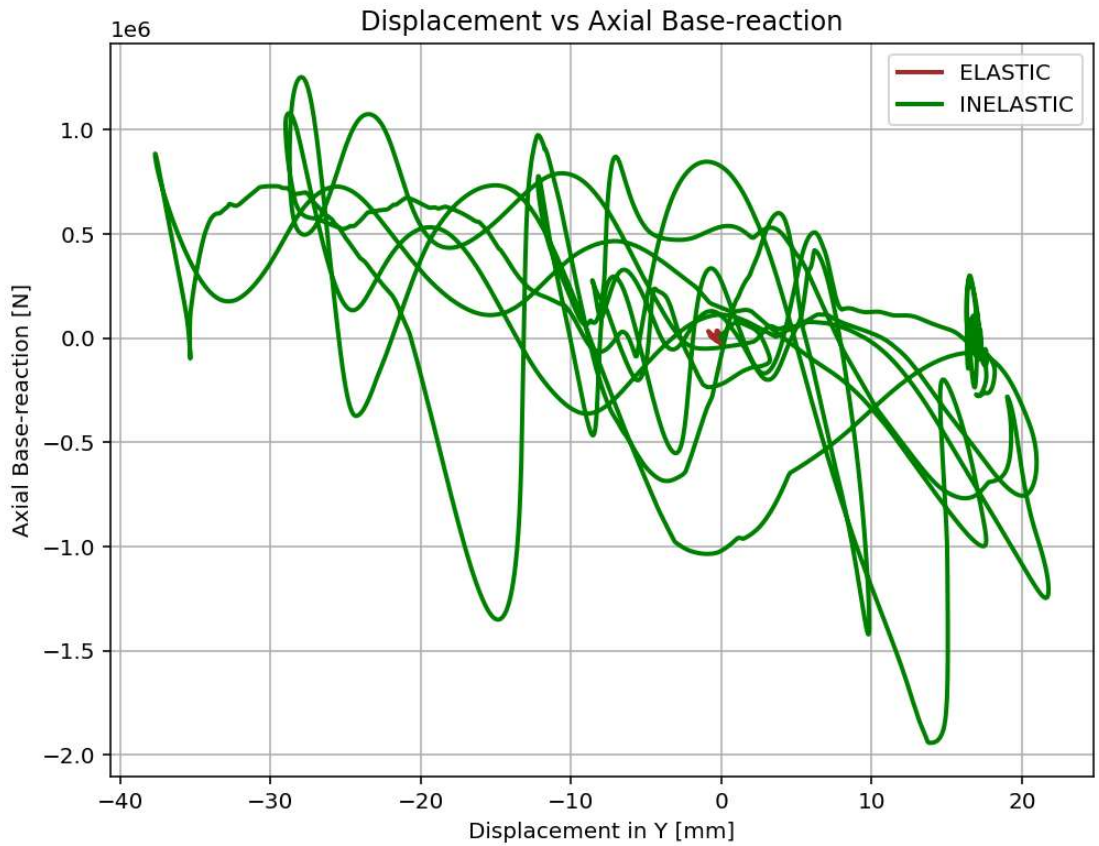

Time vs Base-reaction - MAX. ABS: 3104812.7284397073
1e6
3
2
1
0
−1
−2
−3
Base-reaction [N]
0
20
40
60
80
100
Time [s]

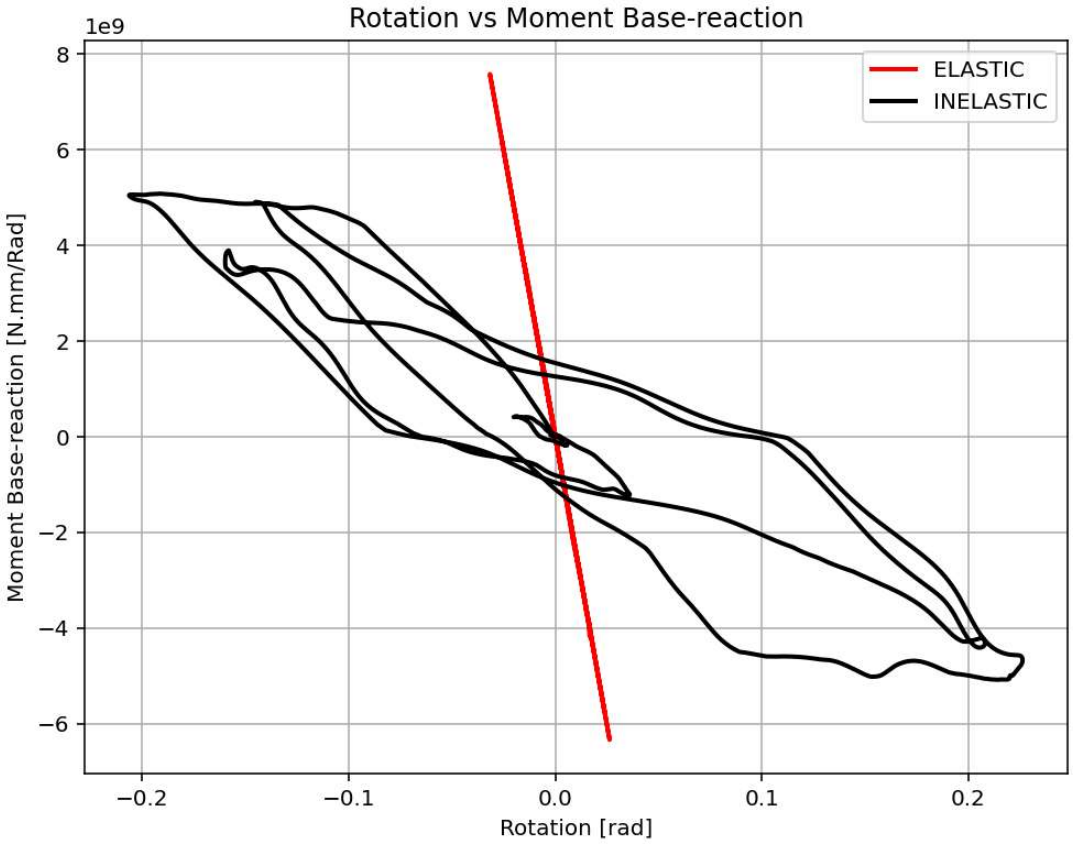

Time vs Base-reaction - MAX. ABS: 2608634.118170861
1e6
2
1
0
−1
−2
Base-reaction [N]
0
20
40
60
80
100
Time [s]


Time vs Axial Base-reaction - MAX. ABS: 36918.838511102214
Axial Base-reaction [N]
Time [s]
40000
30000
20000
10000
0
−10000
−20000
−30000
−40000
0
20
40
60
80
100


Time vs Axial Base-reaction - MAX. ABS: 1942490.7489319341
1e6
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
Axial Base-reaction [N]
0
20
40
60
80
100
Time [s]


Displacement vs Shear Base-reaction
1e6
ELASTIC
INELASTIC
Shear Base-reaction [N]
2
1
0
−1
−2
−3
−600
−400
−200
0
200
400
Displacement in X [mm]


Displacement vs Axial Base-reaction
1e6
ELASTIC
INELASTIC
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
Axial Base-reaction [N]
−40
−30
−20
−10
0
10
20
Displacement in Y [mm]


Rotation vs Moment Base-reaction
1e9
8
6
4
2
0
−2
−4
−6
Moment Base-reaction [N.mm/Rad]
−0.2
−0.1
0.0
0.1
0.2
Rotation [rad]
ELASTIC
INELASTIC