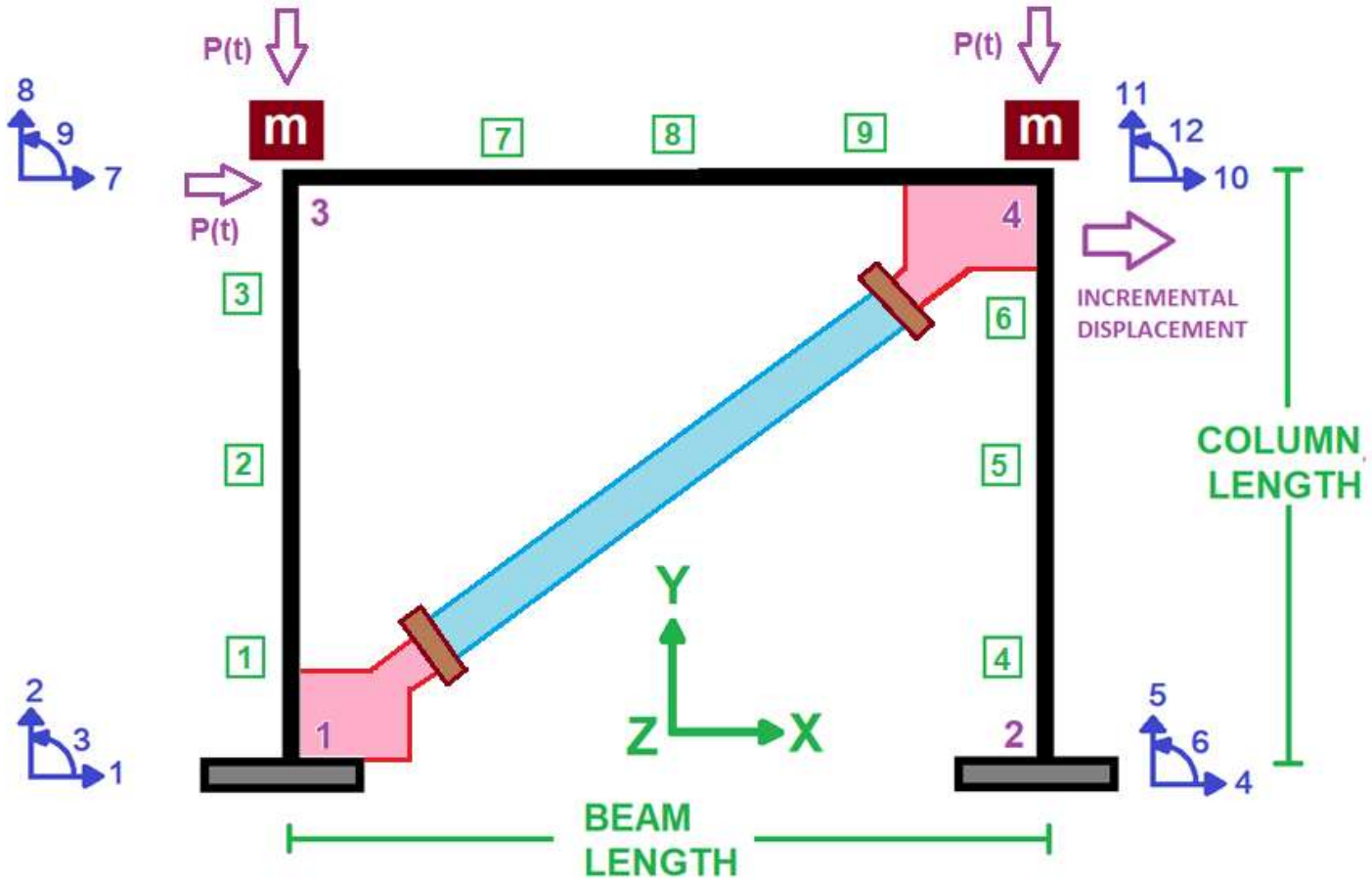
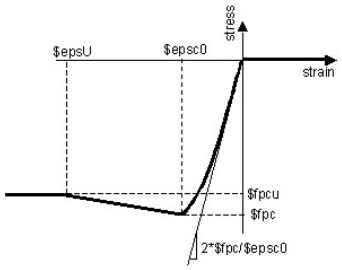
IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL

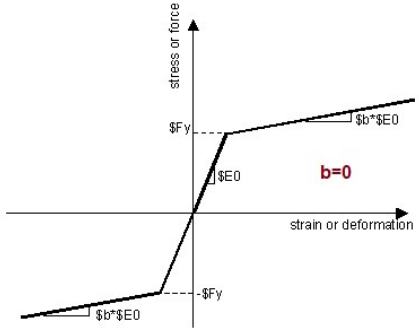
COMPARATIVE STUDY OF ELASTIC AND INELASTIC STRUCTURAL BEHAVIOR THROUGH PUSHOVER DYNAMIC ANALYSIS. HARMONIC IMPACT LOADING ANALYSIS OF CONCRETE FRAME WITH VISCOUS DAMPER USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)

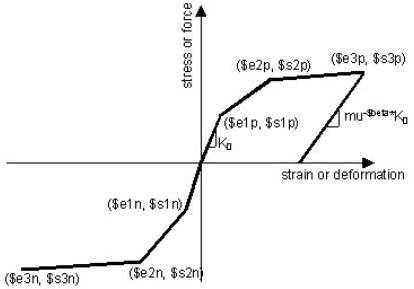

P(t)
P(t)
P(t)
m
m
8
9
7
11
12
10
3
4
7
8
9
3
6
2
5
1
4
INCREMENTAL
DISPLACEMENT
COLUMN
LENGTH
Y
Z
X
1
2
2
3
1
5
6
4
BEAM
LENGTH



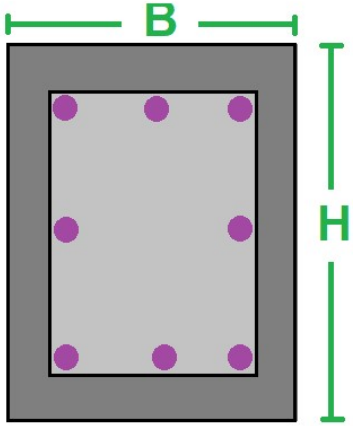
CORE AND COVER CONCRETE RELATION



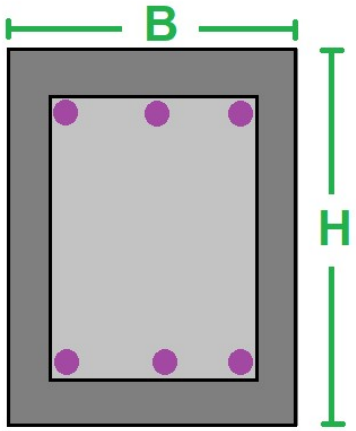
WITHOUT HARDENING AND ULTIMATE STRAIN



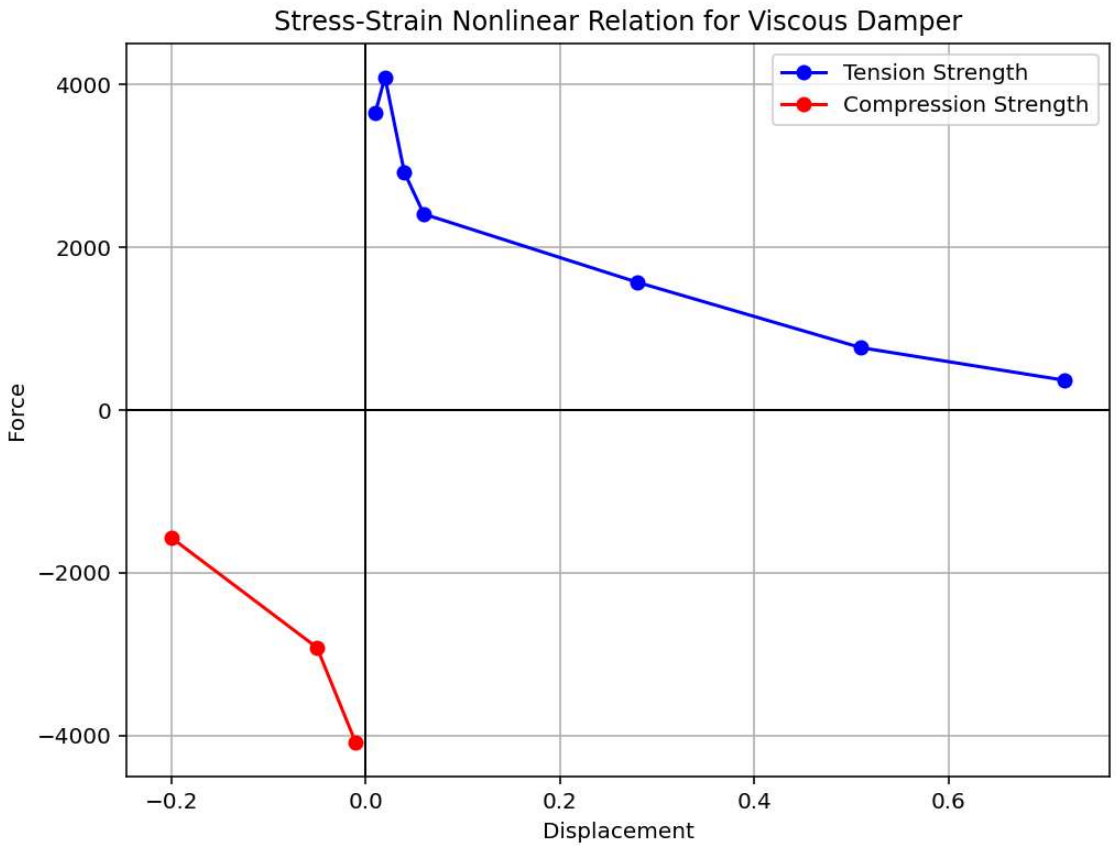
WITH HARDENING AND ULTIMATE STRAIN



COLUMN SECTION



BEAM SECTION


Stress-Strain Nonlinear Relation for Viscous Damper
Tension Strength
Compression Strength
4000
2000
0
−2000
−4000
Force
−0.2
0.0
0.2
0.4
0.6
Displacement

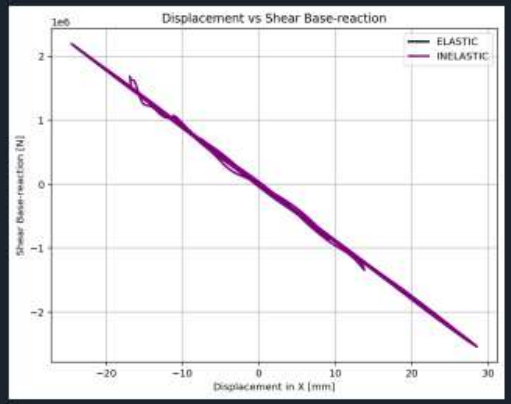
Spyder (Python 3.12)

File Edit Search Source Run Debug Consoles Projects Tools View Help

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

CONFINEMENT_NONCON..._VISCOUS_DAMPER.py

```
1  ##################################################################################################
2  #                          >> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<
3  #  COMPARATIVE STUDY OF ELASTIC AND INELASTIC STRUCTURAL BEHAVIOR THROUGH PUSHOVER DYNAMIC ANALY
4  #                       HARMONIC IMPACT LOADING ANALYSIS OF CONCRETE FRAME WITH VISCOUS DAMPER
5  #--------------------------------------------------------------------------------------------------
6  #                              THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
7  #                                    EMAIL: salar.d.ghashghaei@gmail.com
8  ##################################################################################################
9  """
10 1. The script performs a comparative study of elastic and inelastic structural behavior using pu
11 2. It models a 2D reinforced concrete frame with columns (500x500mm) and beams (500x300mm) using
12 3. Material definitions include confined/unconfined concrete (fc=25MPa) and bilinear steel reinf
13 4. Two analysis types are implemented: static pushover (displacement-controlled) and dynamic tim
14 5. Rayleigh damping is calculated based on initial modal periods and target damping ratios (5%).
15 6. The pushover analysis applies incremental displacements up to 675mm, recording base reactions
16 7. Dynamic analysis uses Newmark integration with ground motion inputs scaled by 0.01g (El Centr
17 8. Key outputs include force-displacement curves, moment-rotation relationships, and stiffness d
18 9. Eigenvalue analysis tracks period elongation due to inelasticity during dynamic events.
19 10. Damage indices are computed for ductility assessment using bilinear curve fitting.
20 11. Overstrength factors (Ω), ductility ratios (μ), and R-factors are quantified for seismic per
21 12. Real-time monitoring of base shear, axial forces, and interstory drifts is implemented.
22 13. The script includes advanced convergence controls (Newton-Raphson, 1e-6 tolerance).
23 14. Confinement effects are modeled with variable enhancement ratios (Kc=1.25 for columns).
24 15. Results are exported to Excel, including displacements, forces, stiffness, and period data.
25 16. Visualization includes deformed shapes, hysteresis loops, and cumulative response envelopes.
26 17. Damping ratios are estimated from free vibration decay in dynamic analyses.
27 18. Both geometric nonlinearities (P-Delta/Corotational) and material nonlinearities are conside
28 19. The code supports parametric studies by varying steel models (with/without hardening) and el
29 20. Comprehensive plotting functions enable side-by-side comparison of elastic vs. inelastic res
30
31 ---------------------------------------------------------------
32 Viscous Dampers:
33
34 Definition:
```



Help | Variable Explorer | Debugger | Plots | Files

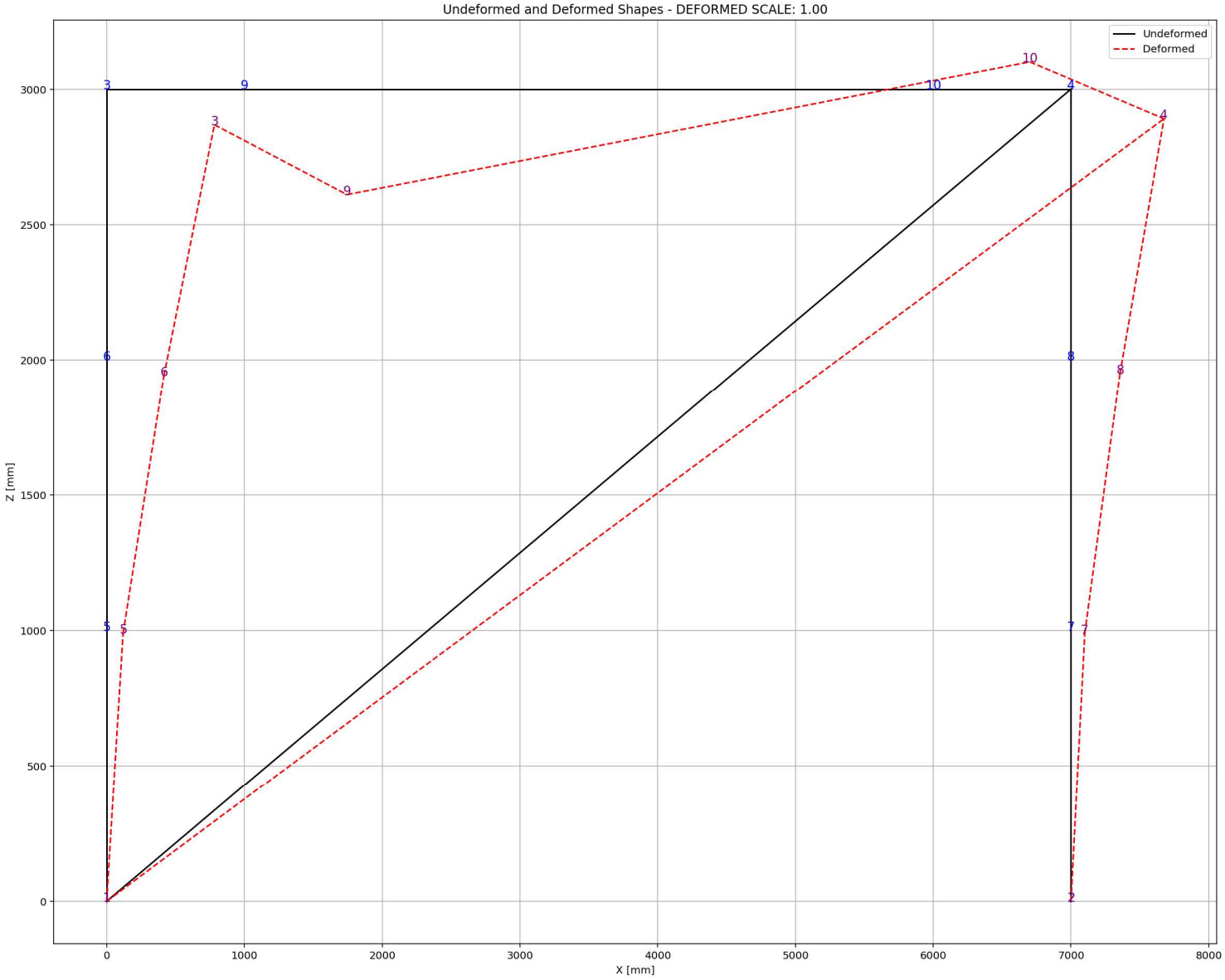
Console 1/A

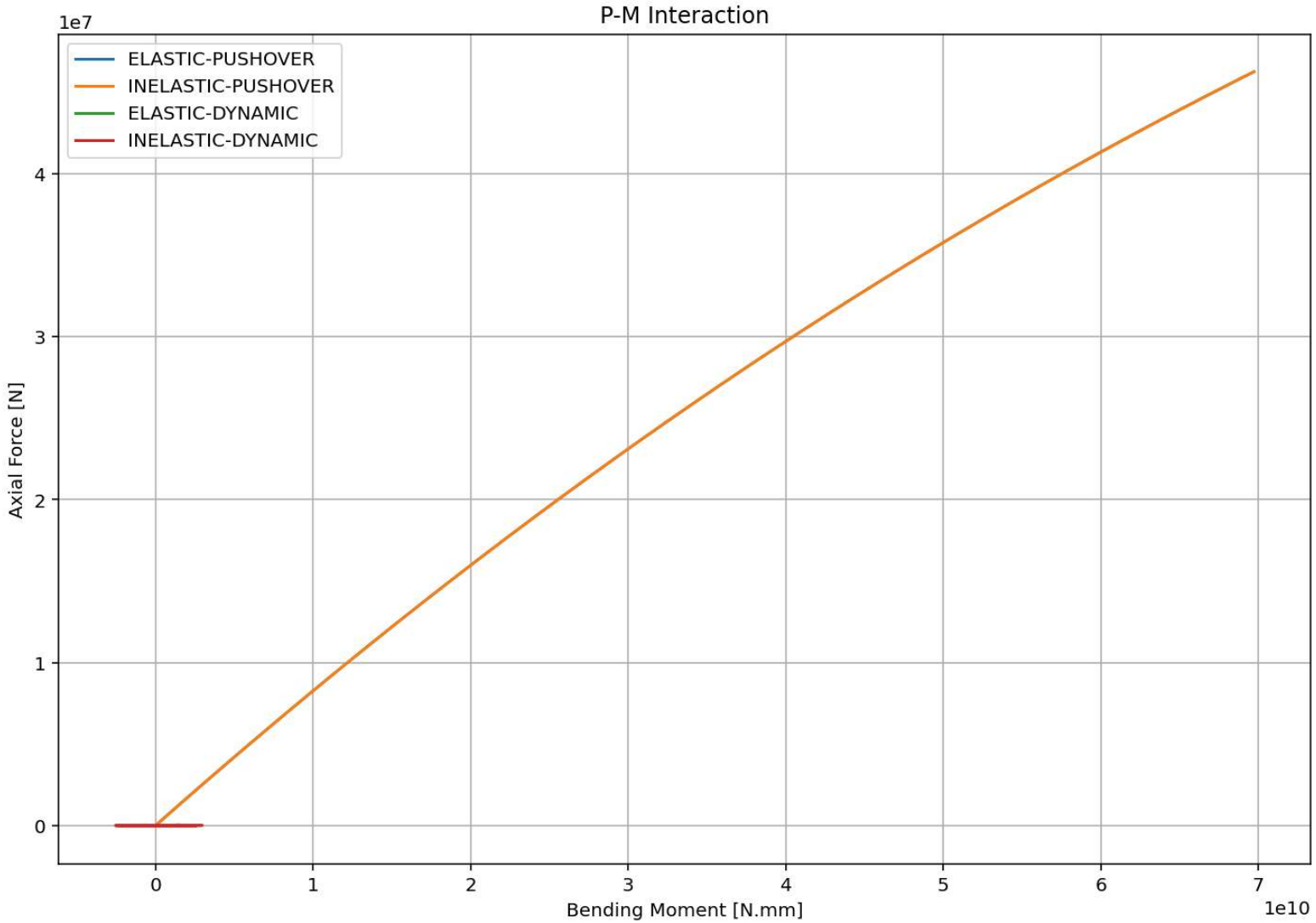
```
    End 2 Forces (P V M): -515.761 -7445.96 -3.08585e+06

ElasticBeam2d: 3
    Connected Nodes: 6 3
    CoordTransf: 1
    mass density:  6.25, cMass: 0
    release code:  0
    End 1 Forces (P V M): 513.596 5765.31 3.08585e+06
    End 2 Forces (P V M): -513.596 -5765.31 2.67946e+06

In [2]:
```

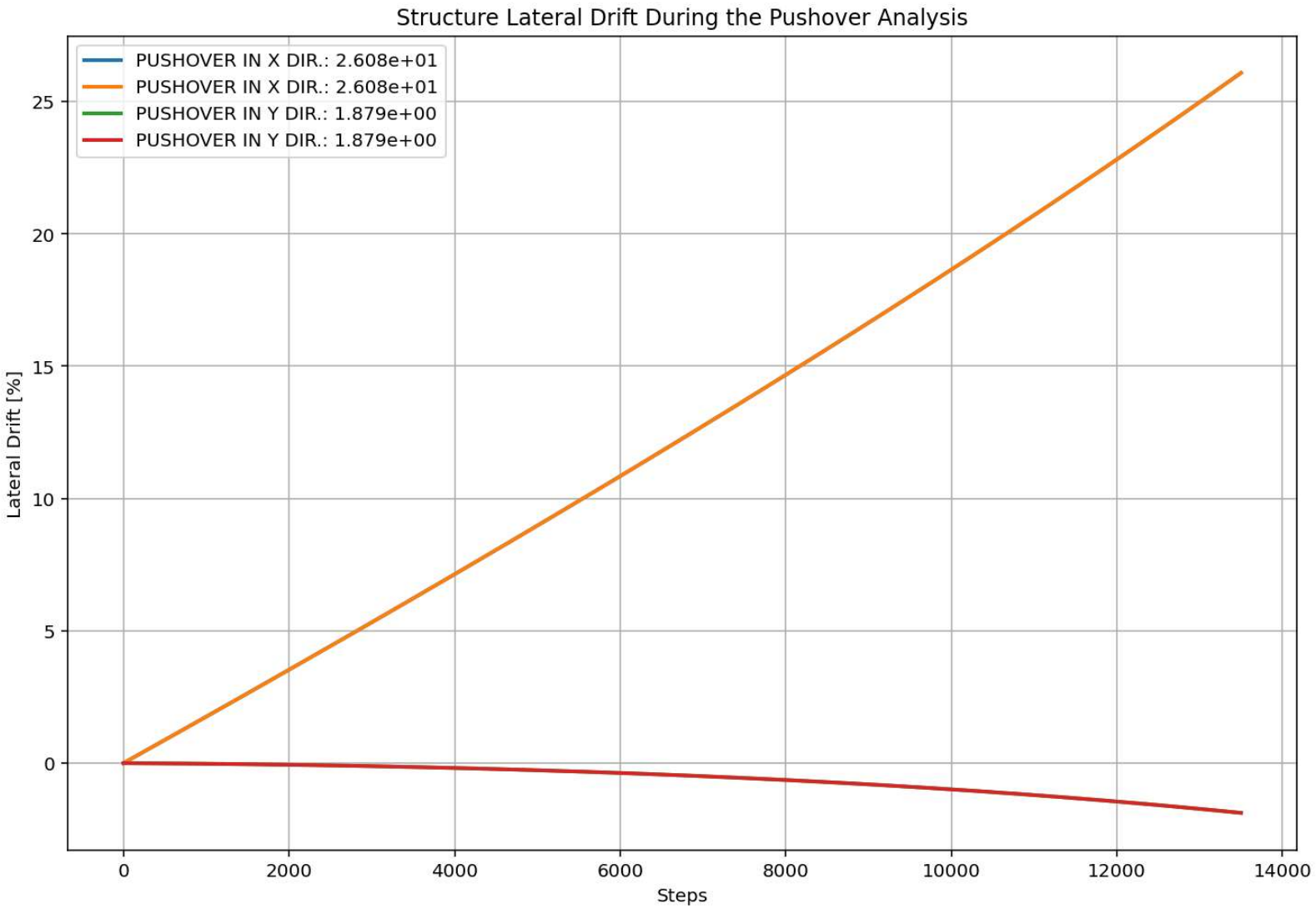
IPython Console | History

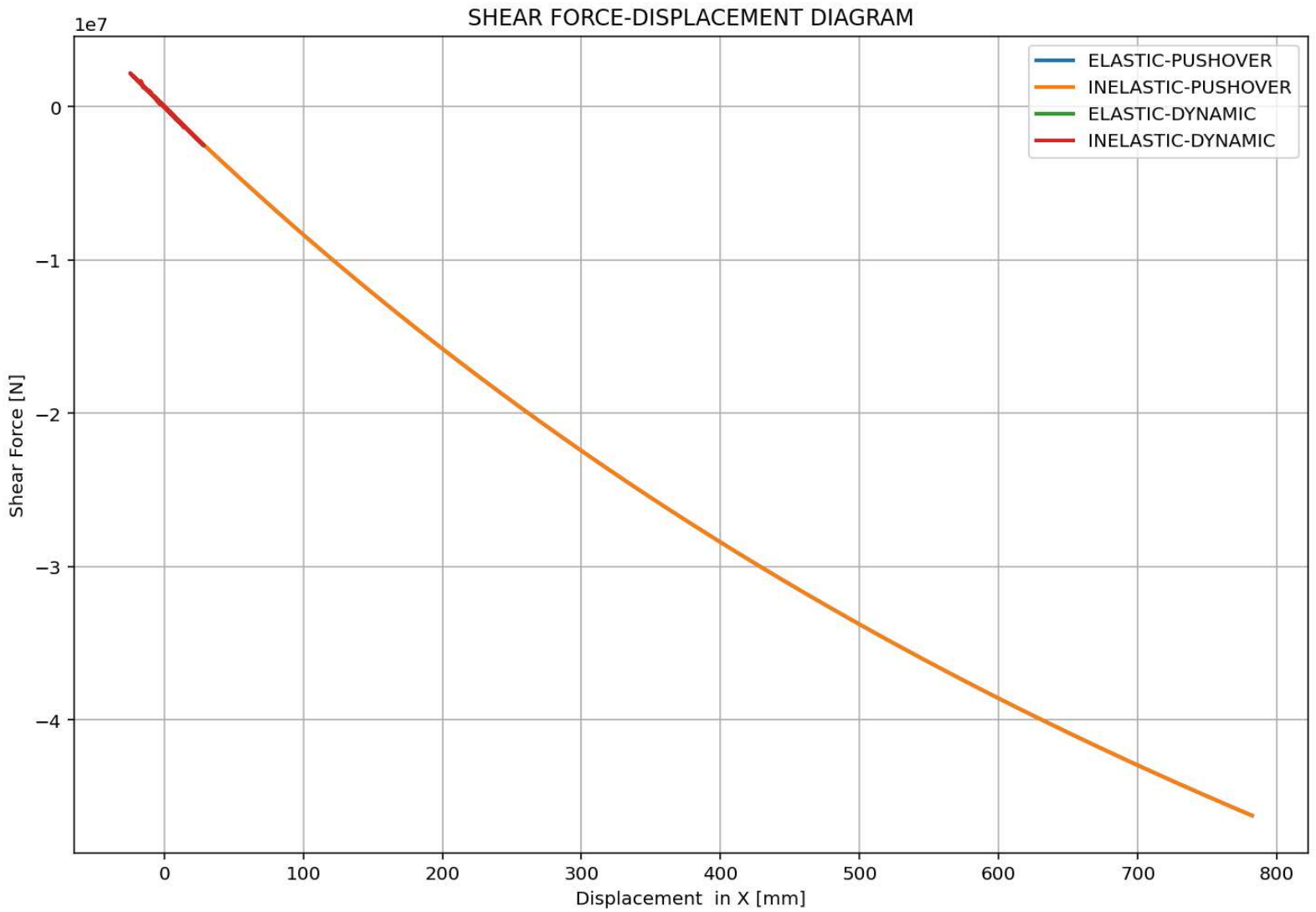
Inline | Conda: anaconda3 (Python 3.12.7) | LSP: Python | Line 966, Col 112 | UTF-8 | CRLF | RW | Mem 31%

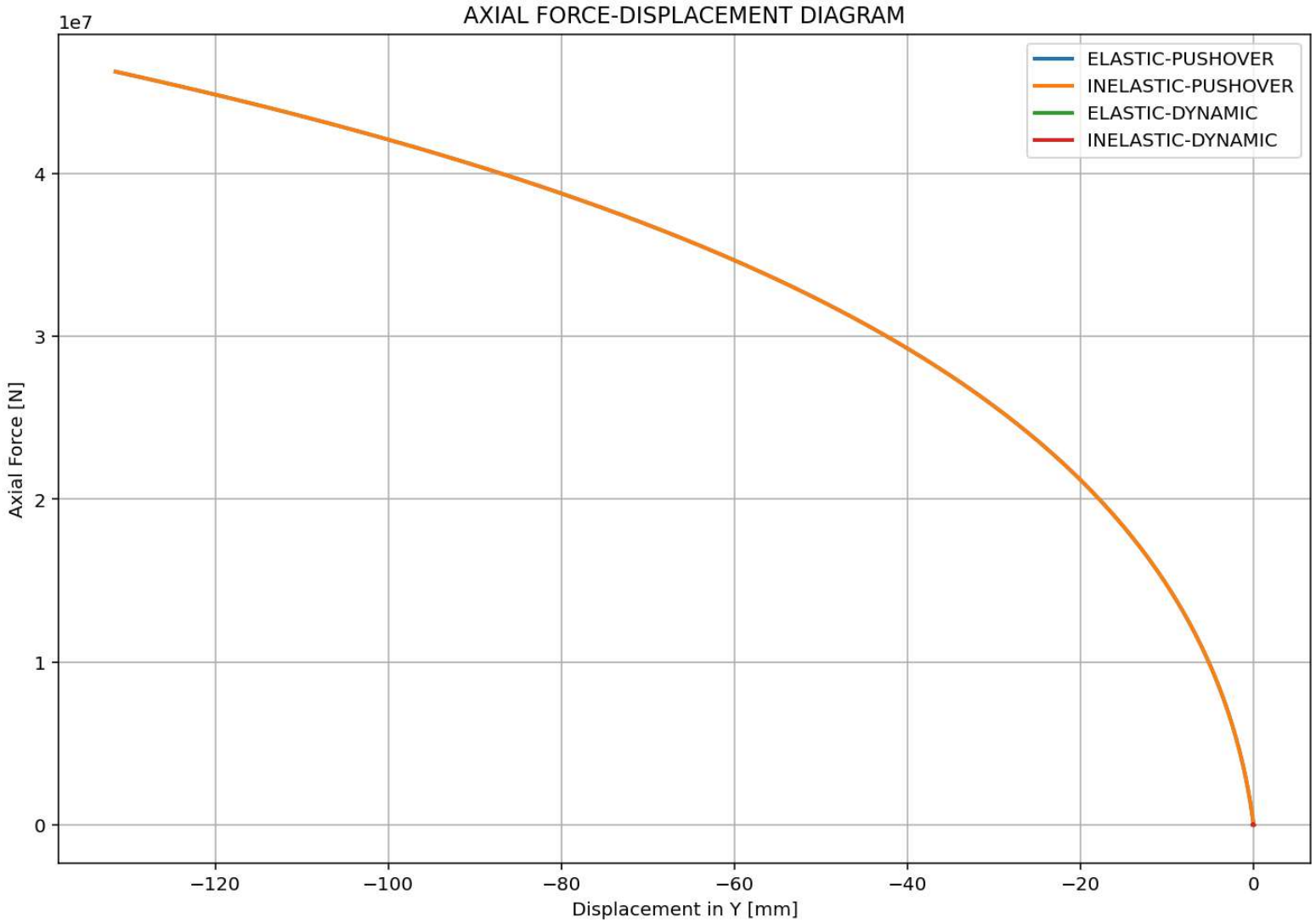
ELASTIC AND INELASTIC STATIC ANALYSIS (PUSHOVER)

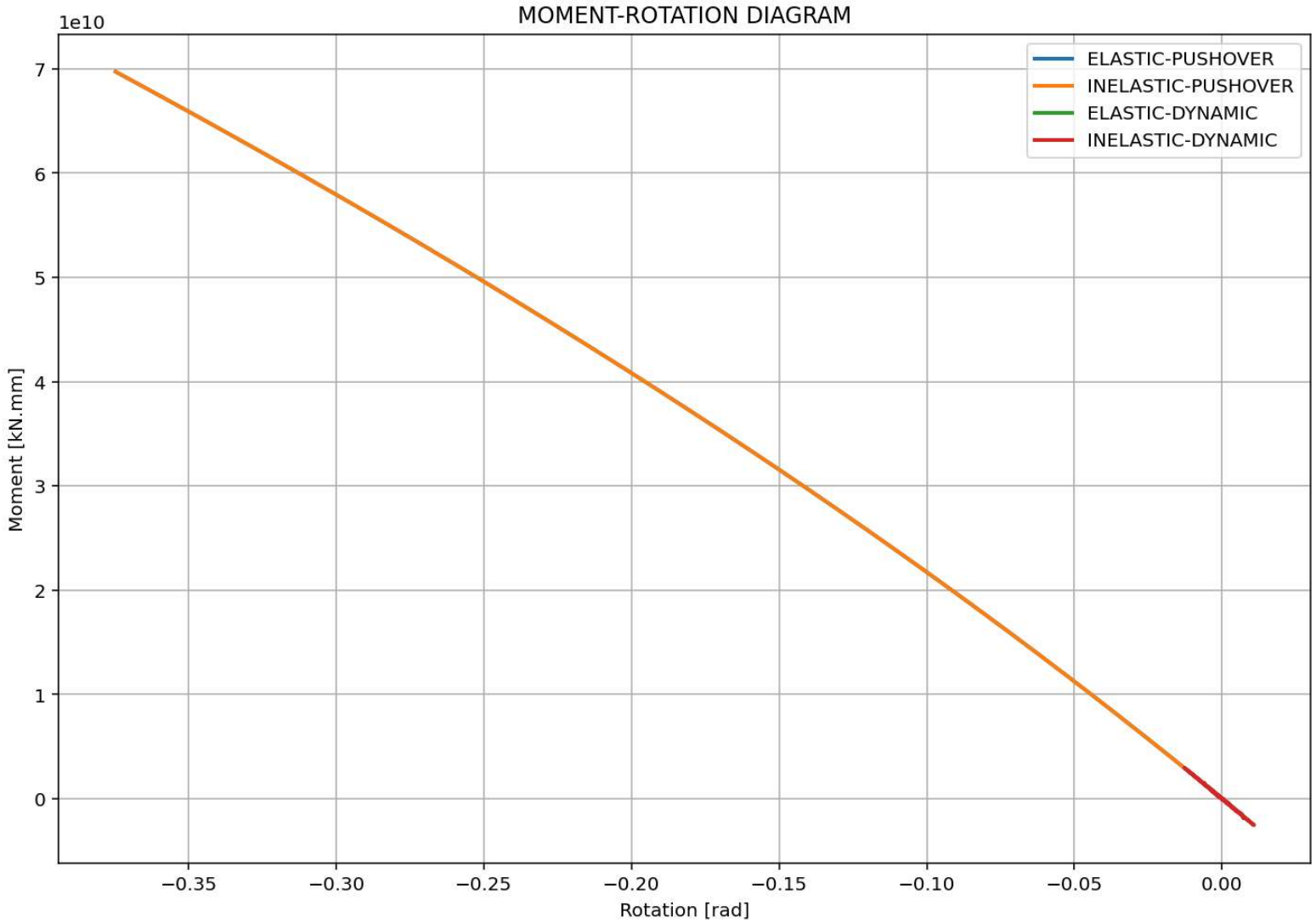

Undeformed and Deformed Shapes - DEFORMED SCALE: 1.00
Undeformed
Deformed
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000
8000
1
2
3
4
5
6
7
8
9
10

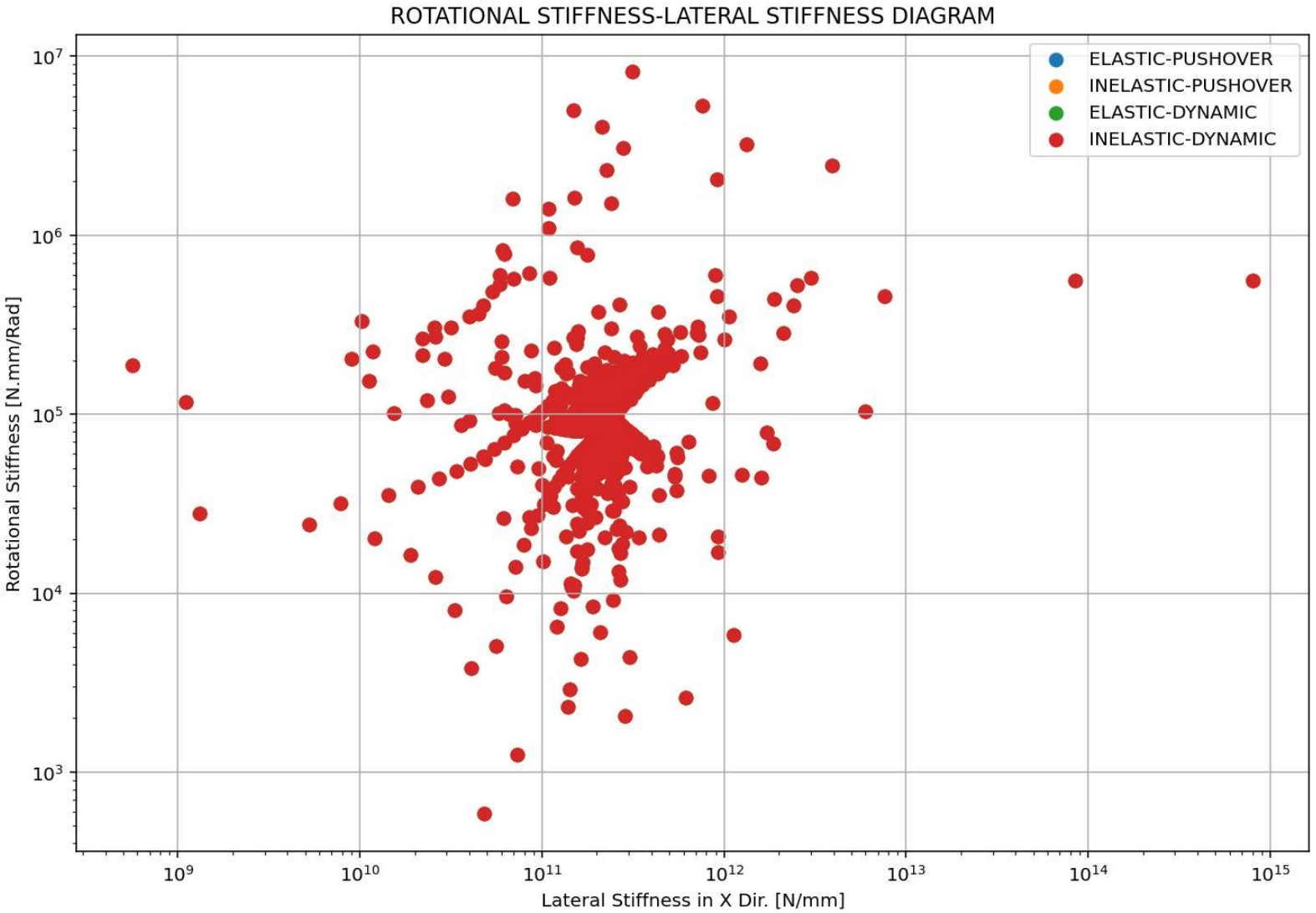

P-M Interaction
1e7
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC
Axial Force [N]
0
1
2
3
4
0
1
2
3
4
5
6
7
Bending Moment [N.mm]
1e10

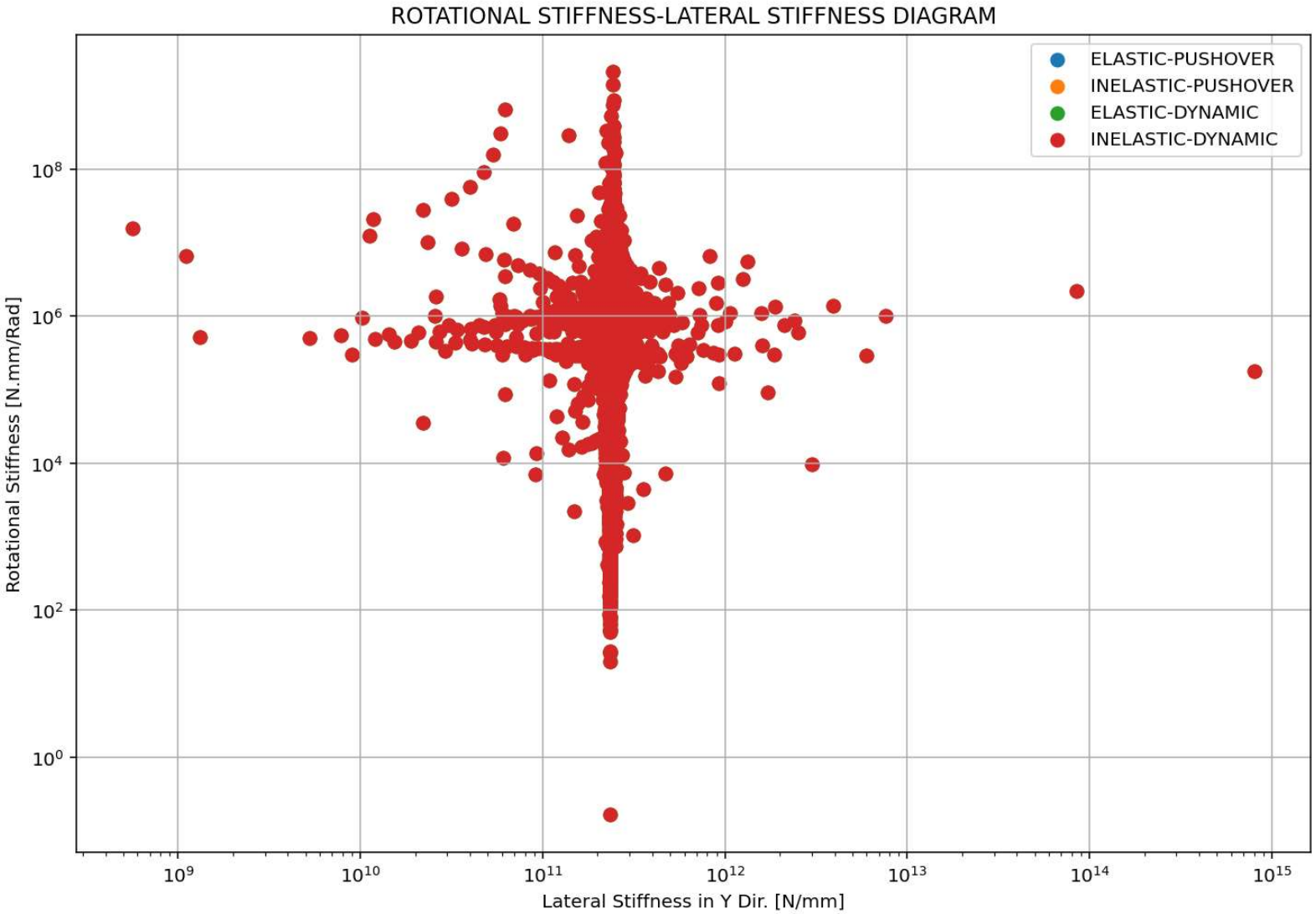

Structure Lateral Drift During the Pushover Analysis
PUSHOVER IN X DIR.: 2.608e+01
PUSHOVER IN X DIR.: 2.608e+01
PUSHOVER IN Y DIR.: 1.879e+00
PUSHOVER IN Y DIR.: 1.879e+00
Lateral Drift [%]
25
20
15
10
5
0
0
2000
4000
6000
8000
10000
12000
14000
Steps

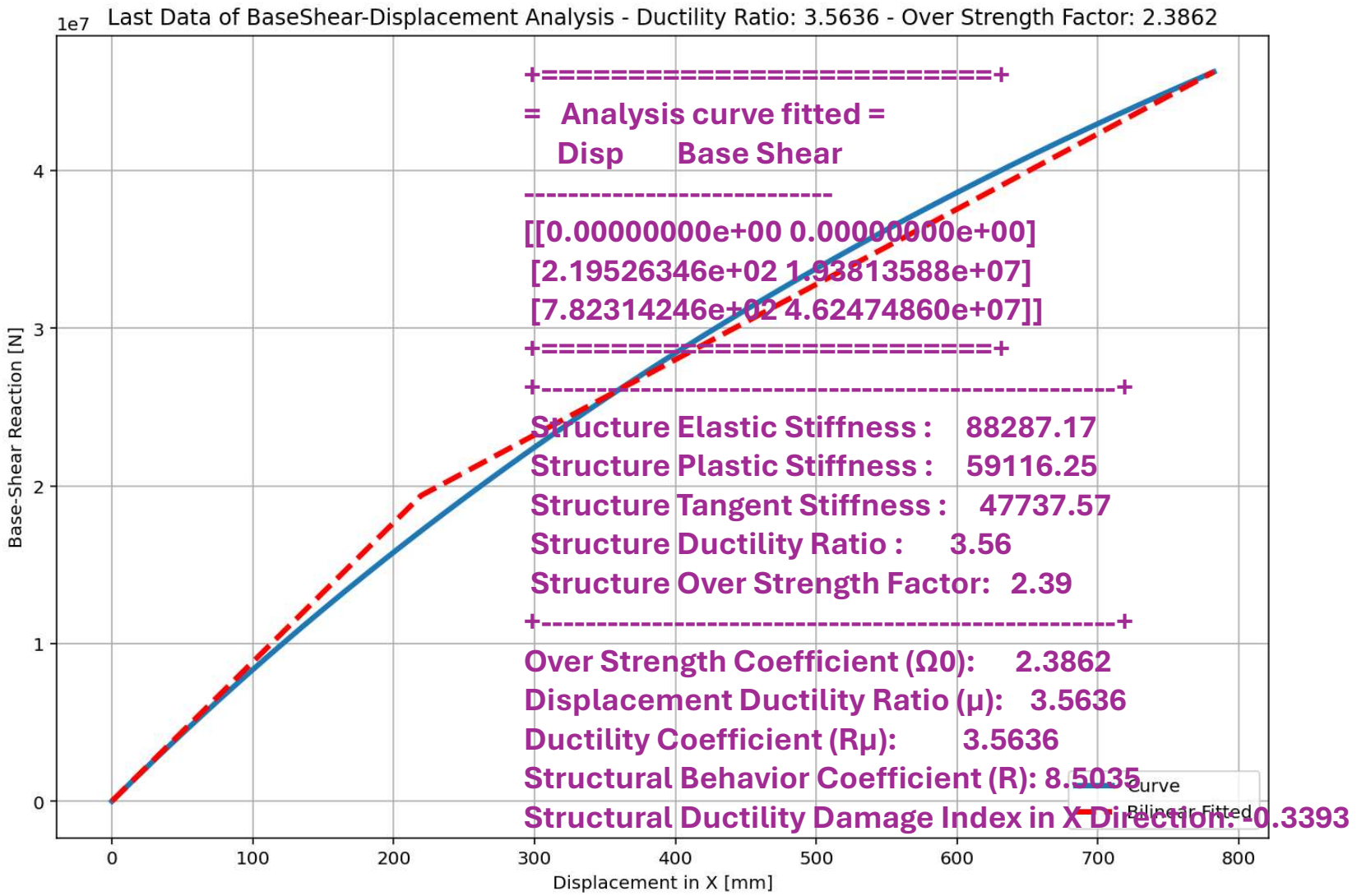

SHEAR FORCE-DISPLACEMENT DIAGRAM
1e7
0
−1
−2
−3
−4
Shear Force [N]
0
100
200
300
400
500
600
700
800
Displacement in X [mm]
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC


AXIAL FORCE-DISPLACEMENT DIAGRAM
1e7
4
3
2
1
0
Axial Force [N]
−120
−100
−80
−60
−40
−20
0
Displacement in Y [mm]
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC

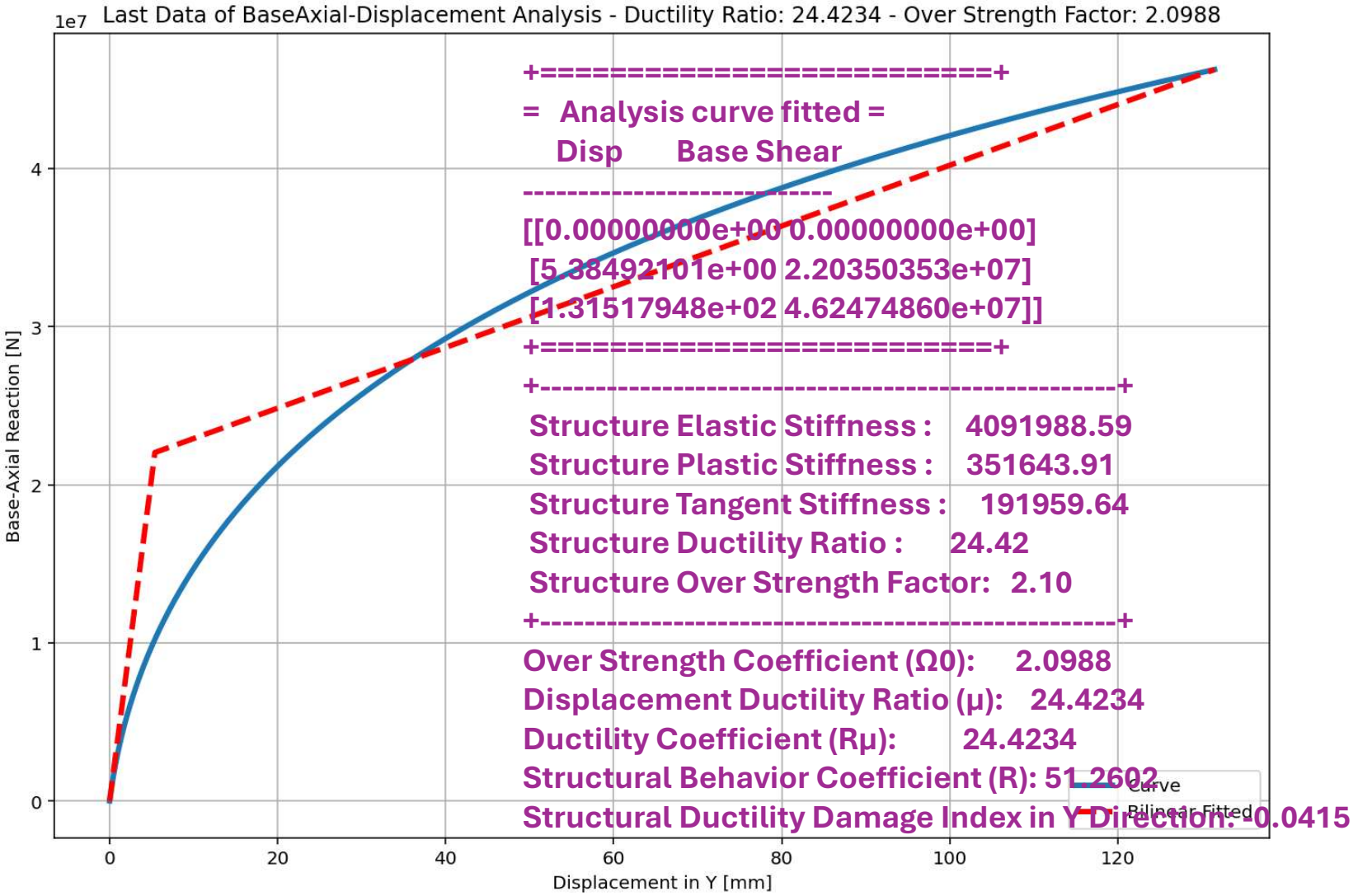

MOMENT-ROTATION DIAGRAM
1e10
7
6
5
4
3
2
1
0
Moment [kN.mm]
−0.35
−0.30
−0.25
−0.20
−0.15
−0.10
−0.05
0.00
Rotation [rad]
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC


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^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}
10^{15}


ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
ELASTIC-PUSHOVER
INELASTIC-PUSHOVER
ELASTIC-DYNAMIC
INELASTIC-DYNAMIC
Rotational Stiffness [N.mm/Rad]
10^{8}
10^{6}
10^{4}
10^{2}
10^{0}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}
10^{15}
Lateral Stiffness in Y Dir. [N/mm]

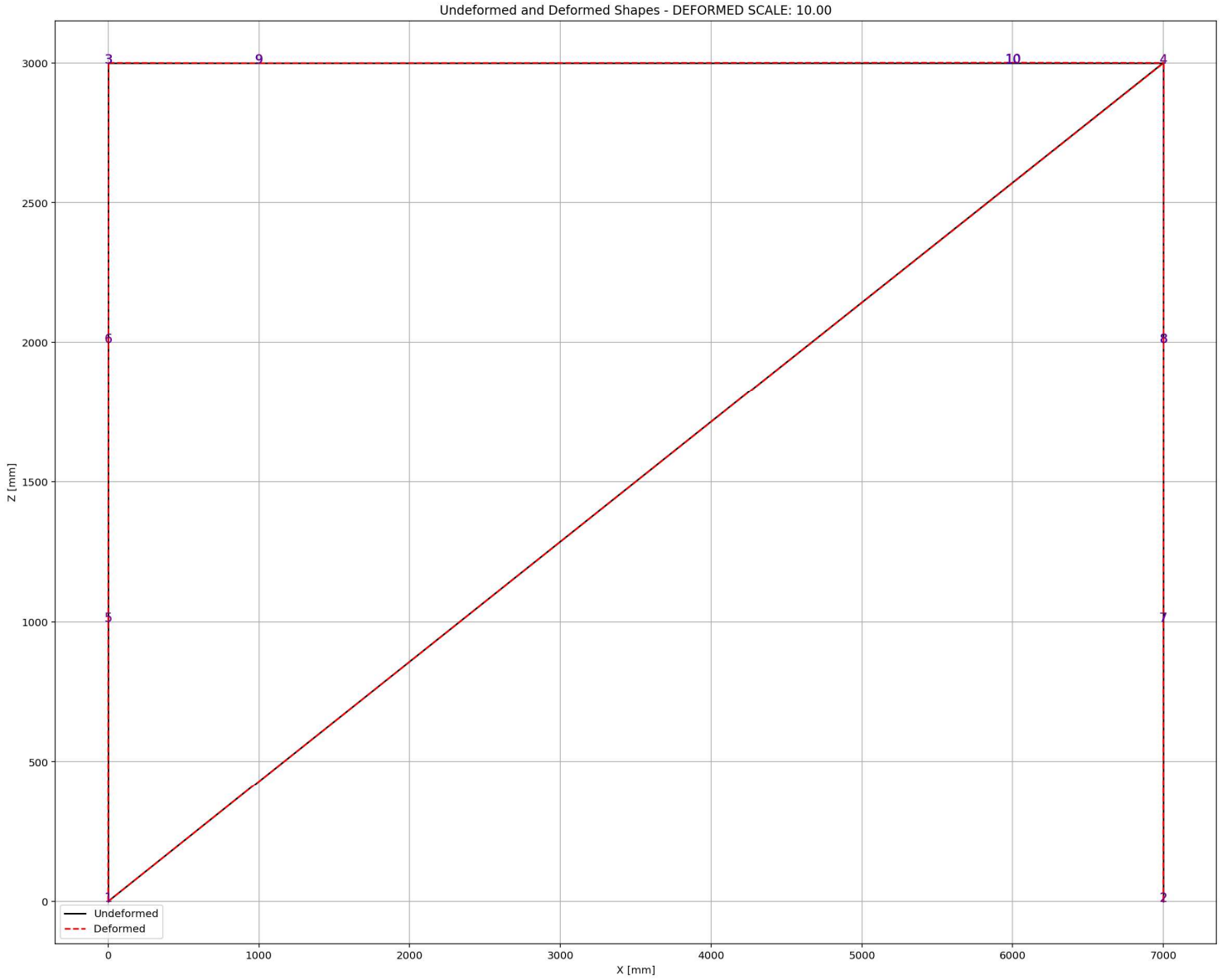

Last Data of BaseShear-Displacement Analysis - Ductility Ratio: 3.5636 - Over Strength Factor: 2.3862
1e7
Base-Shear Reaction [N]
Displacement in X [mm]
0
1
2
3
4
0
100
200
300
400
500
600
700
800
+============================+
= Analysis curve fitted =
Disp Base Shear

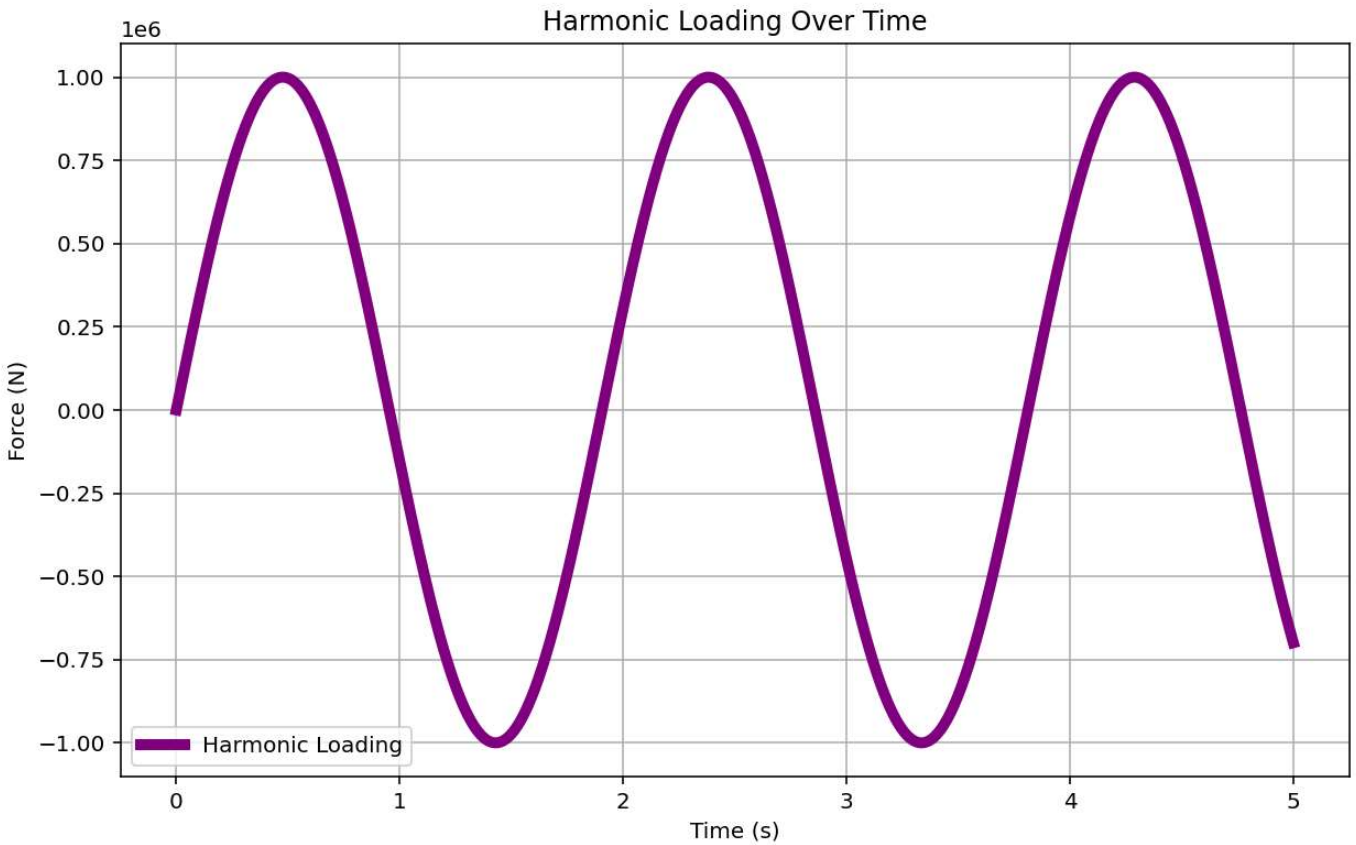
[[0.00000000e+00 0.00000000e+00]
[2.19526346e+02 1.03813588e+07]
[7.82314246e+02 4.62474860e+07]]
+============================+
+---+
Structure Elastic Stiffness : 88287.17
Structure Plastic Stiffness : 59116.25
Structure Tangent Stiffness : 47737.57
Structure Ductility Ratio : 3.56
Structure Over Strength Factor: 2.39
+---+
Over Strength Coefficient (Ω0): 2.3862
Displacement Ductility Ratio (μ): 3.5636
Ductility Coefficient (Rμ): 3.5636
Structural Behavior Coefficient (R): 8.5035
Structural Ductility Damage Index in X Direction: -0.3393
Curve
Bilinear Fitted

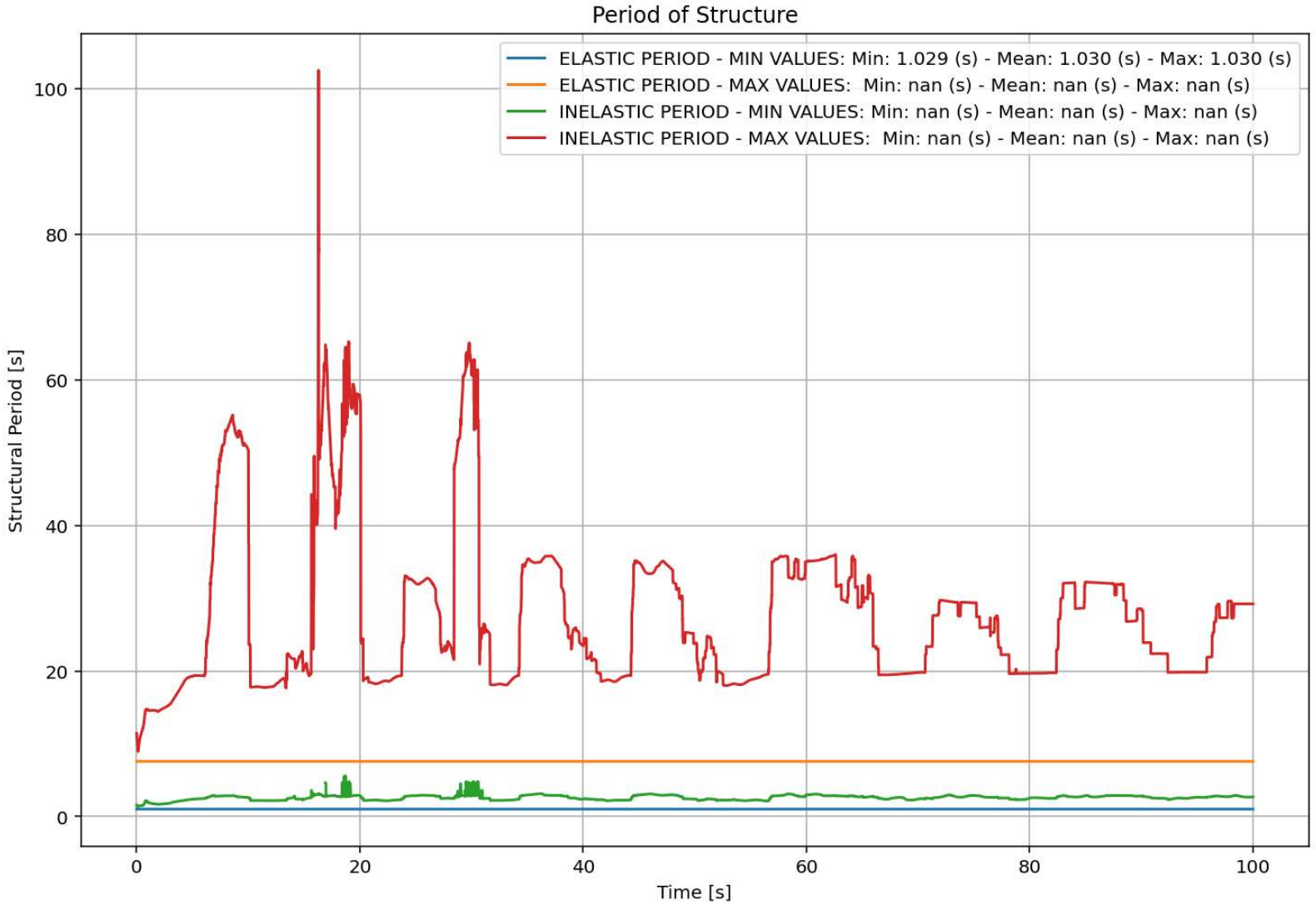

Last Data of BaseAxial-Displacement Analysis - Ductility Ratio: 24.4234 - Over Strength Factor: 2.0988
1e7
Base-Axial Reaction [N]
Displacement in Y [mm]
0
1
2
3
4
0
20
40
60
80
100
120
+============================+
= Analysis curve fitted =
Disp Base Shear

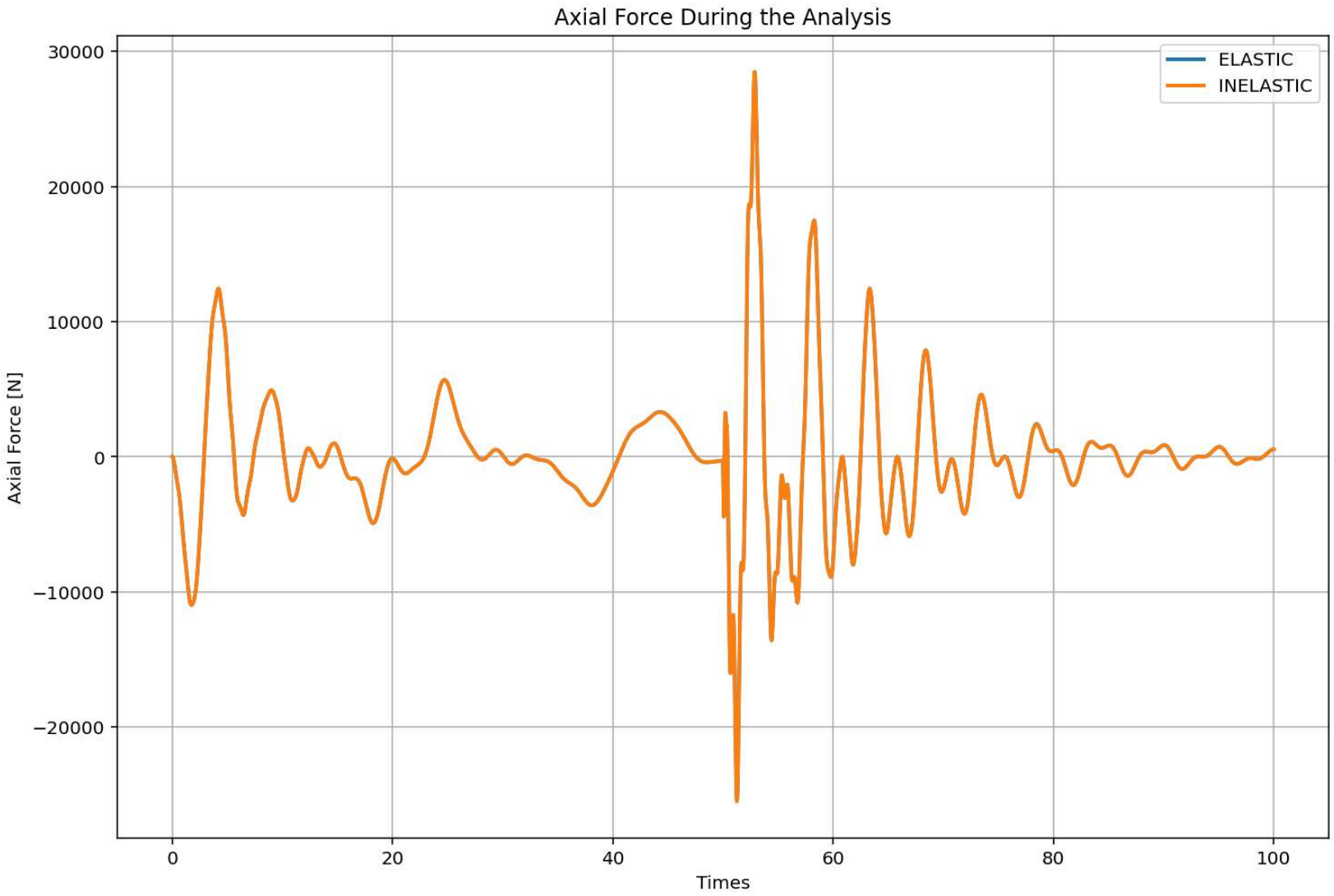
[[0.00000000e+00 0.00000000e+00]
[5.38492101e+00 2.20350353e+07]
[1.31517948e+02 4.62474860e+07]]
+============================+
+---+
Structure Elastic Stiffness : 4091988.59
Structure Plastic Stiffness : 351643.91
Structure Tangent Stiffness : 191959.64
Structure Ductility Ratio : 24.42
Structure Over Strength Factor: 2.10
+---+
Over Strength Coefficient (Ω0): 2.0988
Displacement Ductility Ratio (μ): 24.4234
Ductility Coefficient (Rμ): 24.4234
Structural Behavior Coefficient (R): 51.2602
Structural Ductility Damage Index in Y Direction: -0.0415
Curve
Bilinear Fitted

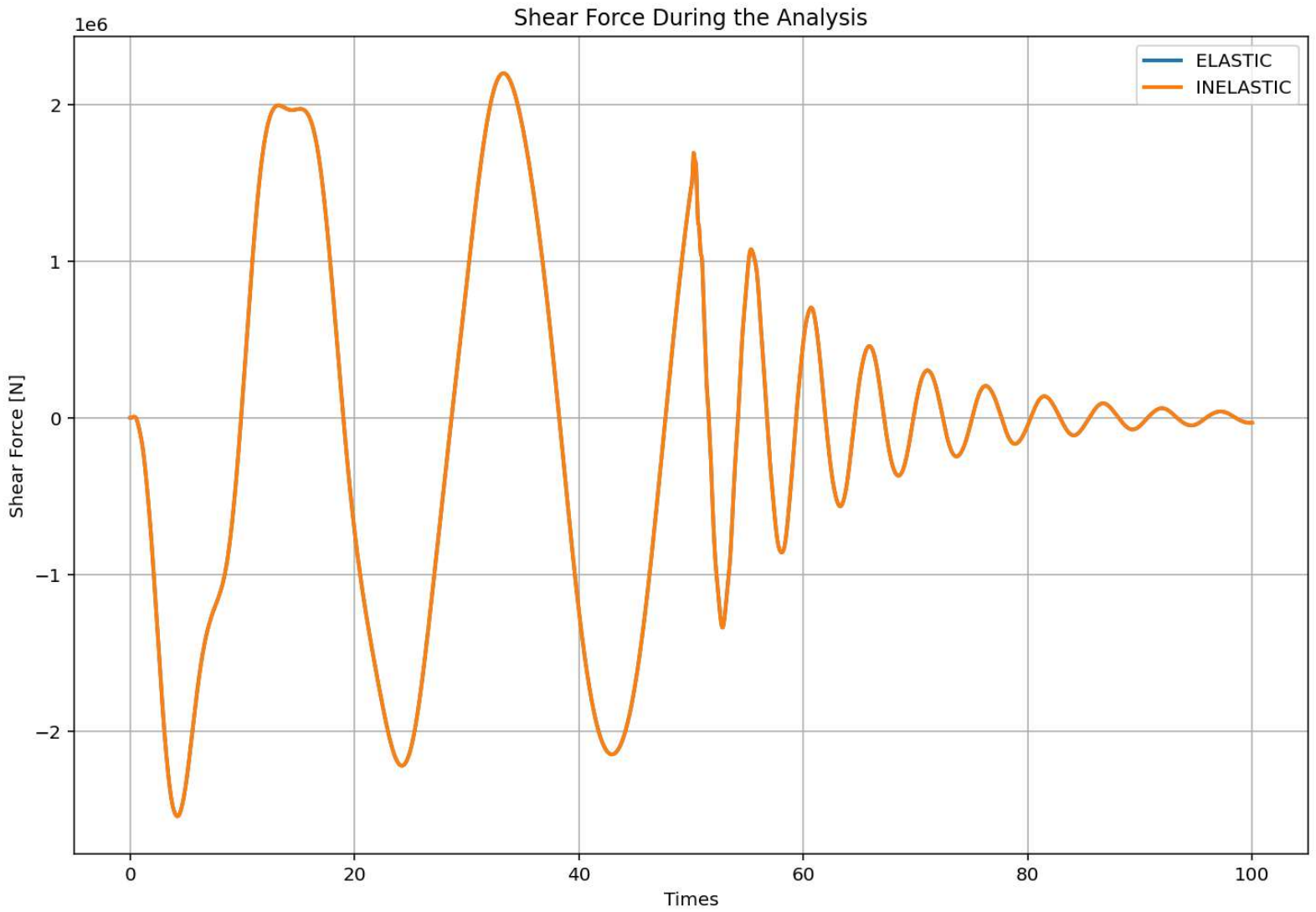
ELASTIC AND INELASTIC DYNAMIC ANALYSIS

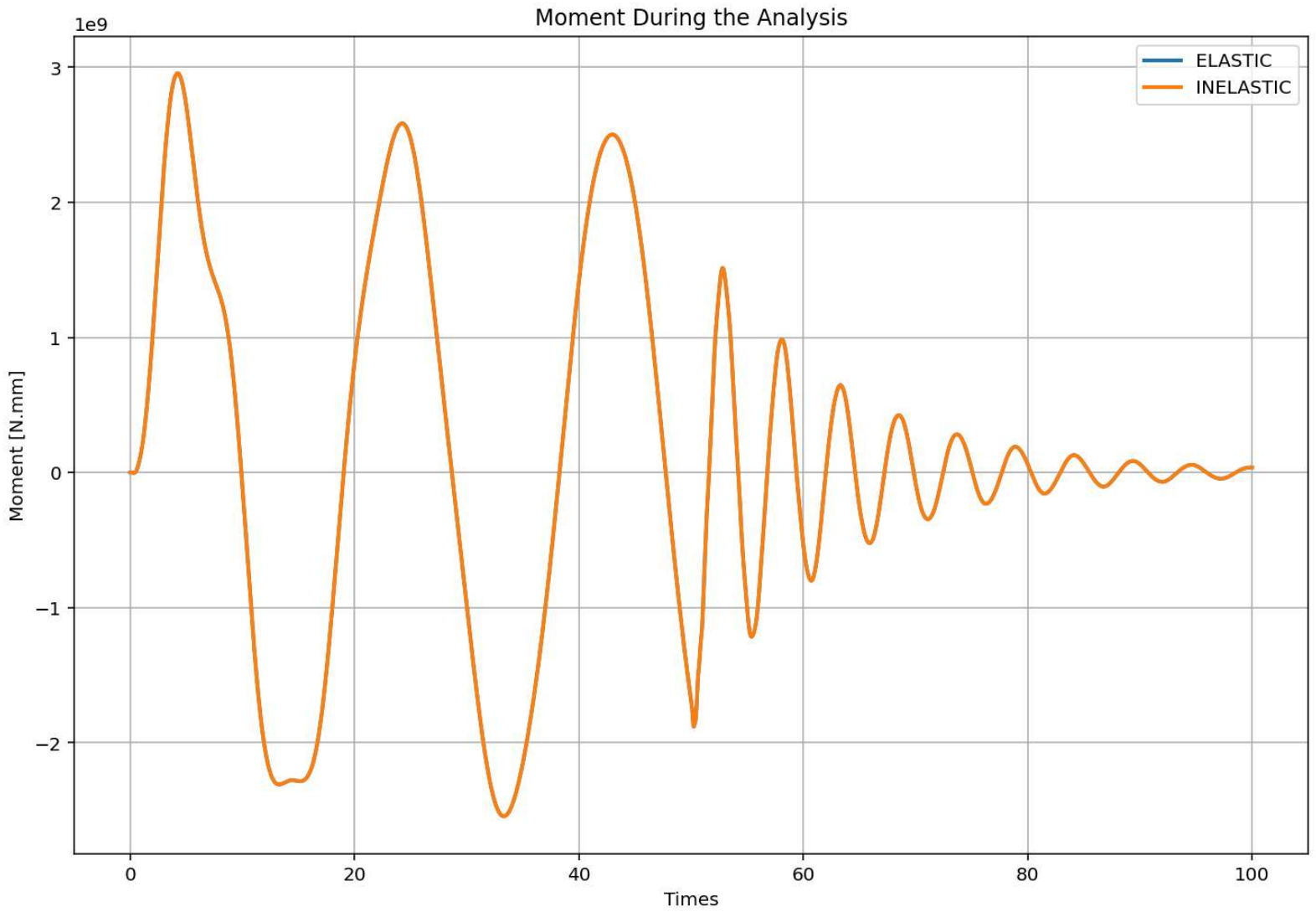

Undeformed and Deformed Shapes - DEFORMED SCALE: 10.00
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000
1
2
3
4
5
6
7
8
9
10
Undeformed
Deformed

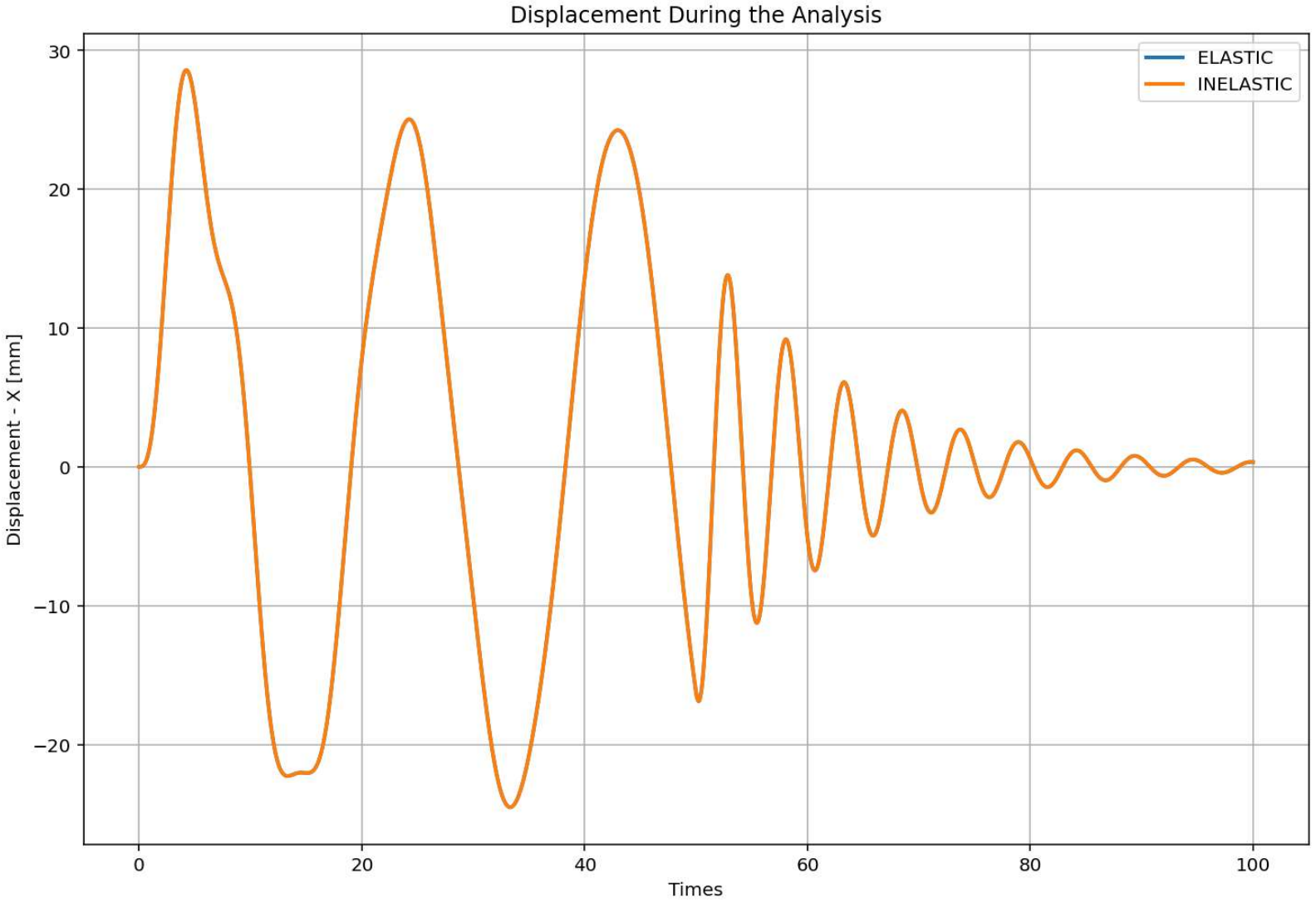

Harmonic Loading Over Time
1e6
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
Force (N)
0
1
2
3
4
5
Time (s)
Harmonic Loading

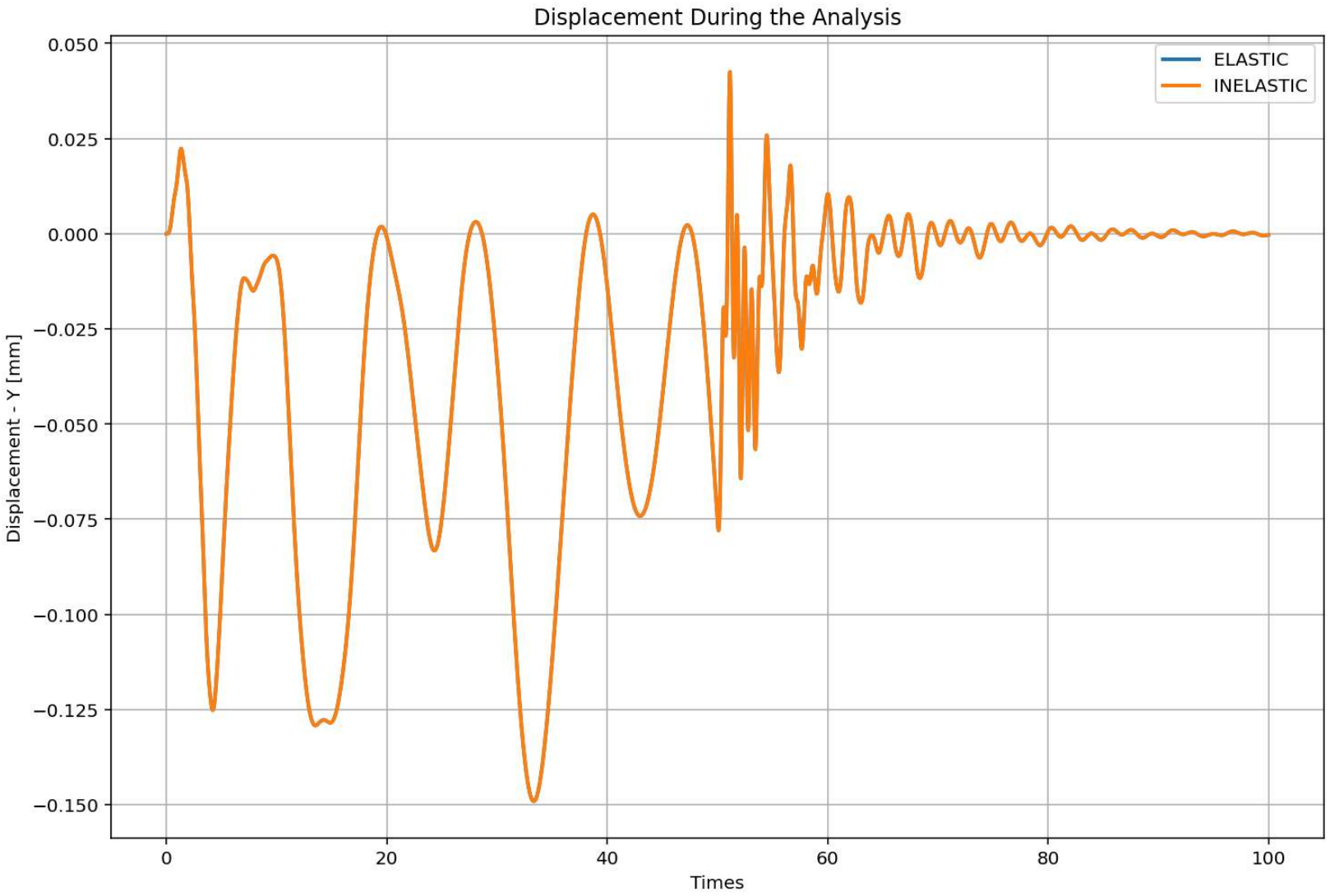

Period of Structure
ELASTIC PERIOD - MIN VALUES: Min: 1.029 (s) - Mean: 1.030 (s) - Max: 1.030 (s)
ELASTIC PERIOD - MAX VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
INELASTIC PERIOD - MIN VALUES: Min: nan (s) - Mean: nan (s) - Max: nan (s)
INELASTIC PERIOD - MAX VALUES: Min: nan (s) - Mean: nan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

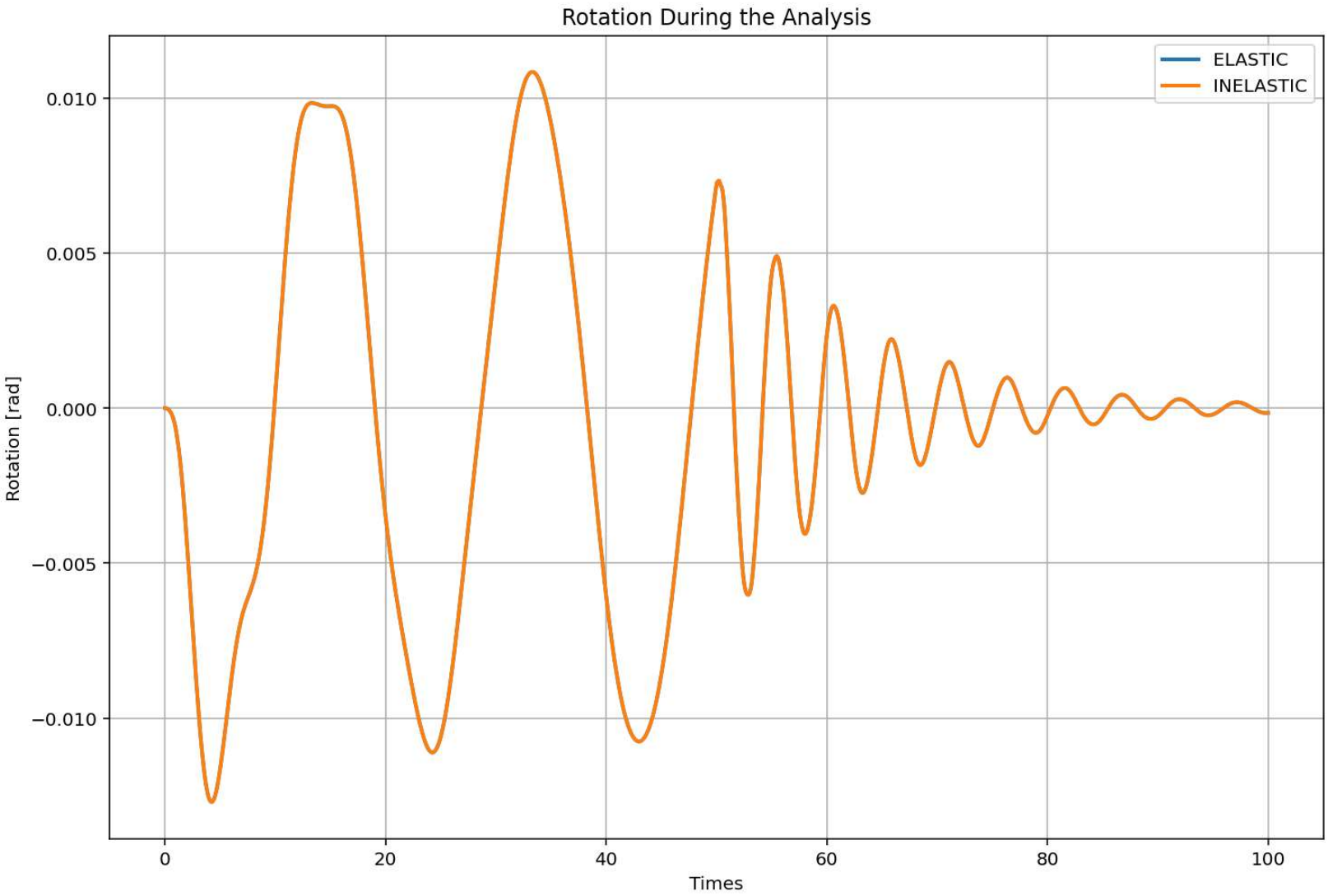

Axial Force During the Analysis
ELASTIC
INELASTIC
Axial Force [N]
30000
20000
10000
0
−10000
−20000
0
20
40
60
80
100
Times

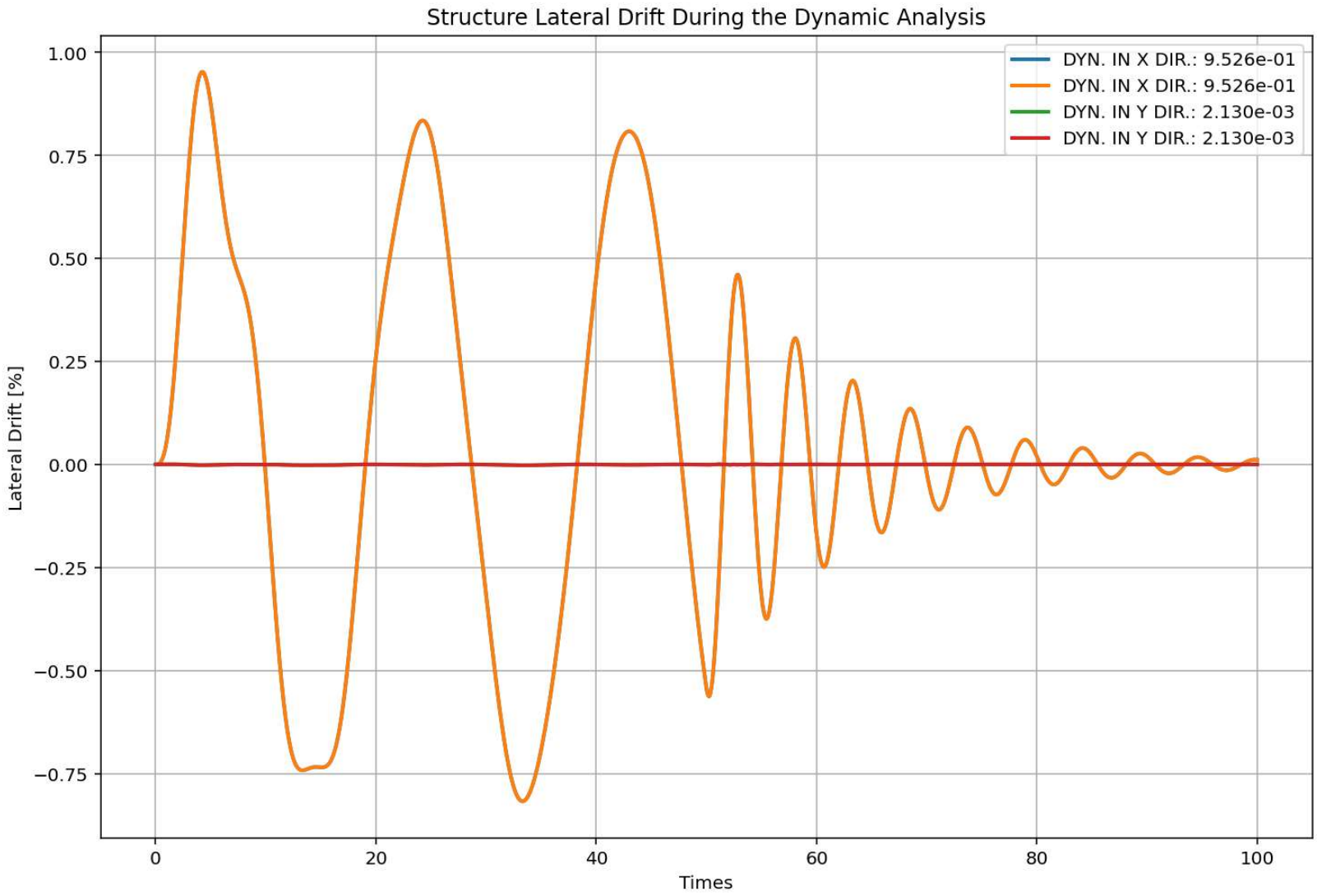

Shear Force During the Analysis
1e6
2
1
0
−1
−2
Shear Force [N]
0
20
40
60
80
100
Times
ELASTIC
INELASTIC

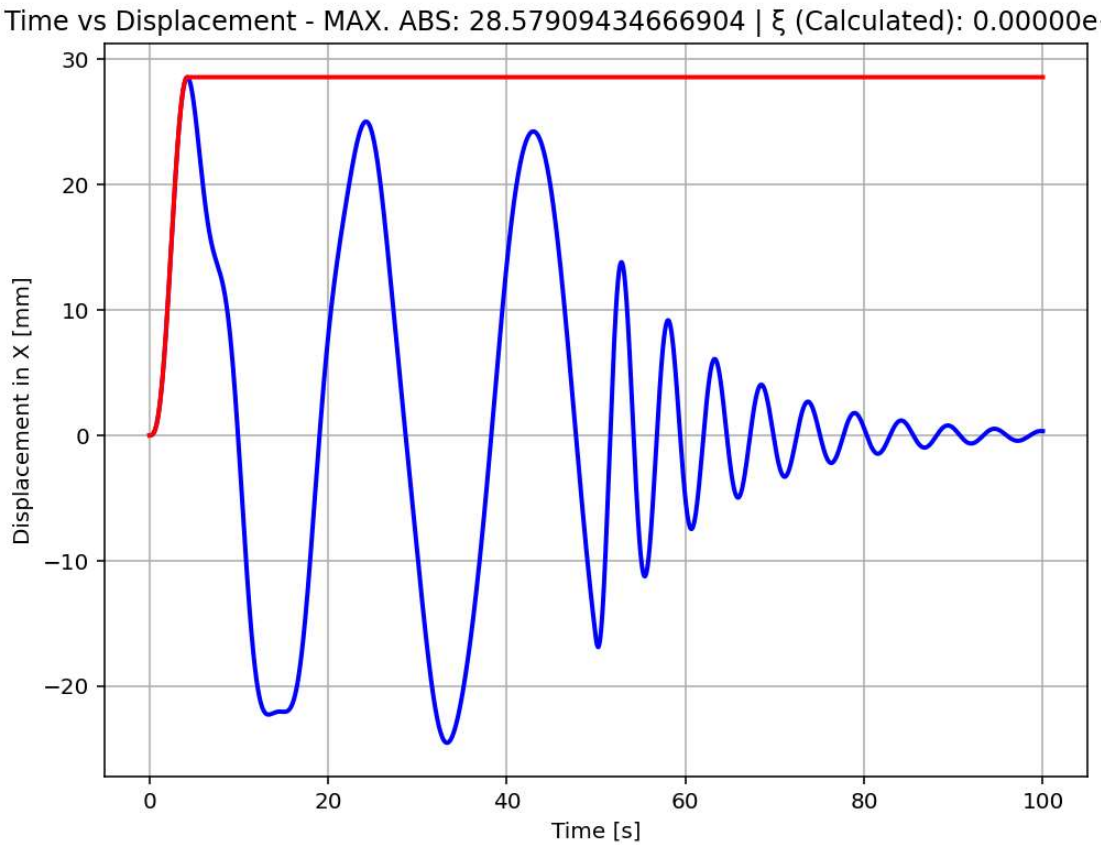

Moment During the Analysis
1e9
3
2
1
0
−1
−2
Moment [N.mm]
0
20
40
60
80
100
Times
ELASTIC
INELASTIC

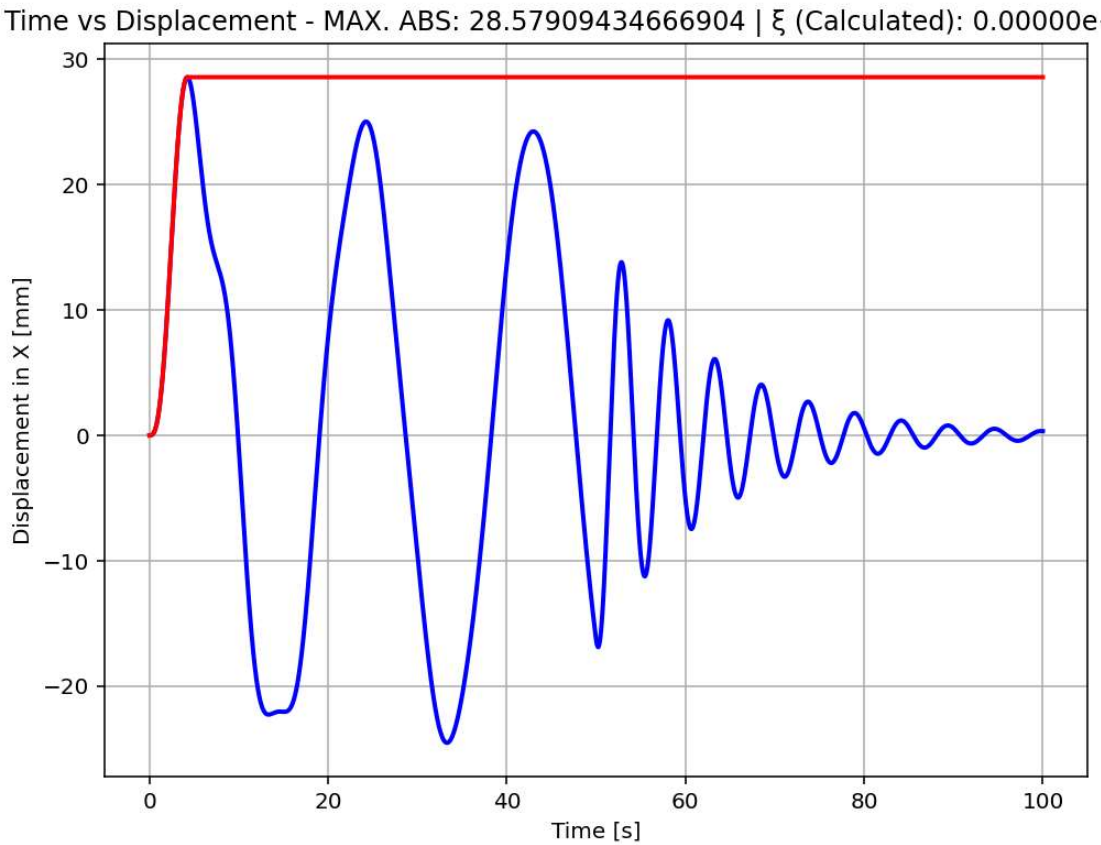

Displacement During the Analysis
ELASTIC
INELASTIC
Displacement - X [mm]
30
20
10
0
−10
−20
0
20
40
60
80
100
Times

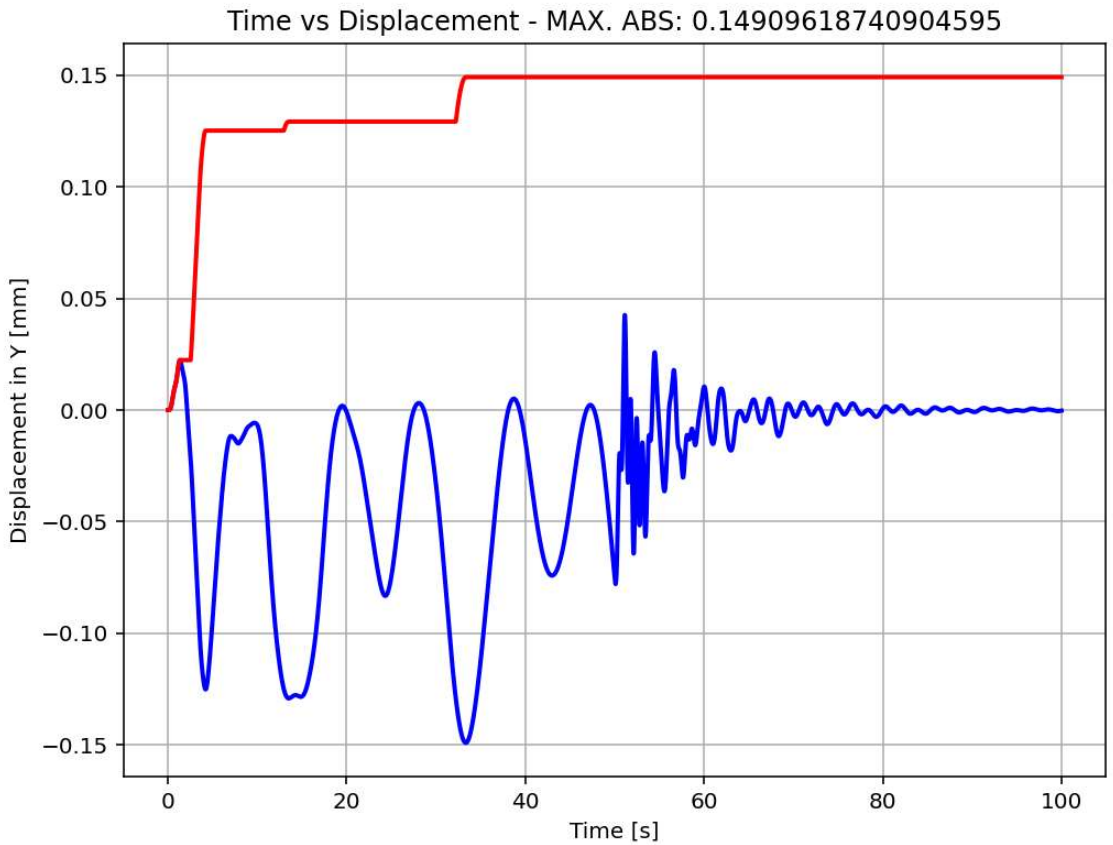

Displacement During the Analysis
ELASTIC
INELASTIC
0.050
0.025
0.000
−0.025
−0.050
−0.075
−0.100
−0.125
−0.150
Displacement - Y [mm]
0
20
40
60
80
100
Times

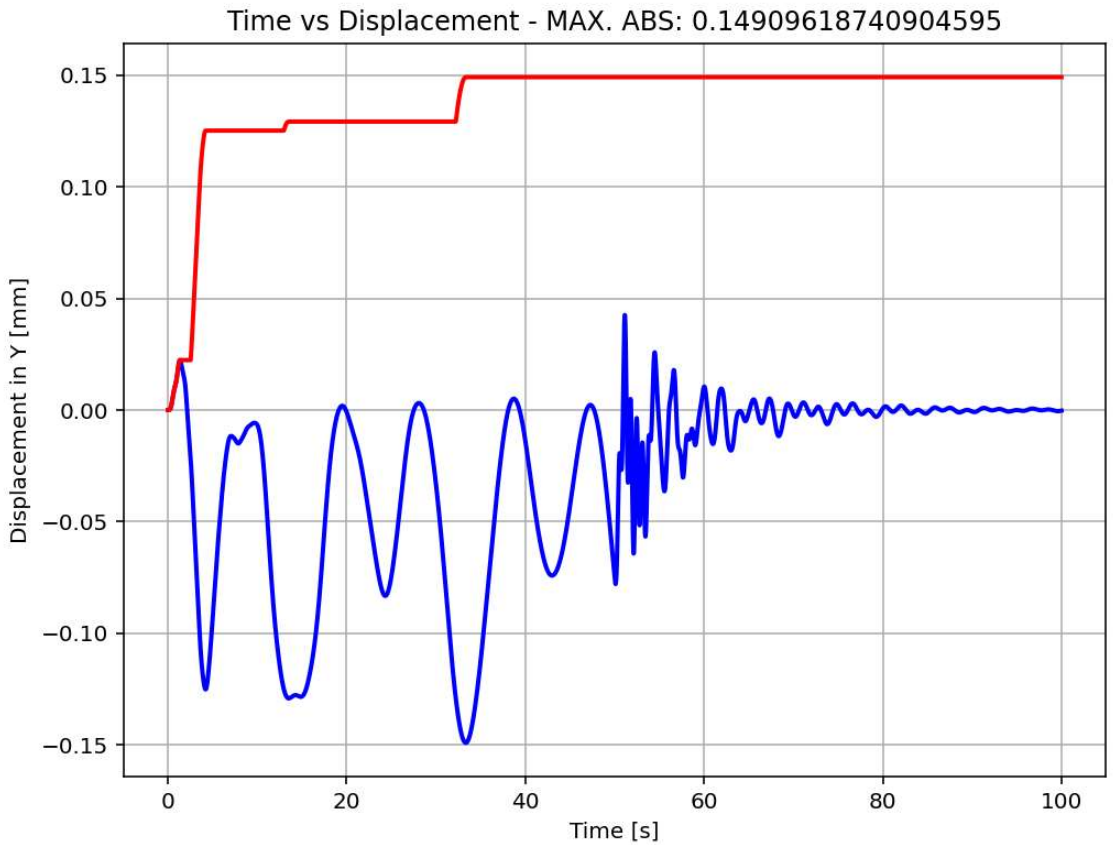

Rotation During the Analysis
ELASTIC
INELASTIC
0.010
0.005
0.000
−0.005
−0.010
Rotation [rad]
0
20
40
60
80
100
Times

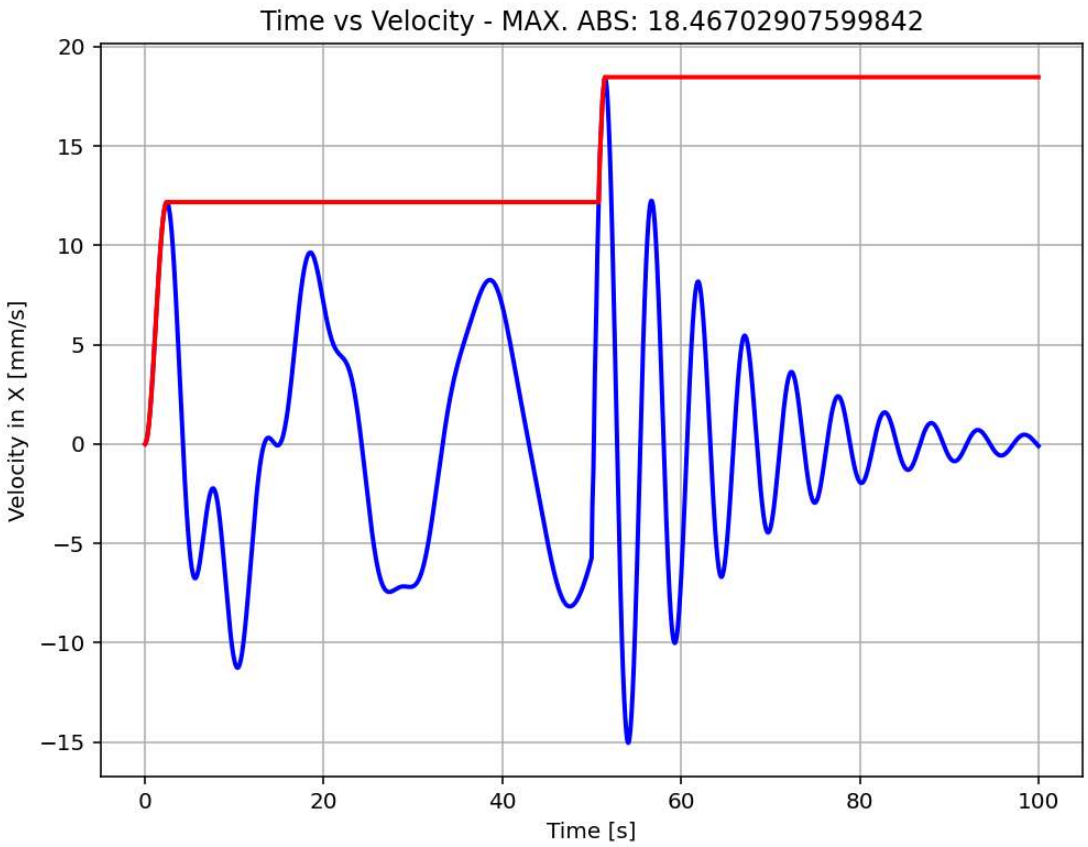

Structure Lateral Drift During the Dynamic Analysis
DYN. IN X DIR.: 9.526e-01
DYN. IN X DIR.: 9.526e-01
DYN. IN Y DIR.: 2.130e-03
DYN. IN Y DIR.: 2.130e-03
Lateral Drift [%]
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
0
20
40
60
80
100
Times

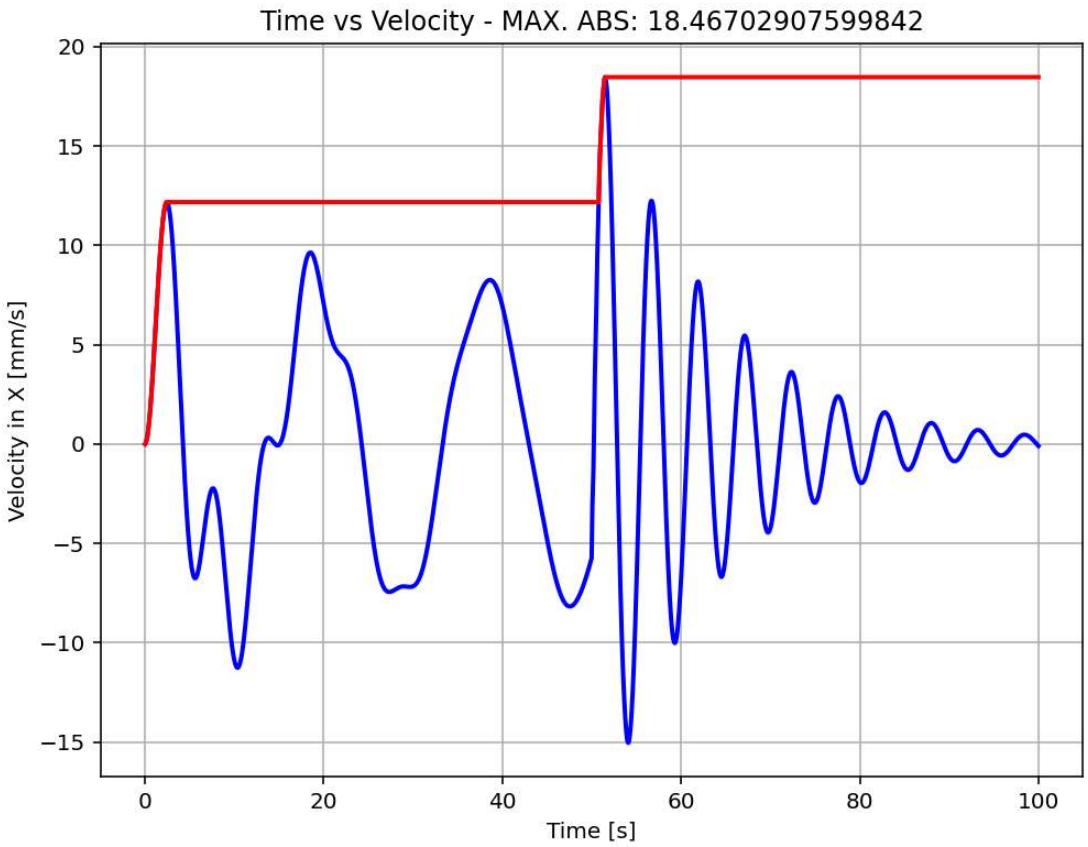

Time vs Displacement - MAX. ABS: 28.57909434666904 | ξ (Calculated): 0.00000e+00 %
Displacement in X [mm]
Time [s]
30
20
10
0
−10
−20
0
20
40
60
80
100

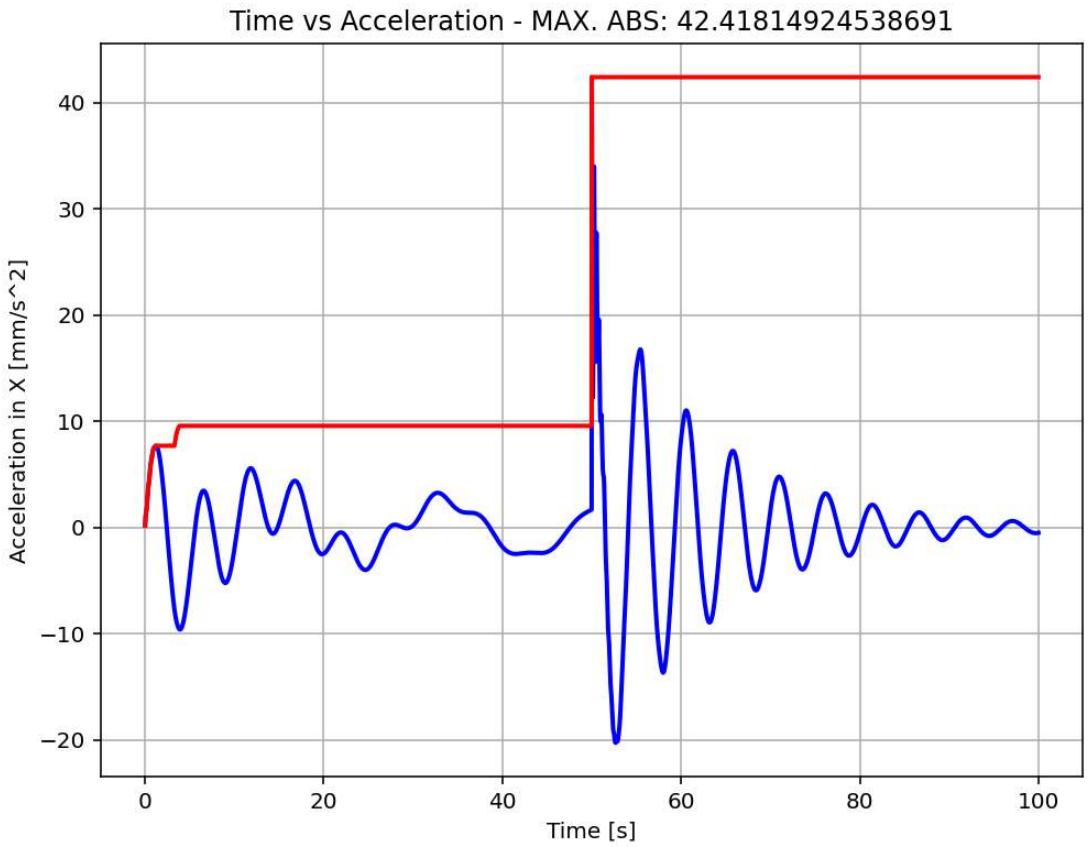

Time vs Displacement - MAX. ABS: 28.57909434666904 | ξ (Calculated): 0.00000e+00 %
Displacement in X [mm]
Time [s]
30
20
10
0
−10
−20
0
20
40
60
80
100

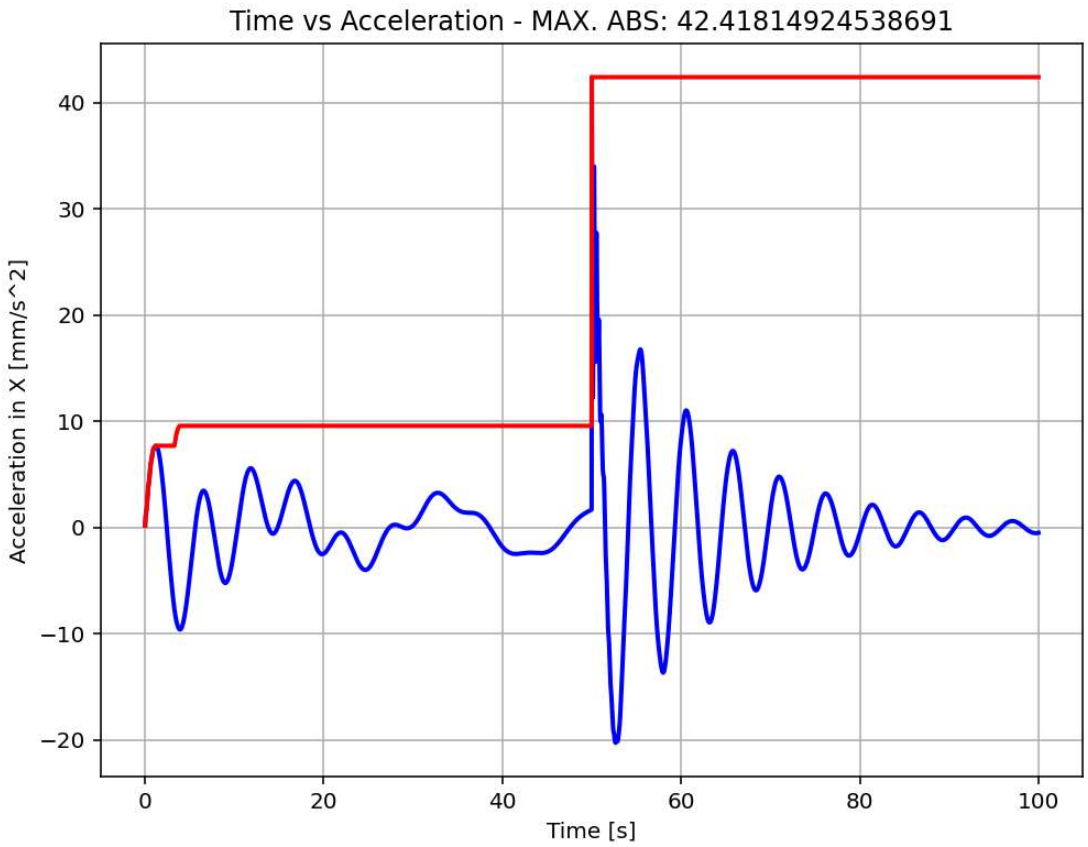

Time vs Displacement - MAX. ABS: 0.14909618740904595
Displacement in Y [mm]
Time [s]
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
0
20
40
60
80
100

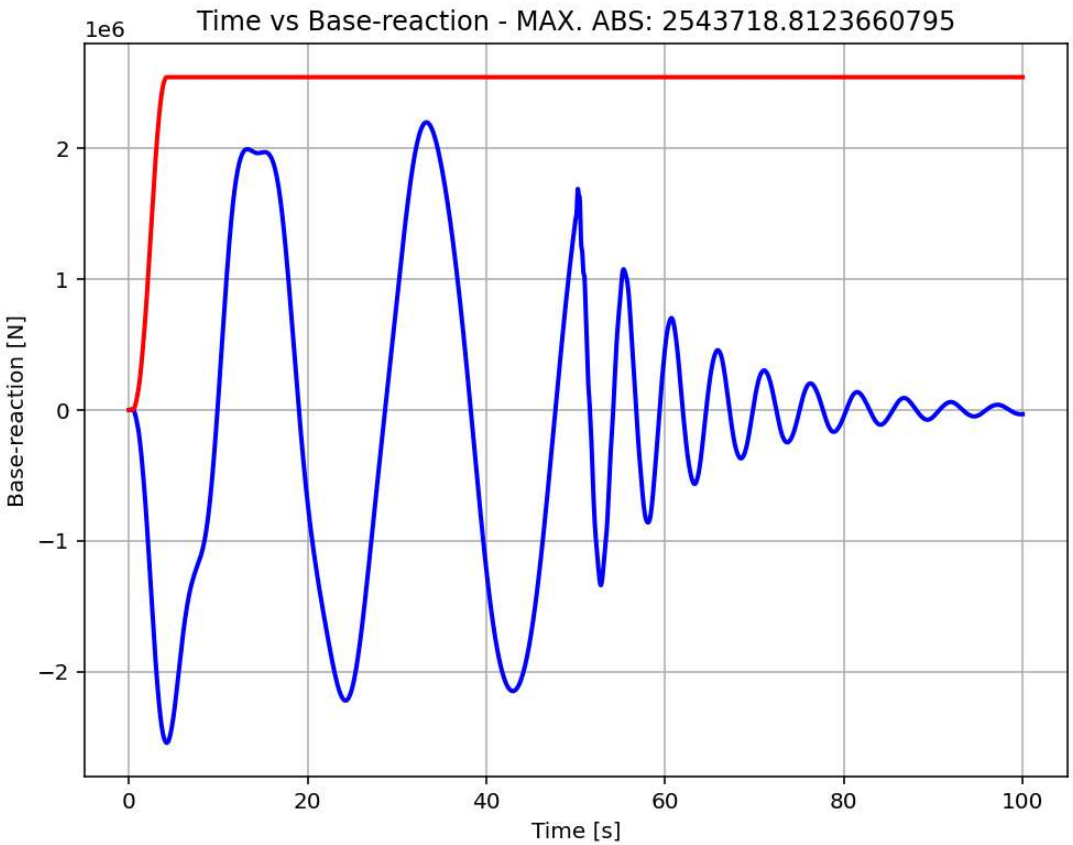

Time vs Displacement - MAX. ABS: 0.14909618740904595
Displacement in Y [mm]
Time [s]
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
0
20
40
60
80
100

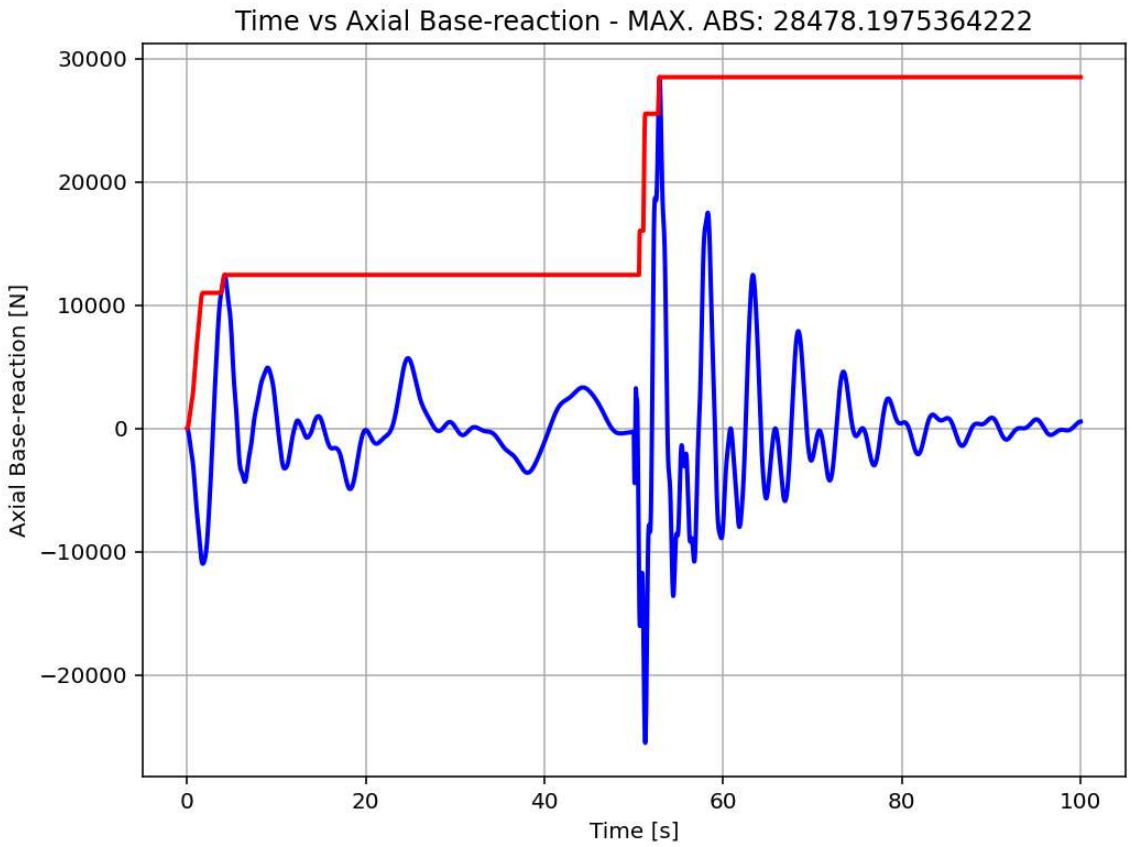

Time vs Velocity - MAX. ABS: 18.46702907599842
Velocity in X [mm/s]
Time [s]
20
15
10
5
0
−5
−10
−15
0
20
40
60
80
100

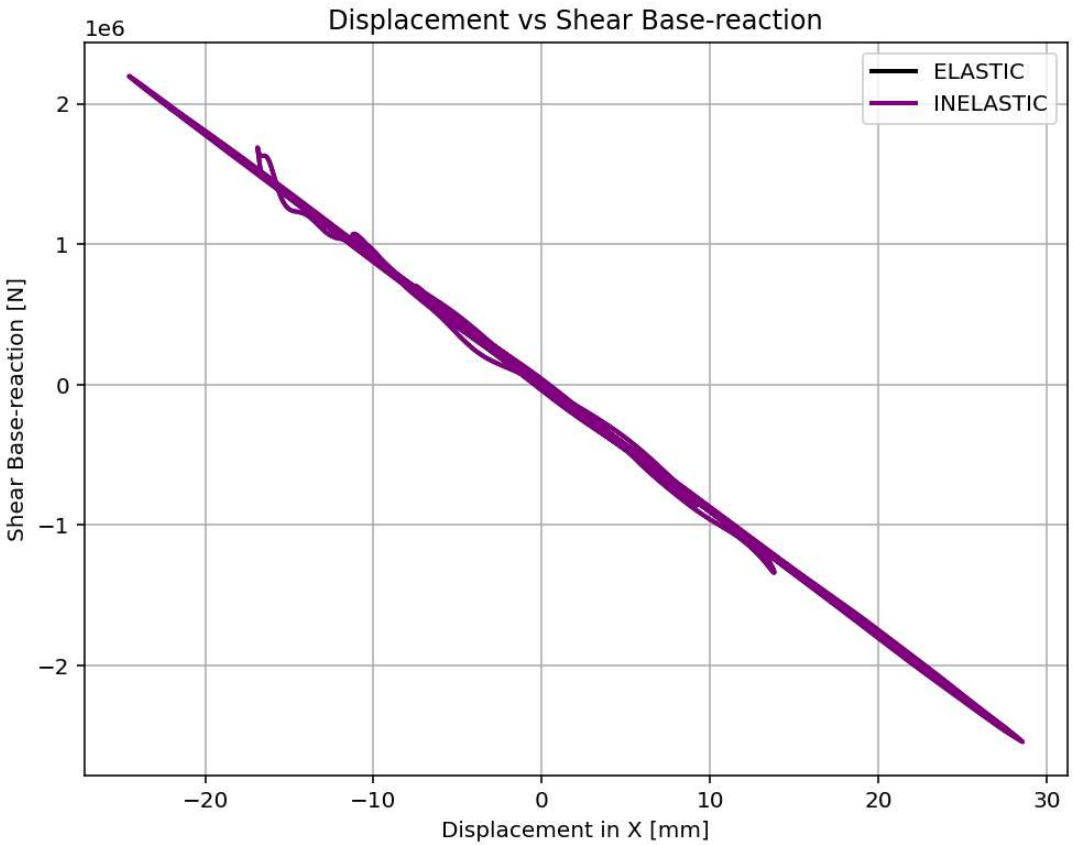

Time vs Velocity - MAX. ABS: 18.46702907599842
Velocity in X [mm/s]
Time [s]
20
15
10
5
0
−5
−10
−15
0
20
40
60
80
100

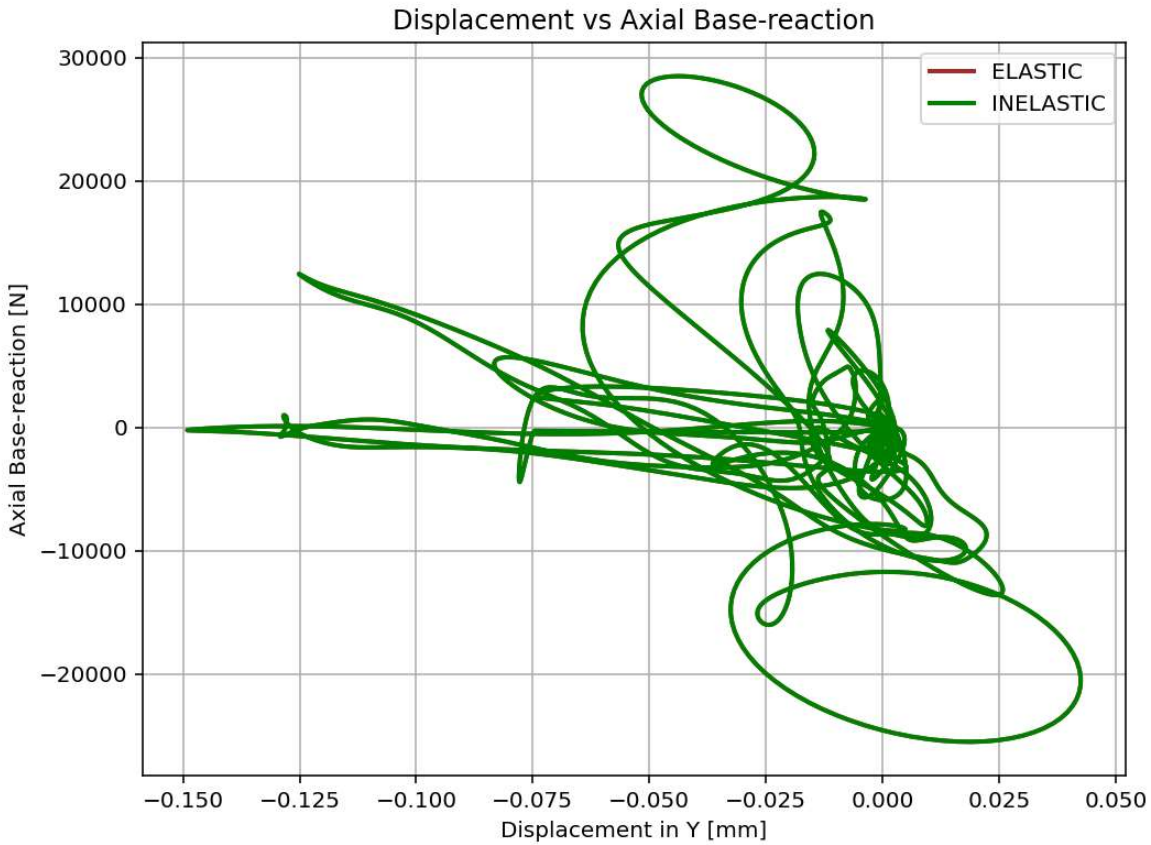

Time vs Acceleration - MAX. ABS: 42.41814924538691
Acceleration in X [mm/s^2]
Time [s]
40
30
20
10
0
−10
−20
0
20
40
60
80
100

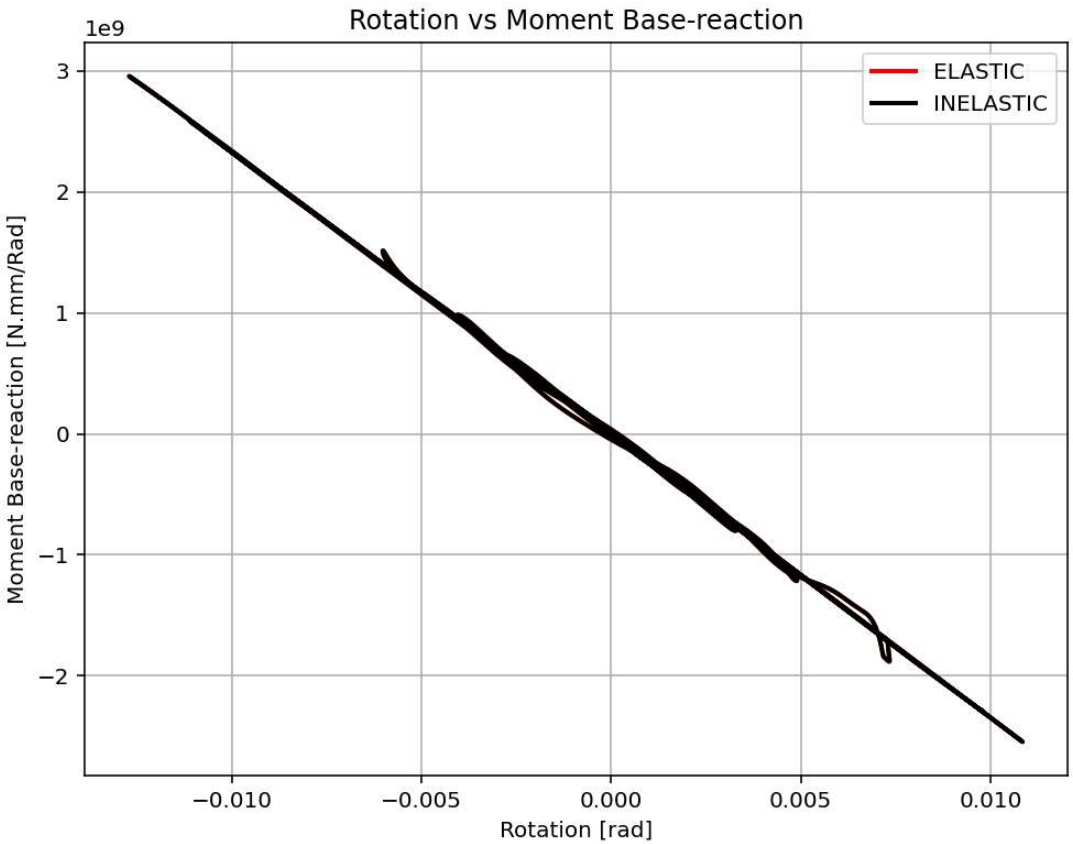

Time vs Acceleration - MAX. ABS: 42.41814924538691
Acceleration in X [mm/s^2]
Time [s]
40
30
20
10
0
−10
−20
0
20
40
60
80
100


Time vs Base-reaction - MAX. ABS: 2543718.8123660795
1e6
2
1
0
−1
−2
Base-reaction [N]
0
20
40
60
80
100
Time [s]


Time vs Axial Base-reaction - MAX. ABS: 28478.1975364222
Axial Base-reaction [N]
Time [s]
30000
20000
10000
0
−10000
−20000
0
20
40
60
80
100


Displacement vs Shear Base-reaction
1e6
ELASTIC
INELASTIC
2
1
0
−1
−2
Shear Base-reaction [N]
−20
−10
0
10
20
30
Displacement in X [mm]


Displacement vs Axial Base-reaction
ELASTIC
INELASTIC
30000
20000
10000
0
−10000
−20000
Axial Base-reaction [N]
−0.150
−0.125
−0.100
−0.075
−0.050
−0.025
0.000
0.025
0.050
Displacement in Y [mm]


Rotation vs Moment Base-reaction
1e9
3
2
1
0
−1
−2
Moment Base-reaction [N.mm/Rad]
−0.010
−0.005
0.000
0.005
0.010
Rotation [rad]
ELASTIC
INELASTIC