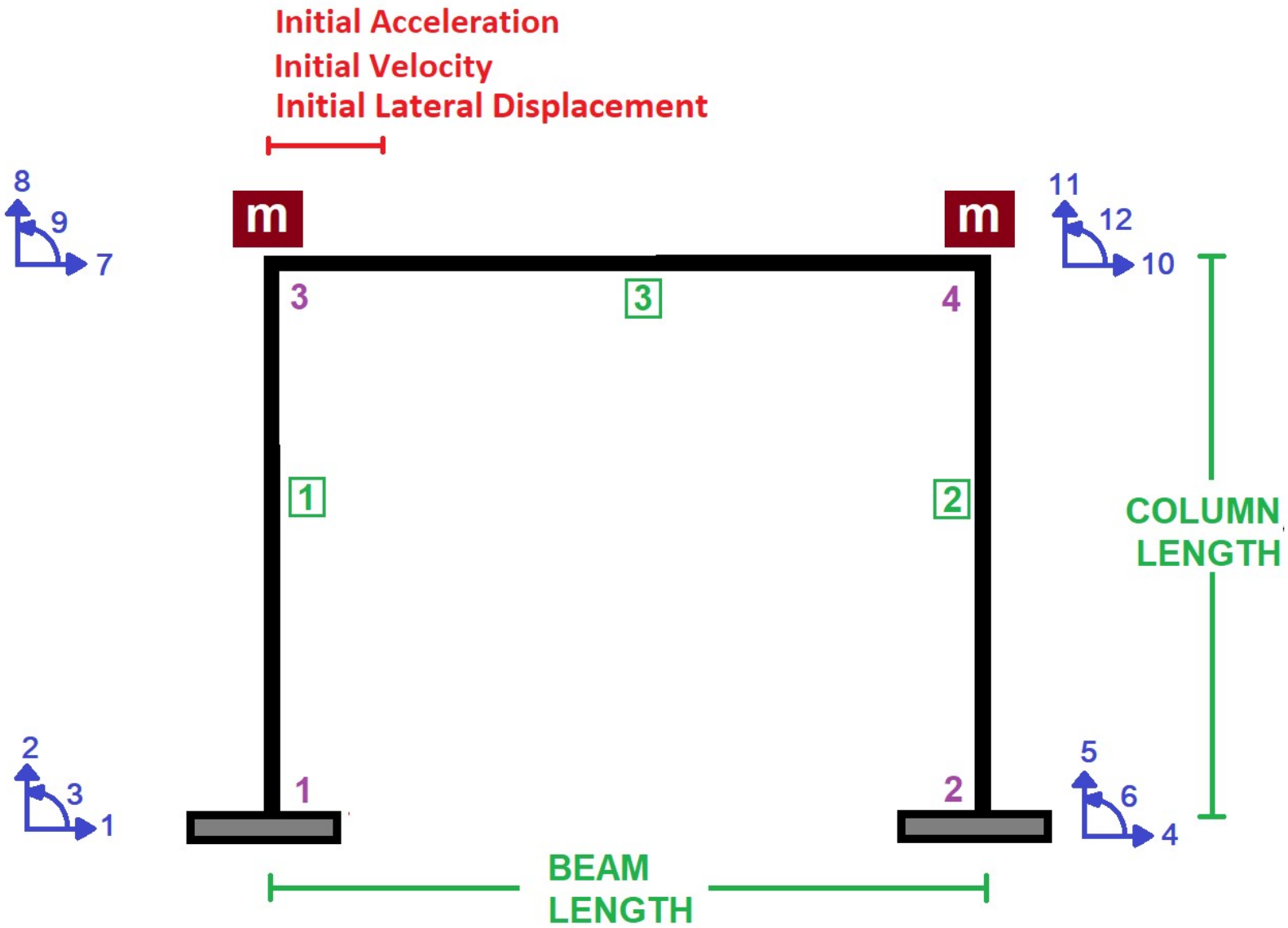
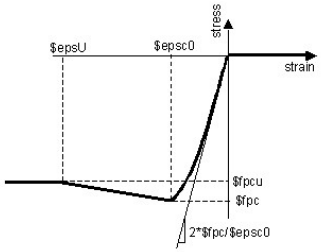
IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL

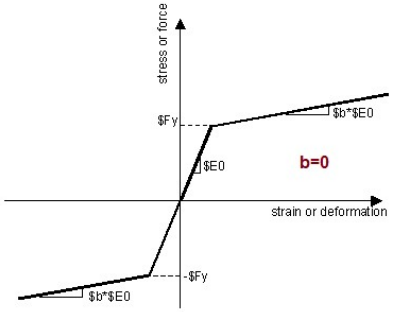
FREE-VIBRATION ANALYSIS OF CONCRETE FRAME. EVALUATING STRAIN HARDENING AND ULTIMATE STRAIN CRITERIA USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)

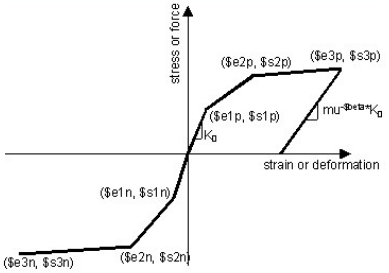

Initial Acceleration
Initial Velocity
Initial Lateral Displacement
m
m
8
9
7
11
12
10
3
3
4
1
2
COLUMN LENGTH
2
3
1
1
2
5
6
4
BEAM LENGTH



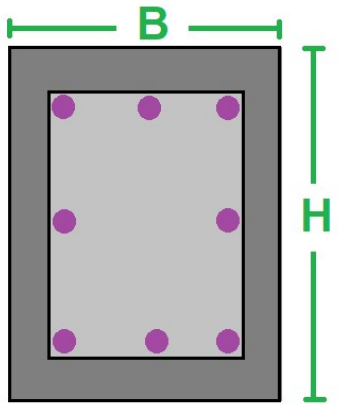
CORE AND COVER CONCRETE REALTION



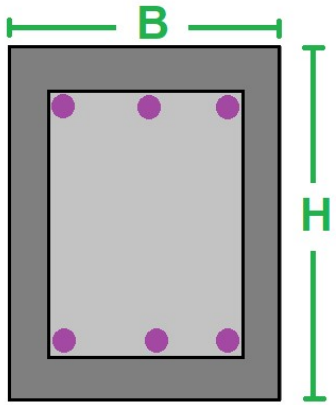
WITHOUT HARDENING AND ULTIMATE STRAIN



WITH HARDENING AND ULTIMATE STRAIN



COLUMN SECTION



BEAM SECTION

Spyder (Python 3.12)

File Edit Search Source Run Debug Consoles Projects Tools View Help

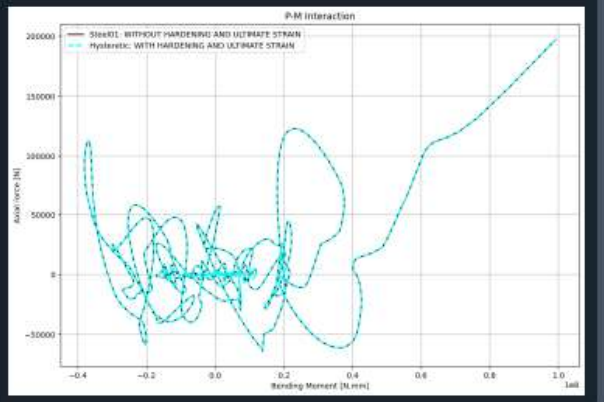
C:\Users\Dell\Desktop\OPENSEES_FILES\CONCRETE_FRA...0_V0_A0\CONCRETE_FRAME_FREE-VIBRATION_U0_V0_A0.py

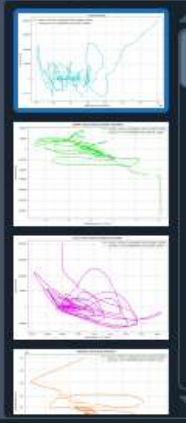
CONCRETE_FRAME_FRE...RATION_U0_V0_A0.py

```
##########################################################################################################
#                                  IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL
# FREE-VIBRATION ANALYSIS OF CONCRETE FRAME. EVALUATING STRAIN HARDENING AND ULTIMATE STRAIN CRITERIA
#---------------------------------------------------------------------------------------------------------
#                          FREE-VIBRATION ANALYSIS WITH INITIAL DISPLACEMENT, VELOCITY AND ACCELERATION
#---------------------------------------------------------------------------------------------------------
#                                  THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
#                                       EMAIL: salar.d.ghashghaei@gmail.com
##########################################################################################################
"""
1. Objective: The study evaluates the dynamic response of a concrete frame under
free-vibration conditions, comparing two steel material models:
   - Steel01: Bilinear elastic-perfectly plastic (*no hardening/ultimate strain*).
   - Hysteretic: Tri-linear with strain hardening, pinching, and stiffness degradation (*includes ulti

2. Model Setup:
   - Geometry: 2D frame with columns (500×500 mm) and beam (500×300 mm), subjected to
   an initial displacement (1.1 mm).
   - Materials: Confined/unconfined concrete (`Concrete01`) and steel rebars (either `Steel01` or `Hys
   - Damping: Rayleigh damping (5% initial guess) calibrated via eigenvalue analysis.

3. Dynamic Response:
   - Period: Natural period (`T`) calculated from eigenanalysis (~0.28 s for fundamental mode).
   - Displacement Decay: Logarithmic decrement used to compute damping ratios (`ξ`).
   The *Hysteretic* model showed higher energy dissipation due to degradation.

4. Force-Displacement Behavior:
   - Shear (X-direction): The *Hysteretic* model exhibited pinching and reduced
   stiffness in hysteresis loops, while *Steel01* maintained symmetric, undegraded cycles.
   - Axial (Y-direction): Both models showed nonlinear coupling, but *Hysteretic*
   introduced residual displacements from cumulative damage.
   - Moment-Rotation: *Hysteretic* displayed strength decay under cyclic rotations,
   unlike *Steel01*'s stable post-yield plateau.
```

...CRETE_FRAME_EXAMPLES\FREE-VIBRATION\FREE-VIBRATION_U0_V0_A0

25 %





Help | Variable Explorer | Debugger | Plots | Files

Console 1/A

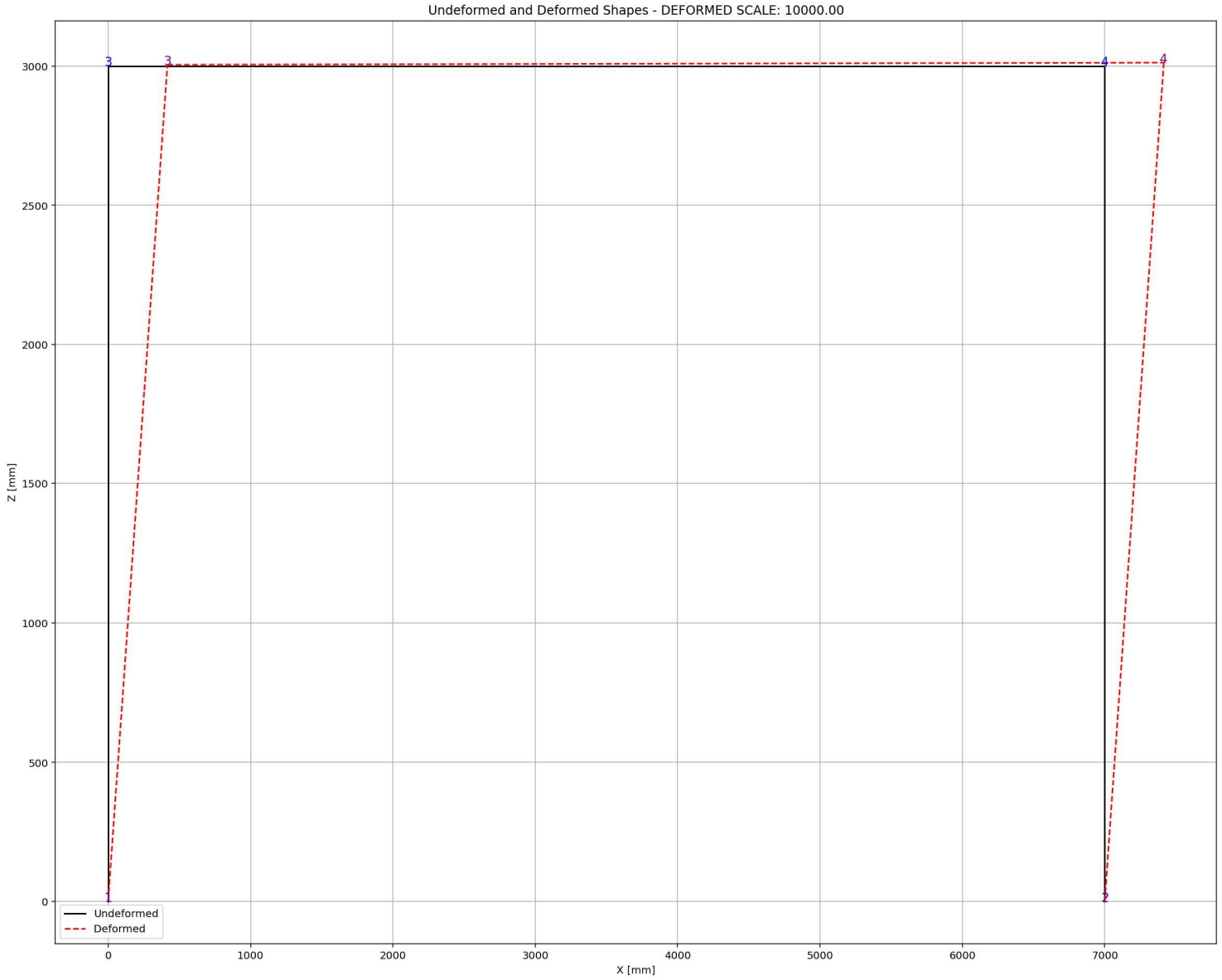
```
149.9799999999361 0.04164300141950749 -298.78344890527677
149.9849999999361 0.041646588585402856 -298.8106582628139
149.9899999999361 0.041650175224349745 -298.8378631935062
149.99499999993608 0.041653761319097295 -298.86506355397717
149.99999999993608 0.04165734685240l3 -298.89225919948825
150.00499999993608 0.041660931807024196 -298.9194499799863
WITHOUT HARDENING AND ULTIMATE STRAIN:
 Period 01: {PERIOD_01:.4e}  - Period 02: {PERIOD_02:.4e}
WITH HARDENING AND ULTIMATE STRAIN:
 Period 01: {PERIOD_012:.4e}  - Period 02: {PERIOD_022:.4e}
```

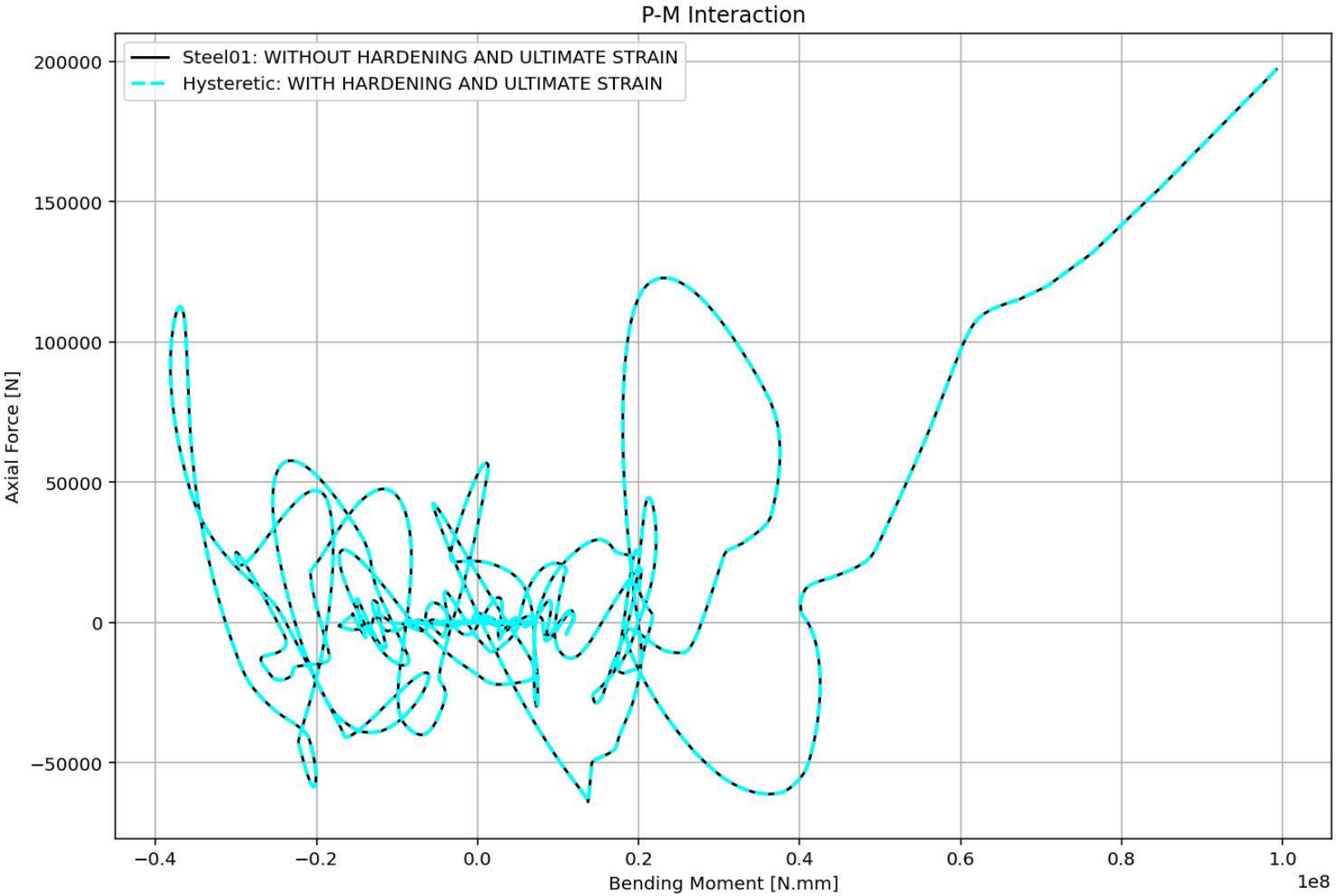
IPython Console | History

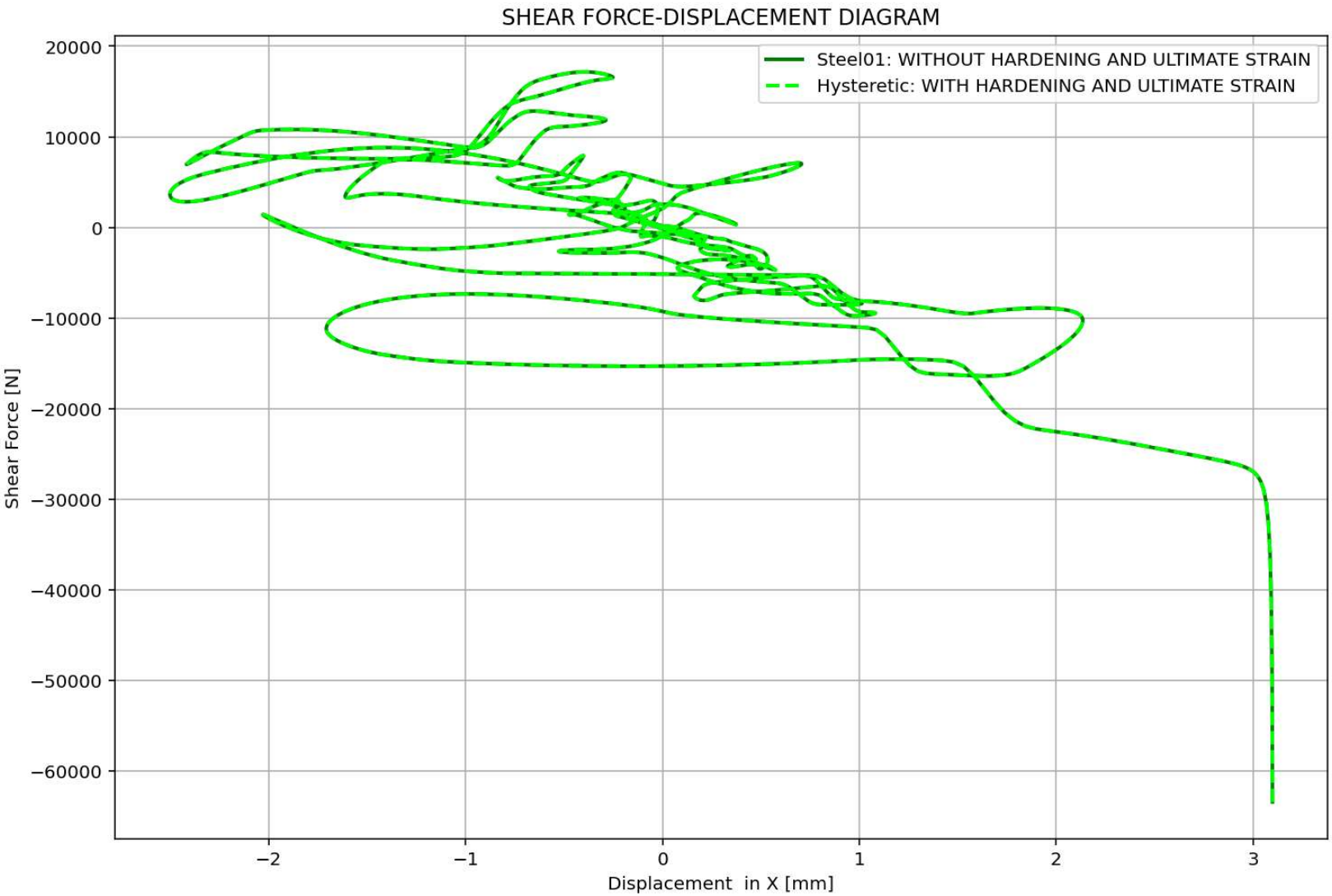
Inline | Conda: anaconda3 (Python 3.12.7) | LSP: Python | Line 19, Col 72 | UTF-8 | CRLF | RW | Mem 44%

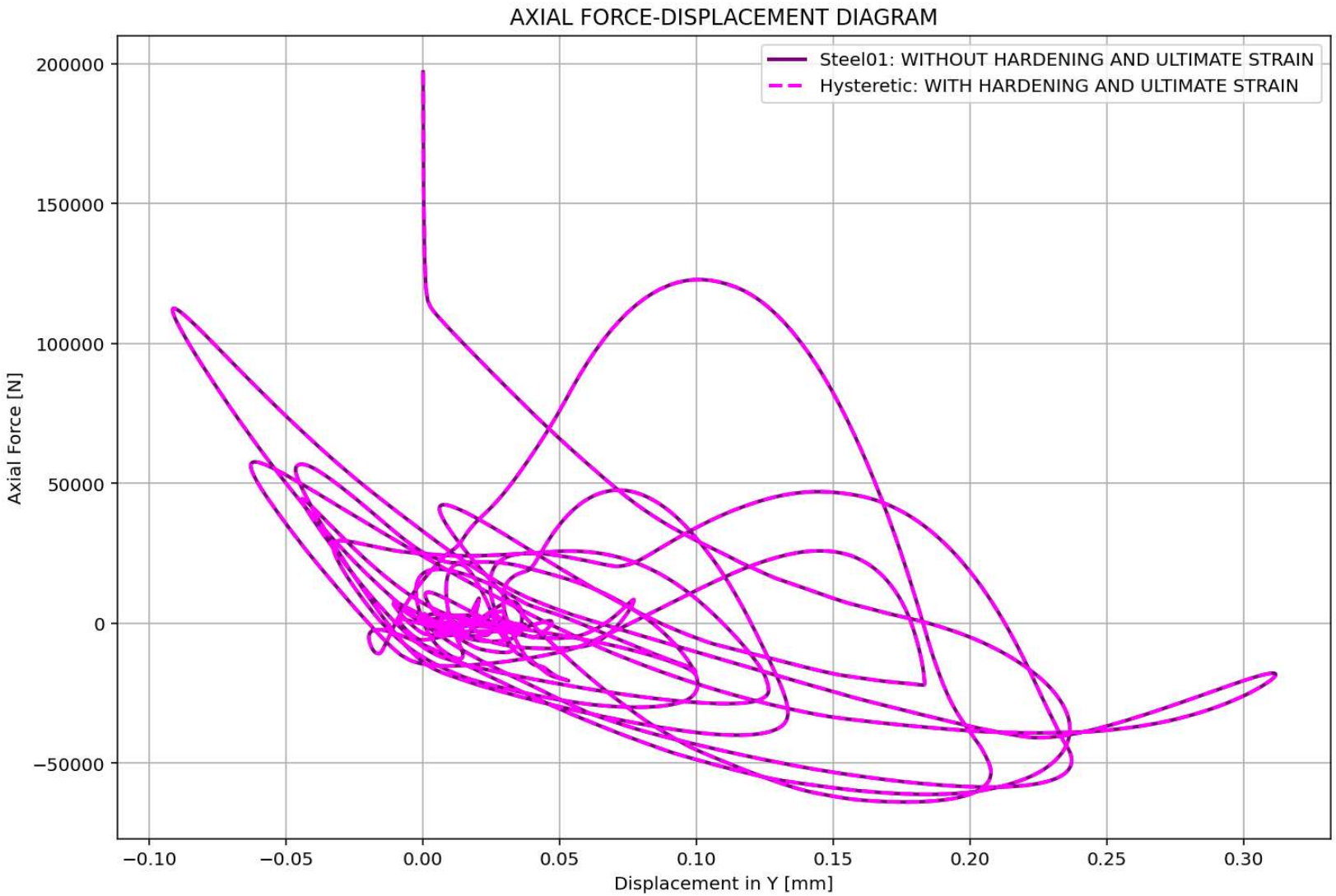
Free Vibration Analysis

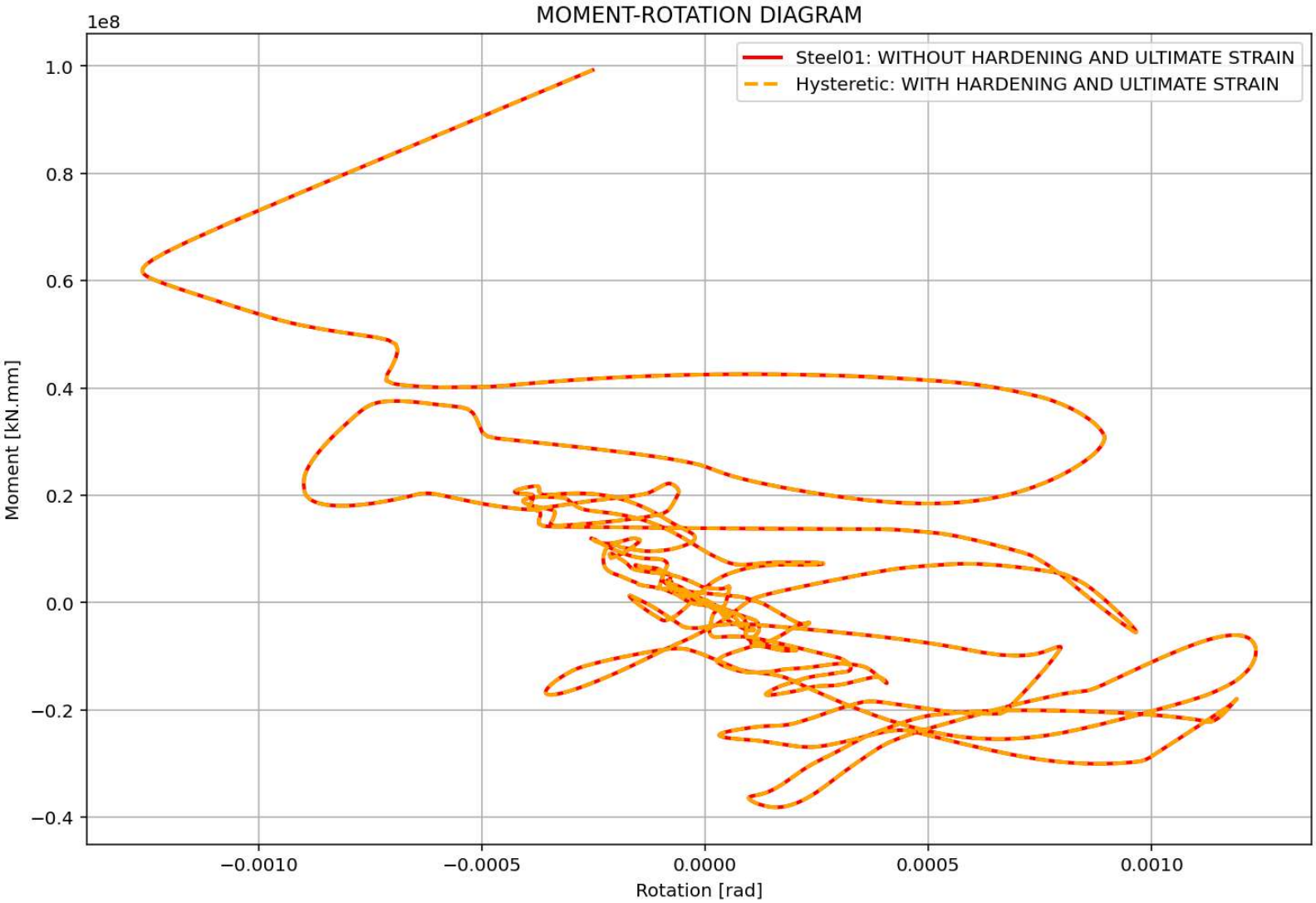
With Initial Displacement ,Velocity and Acceleration

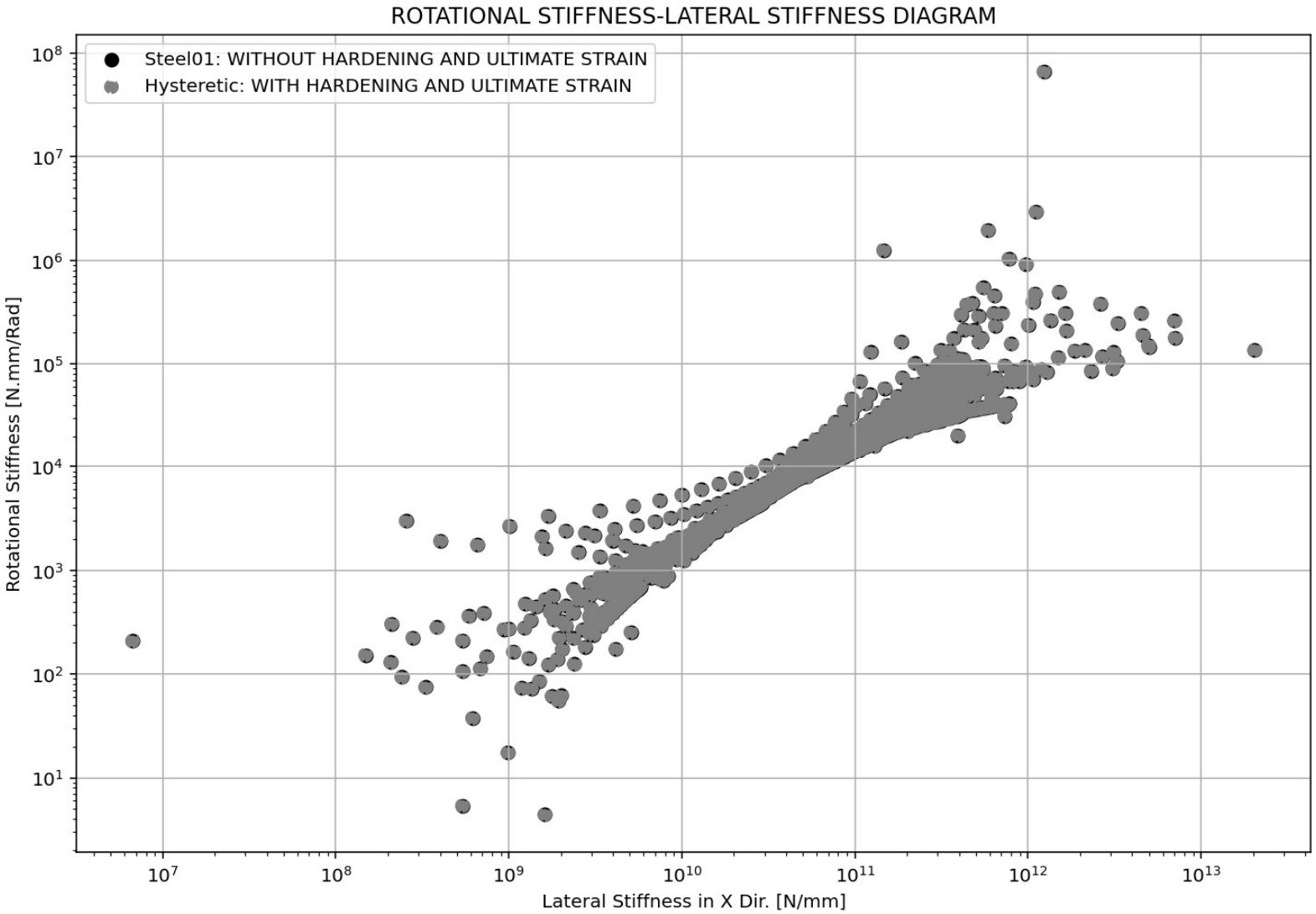

Undeformed and Deformed Shapes - DEFORMED SCALE: 10000.00
Z [mm]
X [mm]
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000
1
2
3
3
4
4
Undeformed
Deformed

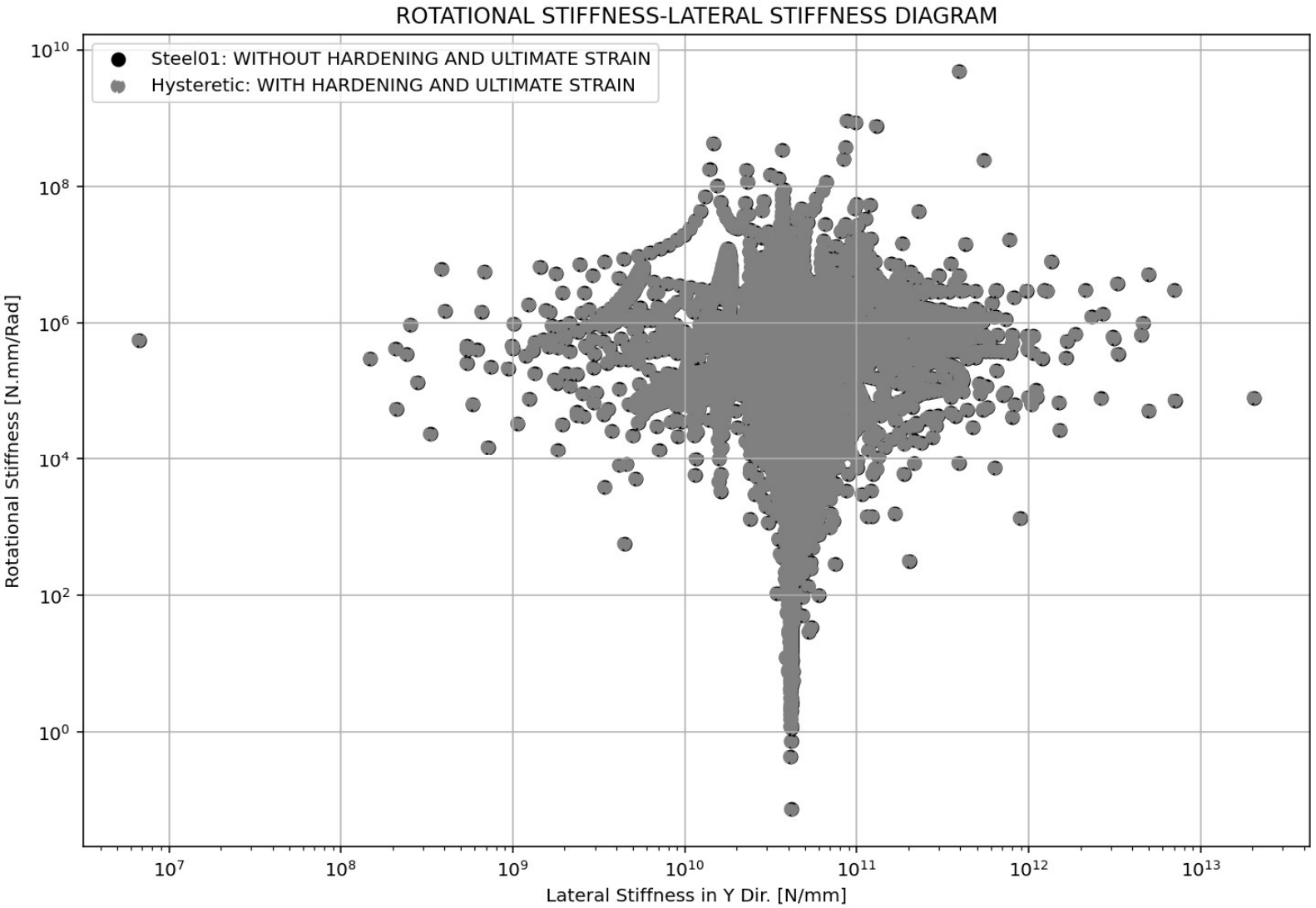

P-M Interaction
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Axial Force [N]
200000
150000
100000
50000
0
−50000
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
1.0
1e8
Bending Moment [N.mm]

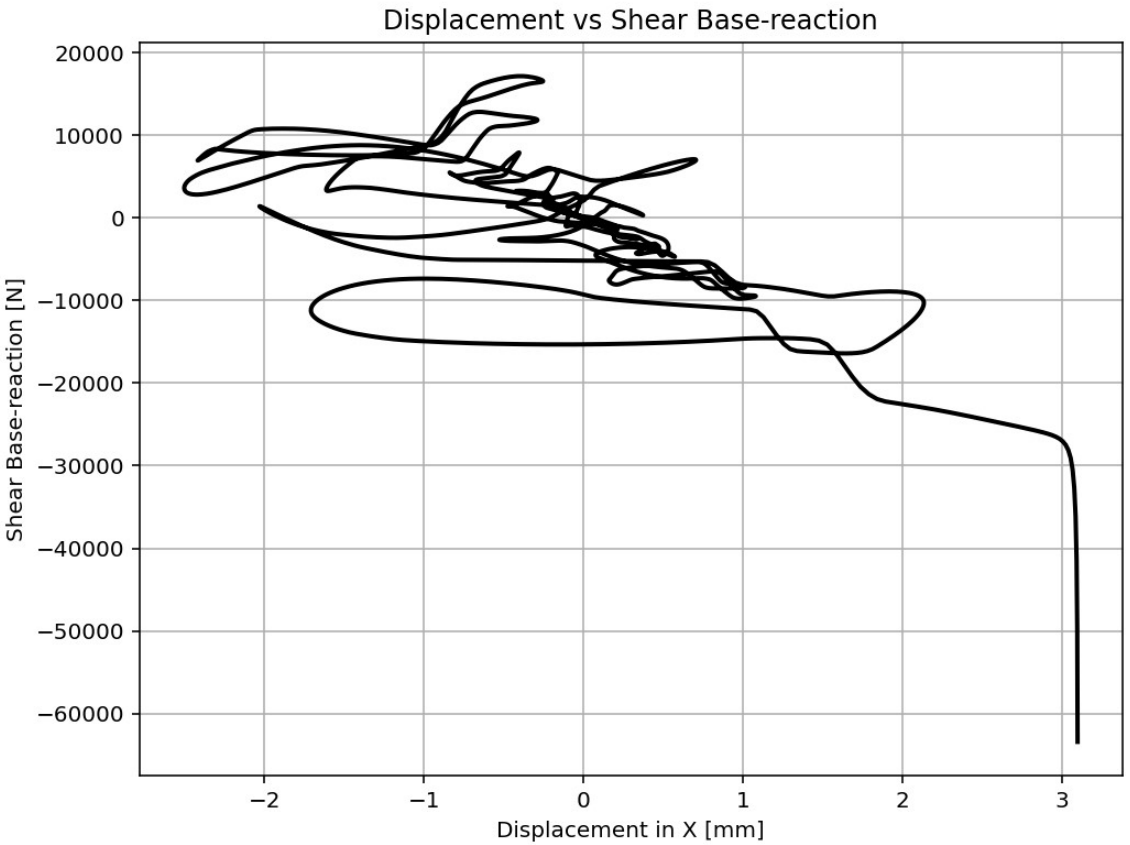

SHEAR FORCE-DISPLACEMENT DIAGRAM
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Shear Force [N]
20000
10000
0
−10000
−20000
−30000
−40000
−50000
−60000
−2
−1
0
1
2
3
Displacement in X [mm]

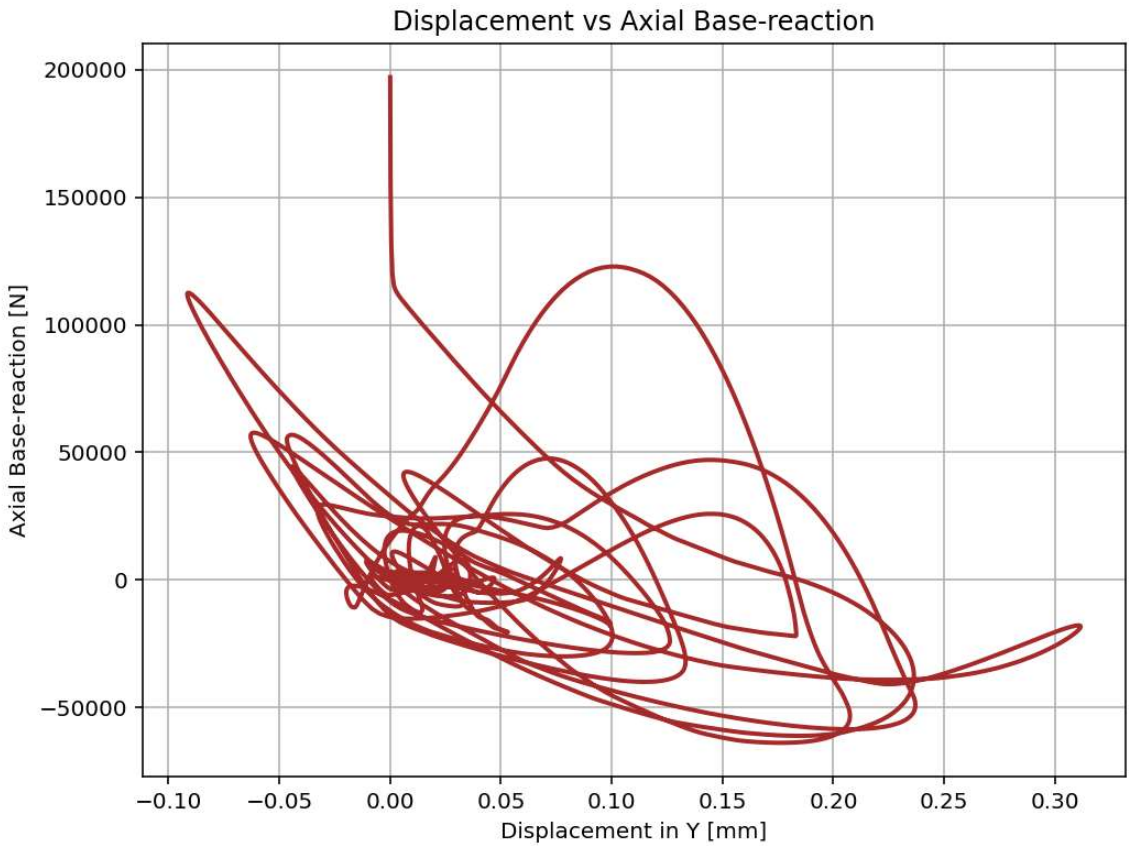

AXIAL FORCE-DISPLACEMENT DIAGRAM
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Axial Force [N]
200000
150000
100000
50000
0
−50000
−0.10
−0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Displacement in Y [mm]

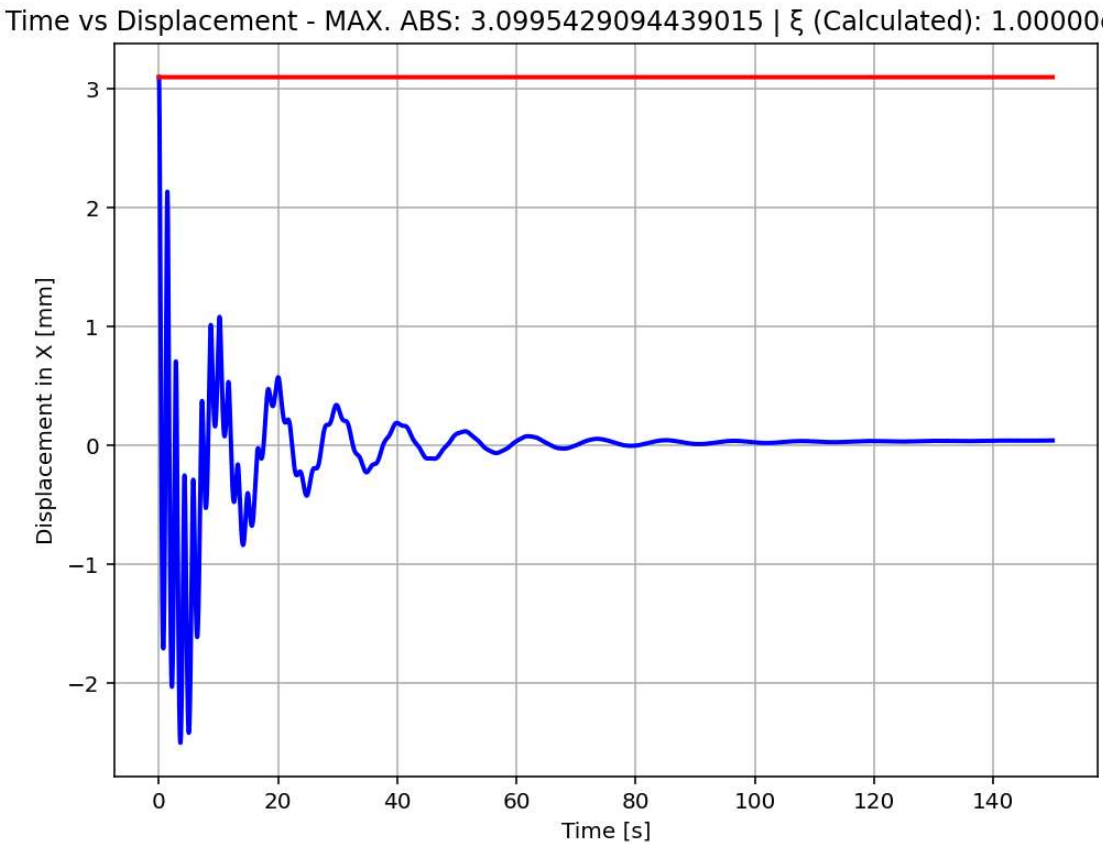

MOMENT-ROTATION DIAGRAM
1e8
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Moment [kN.mm]
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.0010
−0.0005
0.0000
0.0005
0.0010
Rotation [rad]

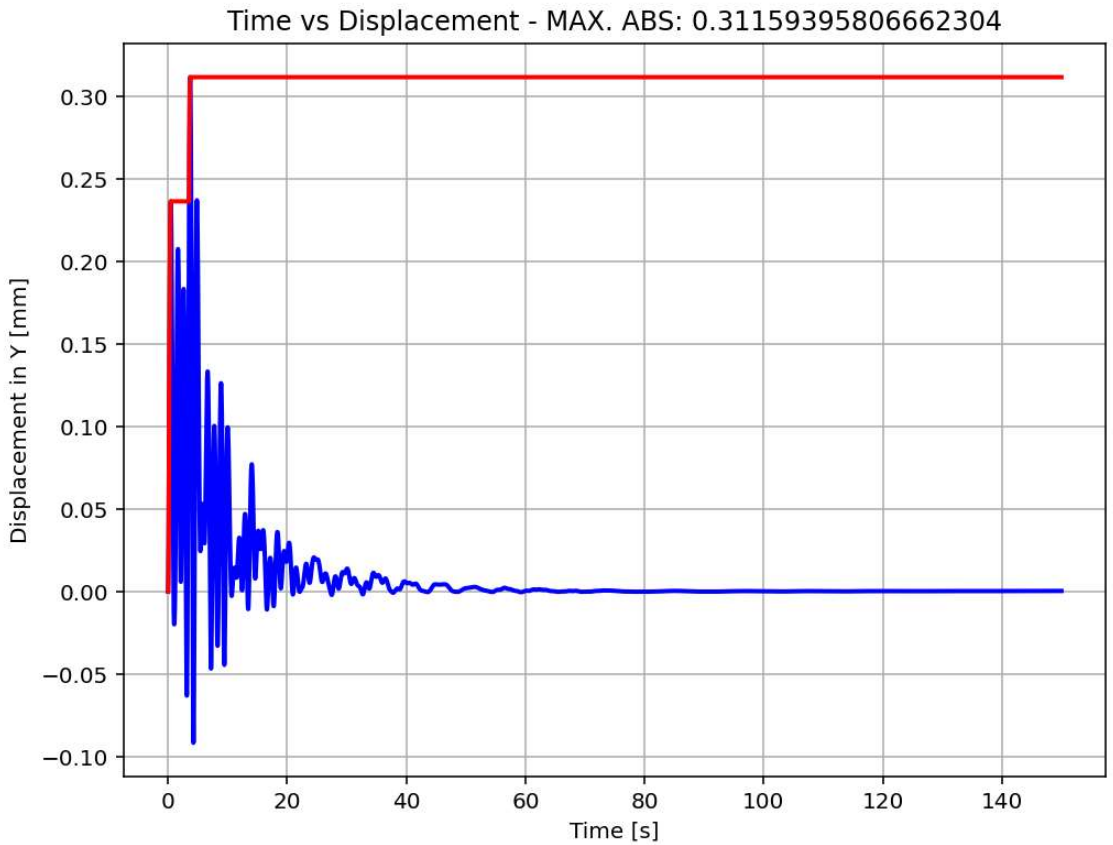

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in X Dir. [N/mm]
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
10^{8}
10^{7}
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}

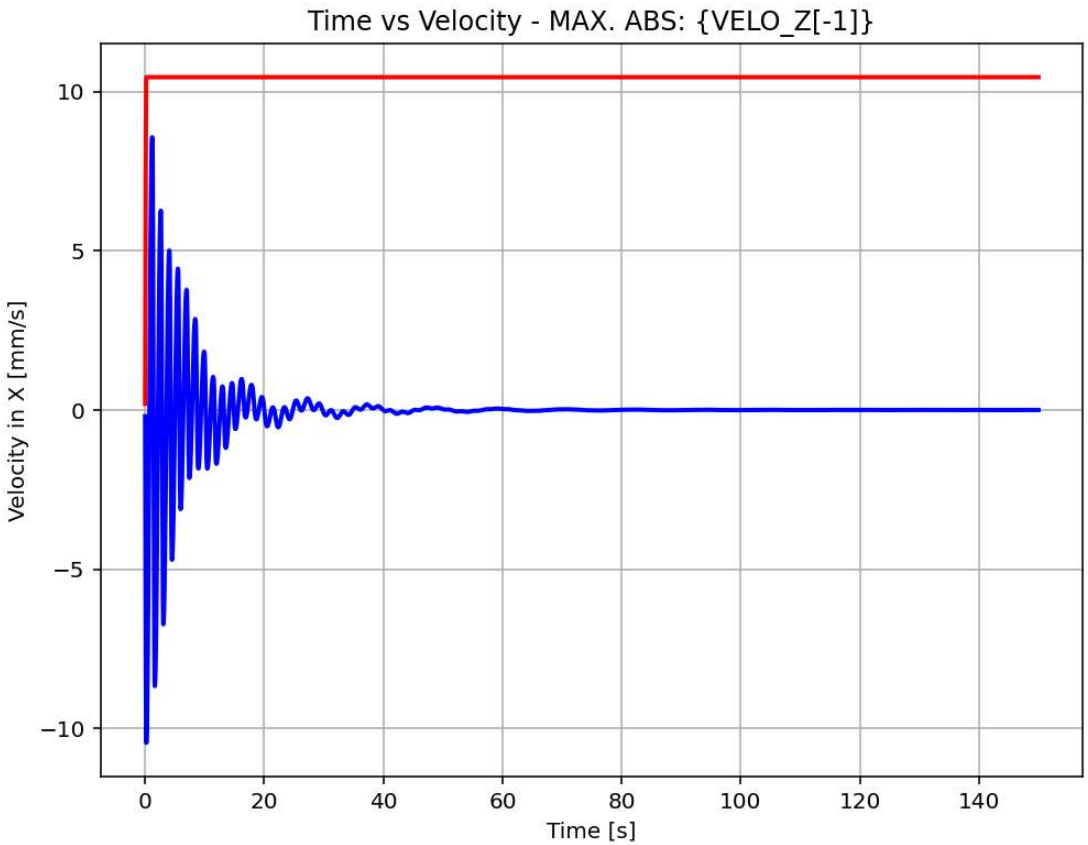

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in Y Dir. [N/mm]
10^{10}
10^{8}
10^{6}
10^{4}
10^{2}
10^{0}
10^{7}
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}

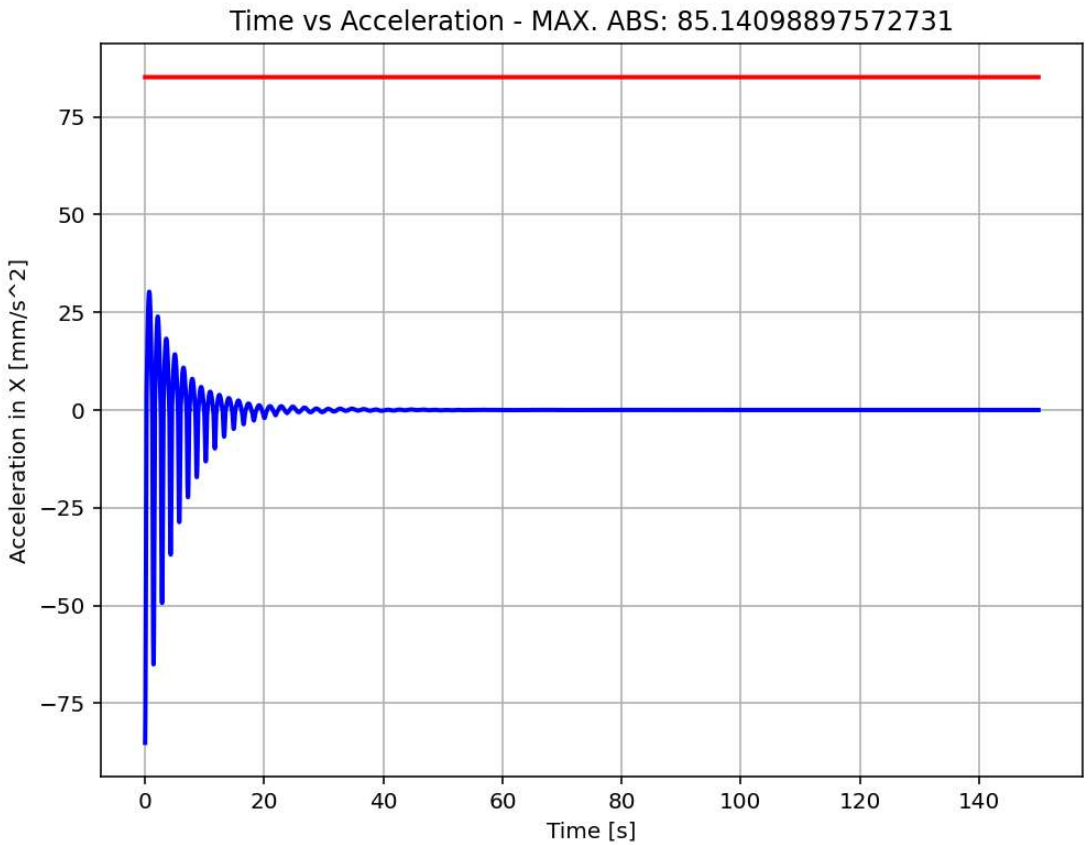

Displacement vs Shear Base-reaction
Shear Base-reaction [N]
20000
10000
0
−10000
−20000
−30000
−40000
−50000
−60000
−2
−1
0
1
2
3
Displacement in X [mm]

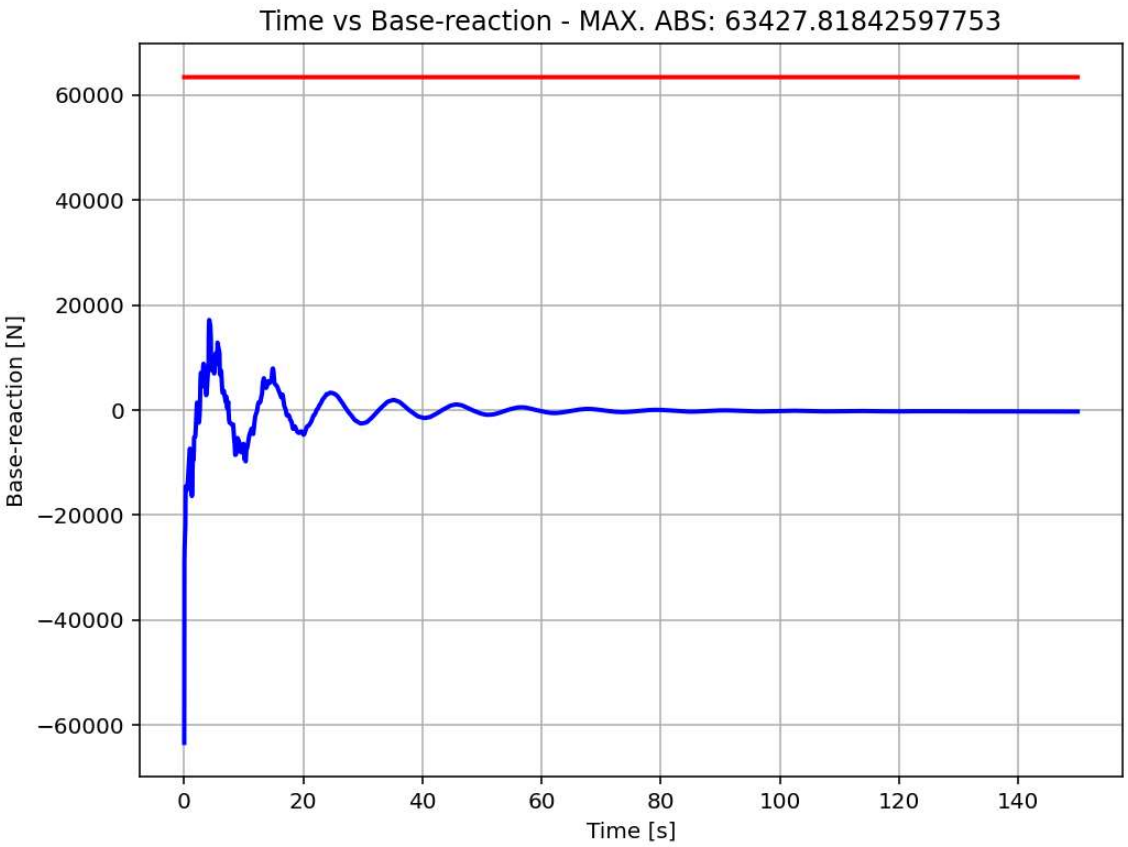

Displacement vs Axial Base-reaction
Axial Base-reaction [N]
200000
150000
100000
50000
0
−50000
−0.10
−0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Displacement in Y [mm]


Time vs Displacement - MAX. ABS: 3.0995429094439015 | ξ (Calculated): 1.00000e+02 %
Displacement in X [mm]
Time [s]
3
2
1
0
−1
−2
0
20
40
60
80
100
120
140


Time vs Displacement - MAX. ABS: 0.31159395806662304
Displacement in Y [mm]
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
0
20
40
60
80
100
120
140
Time [s]


Time vs Velocity - MAX. ABS: {VELO_Z[-1]}
Velocity in X [mm/s]
Time [s]
10
5
0
−5
−10
0
20
40
60
80
100
120
140


Time vs Acceleration - MAX. ABS: 85.14098897572731
Acceleration in X [mm/s^2]
75
50
25
0
−25
−50
−75
0
20
40
60
80
100
120
140
Time [s]


Time vs Base-reaction - MAX. ABS: 63427.81842597753
Base-reaction [N]
60000
40000
20000
0
−20000
−40000
−60000
0
20
40
60
80
100
120
140
Time [s]