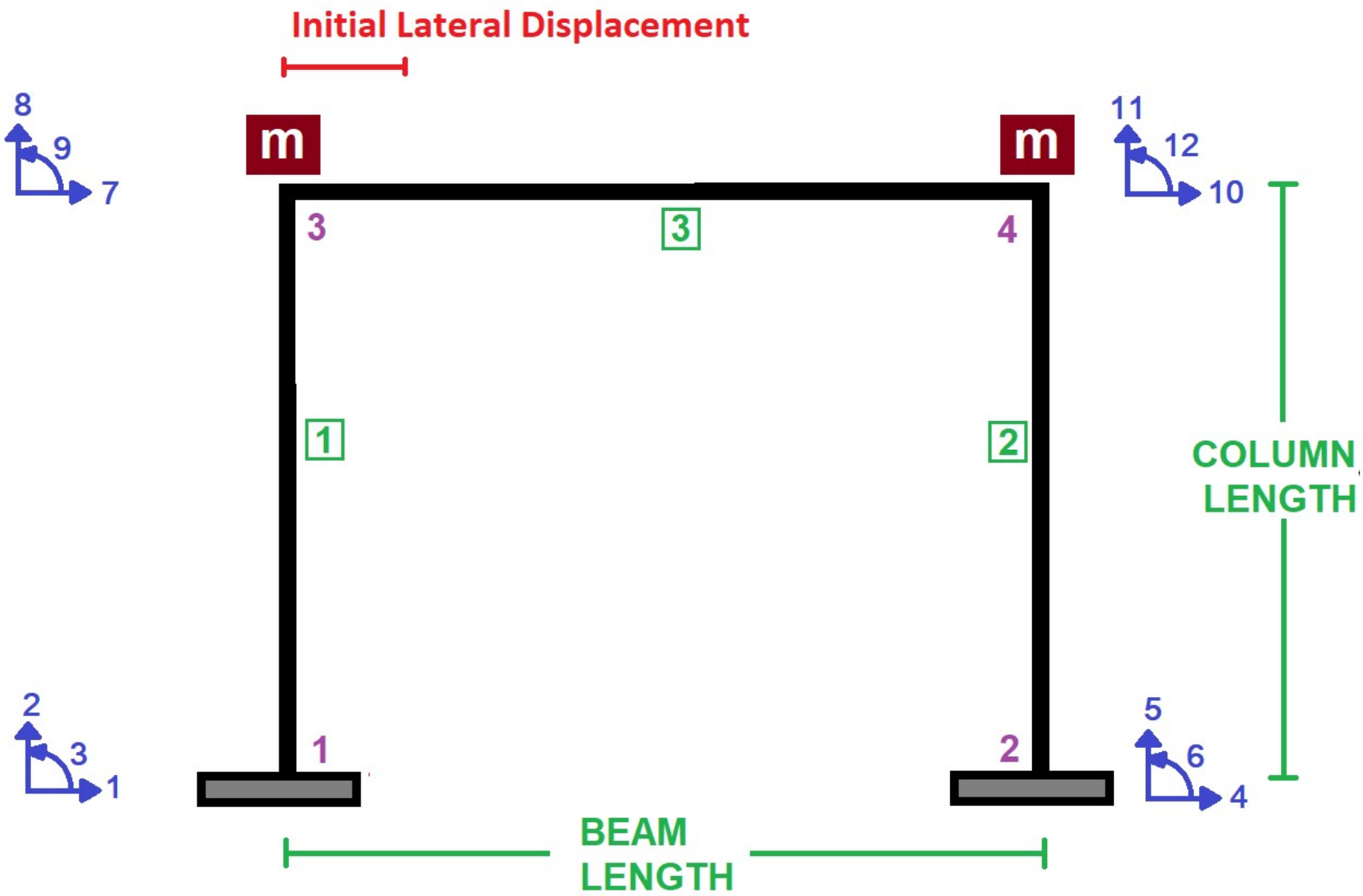
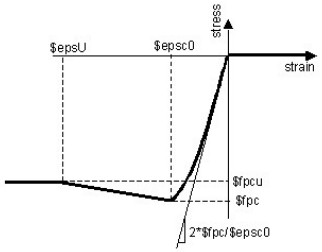
IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL

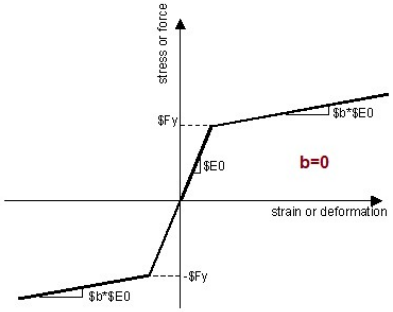
FREE-VIBRATION ANALYSIS OF CONCRETE FRAME. EVALUATING STRAIN HARDENING AND ULTIMATE STRAIN CRITERIA USING OPENSEES

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)

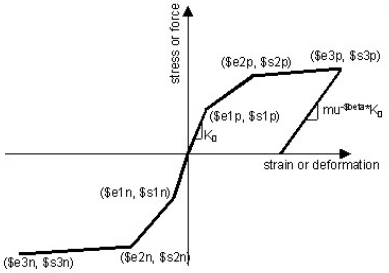

Initial Lateral Displacement
m
m
8
9
7
11
12
10
3
3
4
1
2
COLUMN LENGTH
2
3
1
1
2
5
6
4
BEAM LENGTH



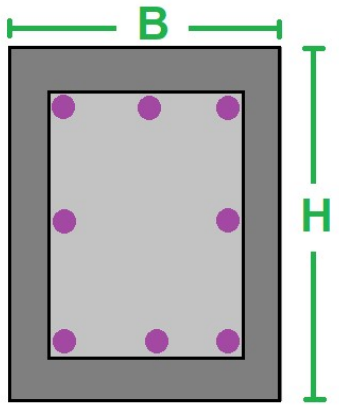
CORE AND COVER CONCRETE REALTION



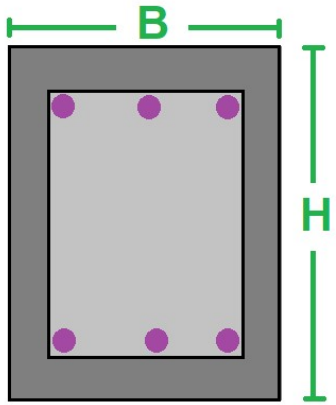
WITHOUT HARDENING AND ULTIMATE STRAIN



WITH HARDENING AND ULTIMATE STRAIN



COLUMN SECTION



BEAM SECTION

Spyder (Python 3.12)

File Edit Search Source Run Debug Consoles Projects Tools View Help

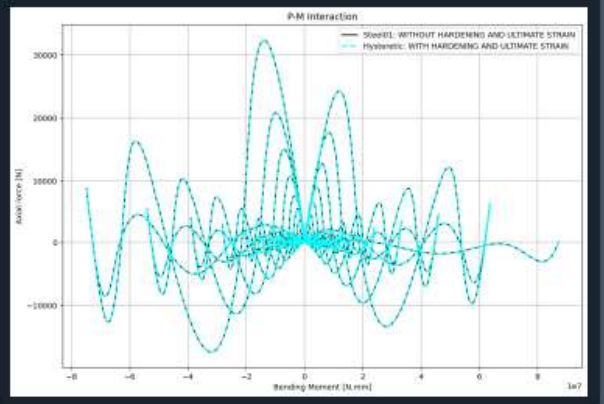
C:\Users\Dell\Desktop\OPENSEES_FILES\CONCRETE_FRA...-VIBRATION_U0\CONCRETE_FRAME_FREE-VIBRATION_U0.py

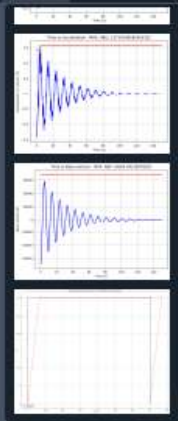
CONCRETE_FRAME_FREE-VIBRATION_U0.py

```
##########################################################################################################
#                                  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
#---------------------------------------------------------------------------------------------------------
#                                  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.
```

...ES\CONCRETE_FRAME_EXAMPLES\FREE-VIBRATION\FREE-VIBRATION_U0

25 %





Help | Variable Explorer | Debugger | Plots | Files

Console 1/A

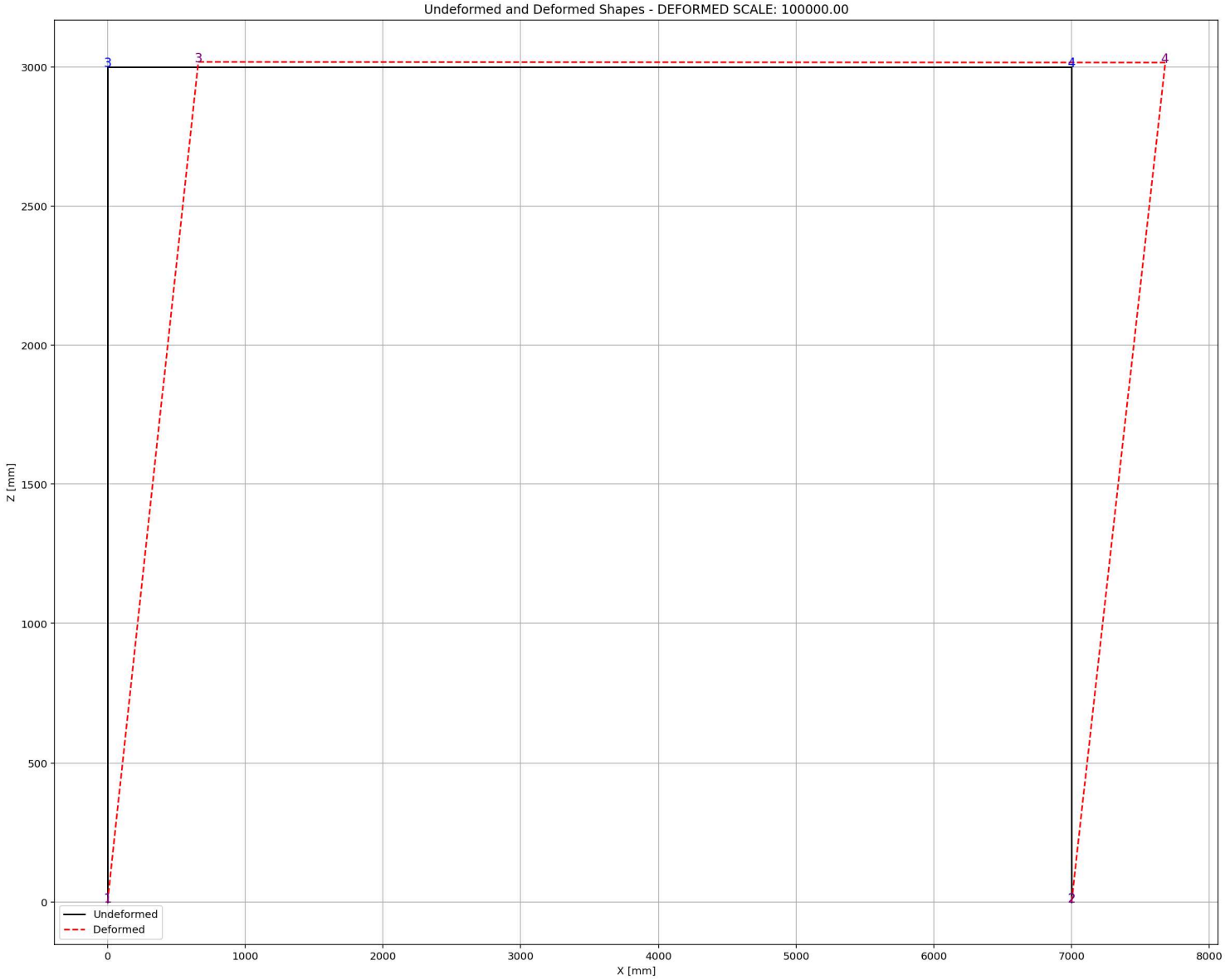
```
Lobatto
    End 1 Forces (P V M): -0.745944 25.0511 65123.1
    End 2 Forces (P V M): 0.745944 -25.0511 10030.2

Element: 3 Type: ForceBeamColumn2d  Connected Nodes: 3 4
    Number of Sections: 5   Mass density: 0
Lobatto
    End 1 Forces (P V M): 1.41957 -2.85318 -9941.83
    End 2 Forces (P V M): -1.41957 2.85318 -10030.4

In [3]:
```

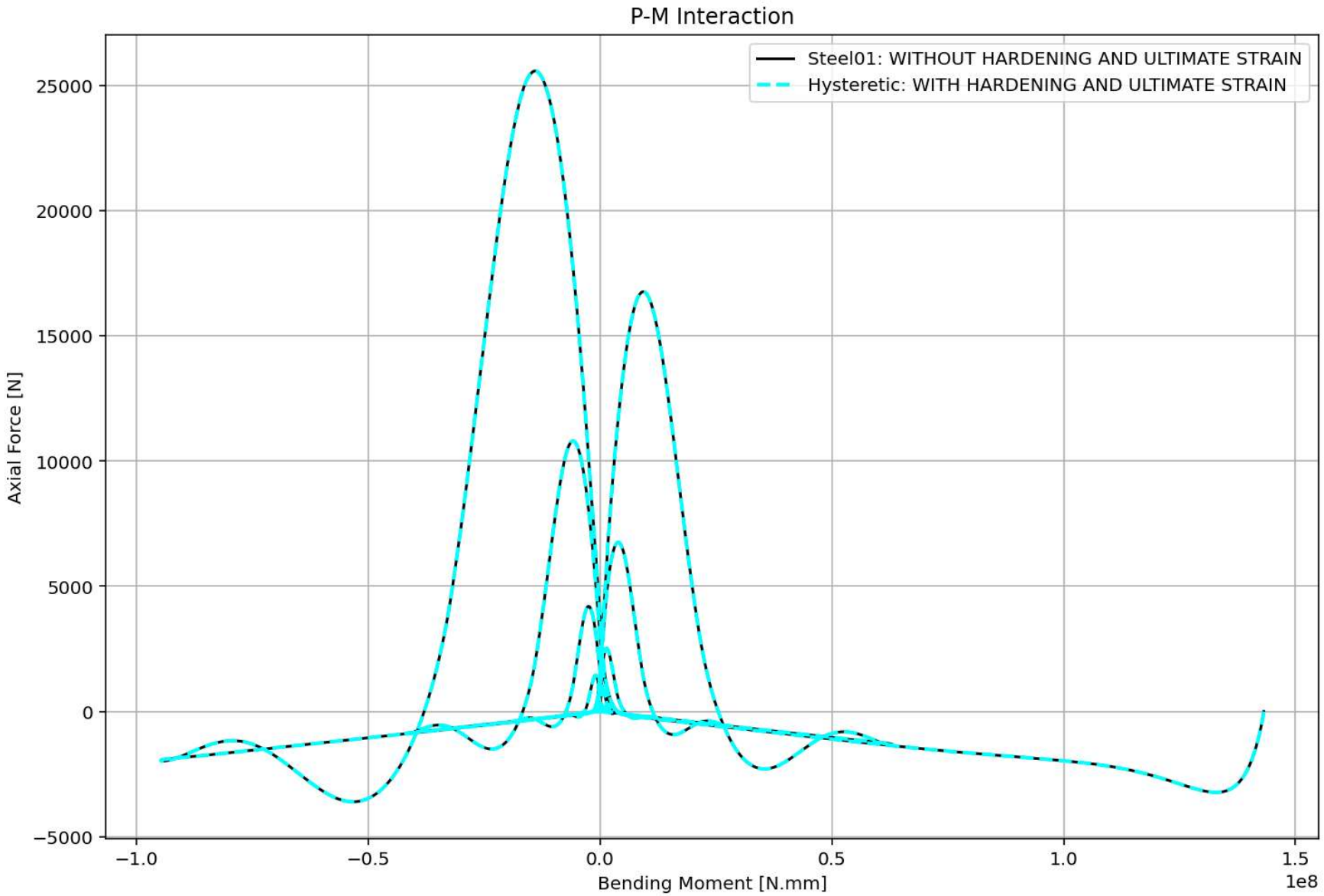
IPython Console | History

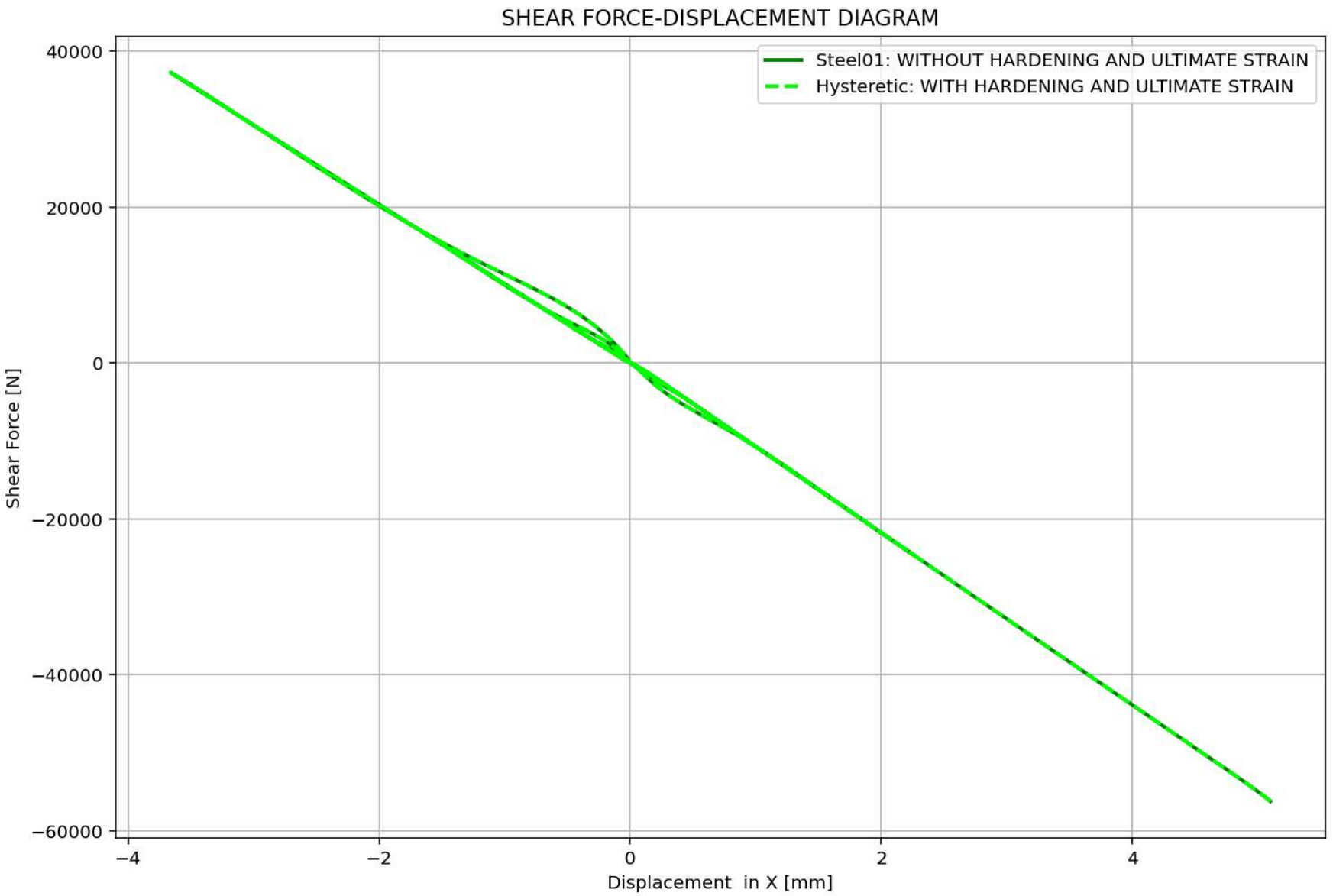
Start | Inline | Conda: anaconda3 (Python 3.12.7) | LSP: Python | Line 5, Col 38 | UTF-8 | CRLF | RW | Mem 46%

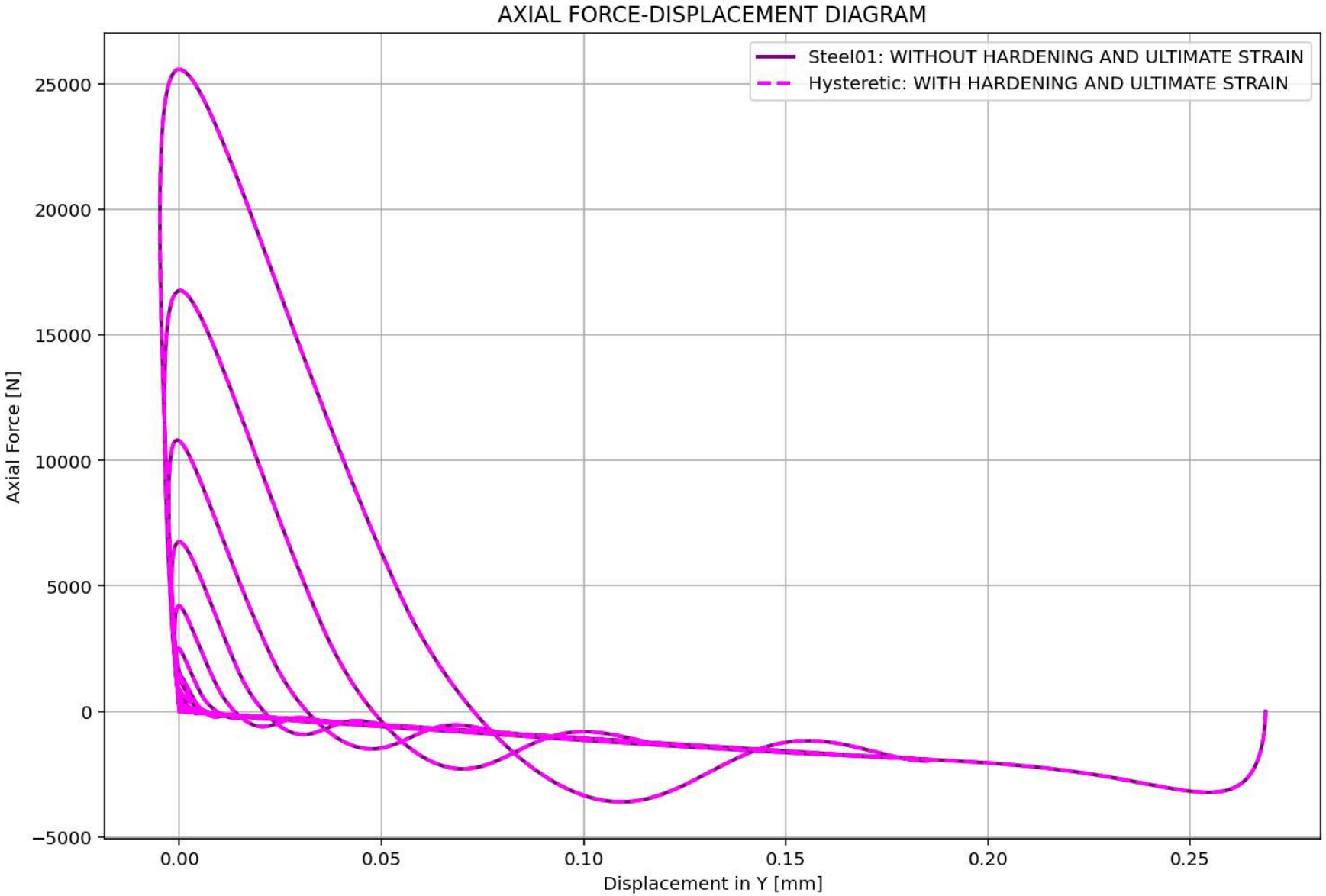
Free Vibration Analysis

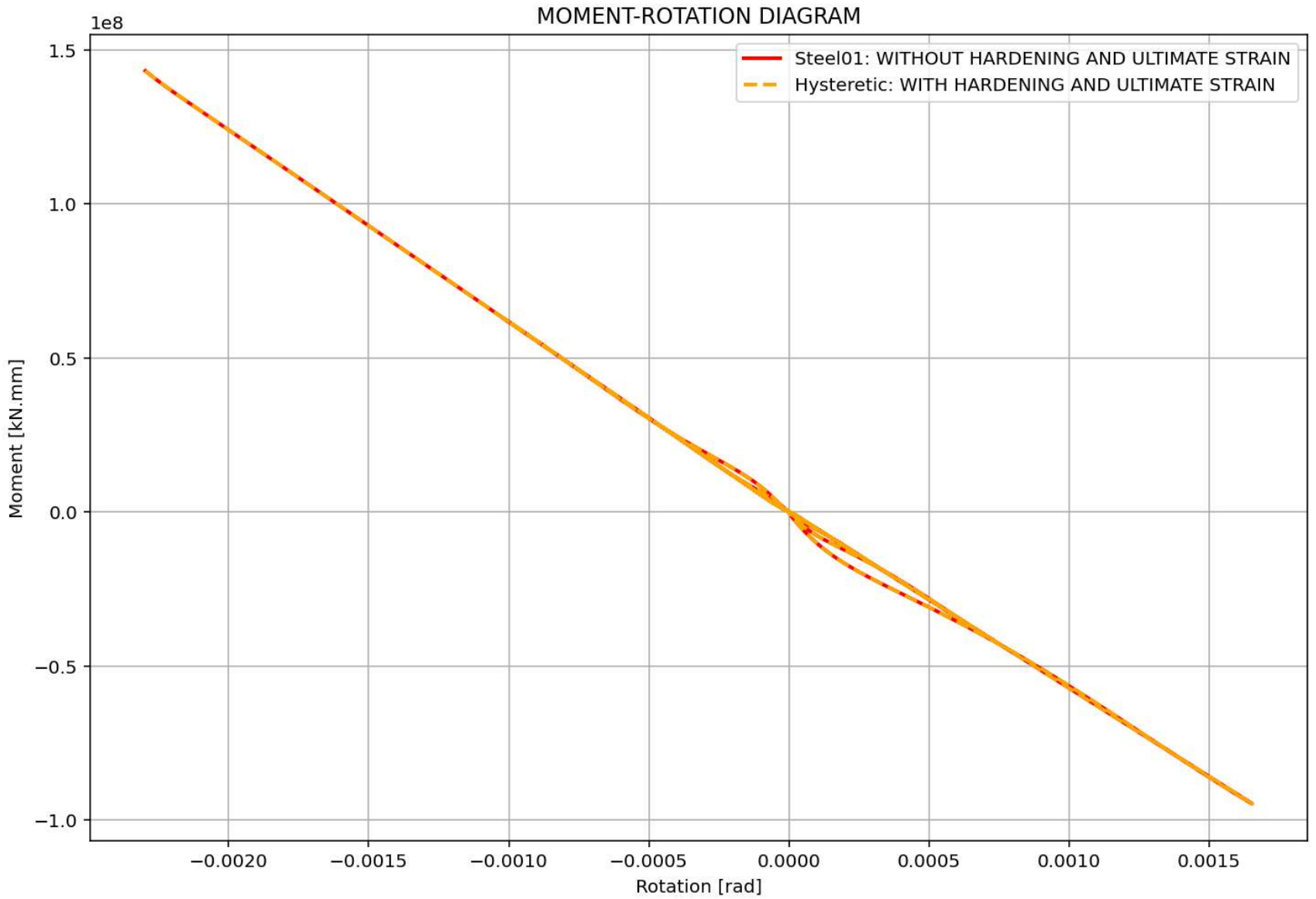
With Initial Displacement

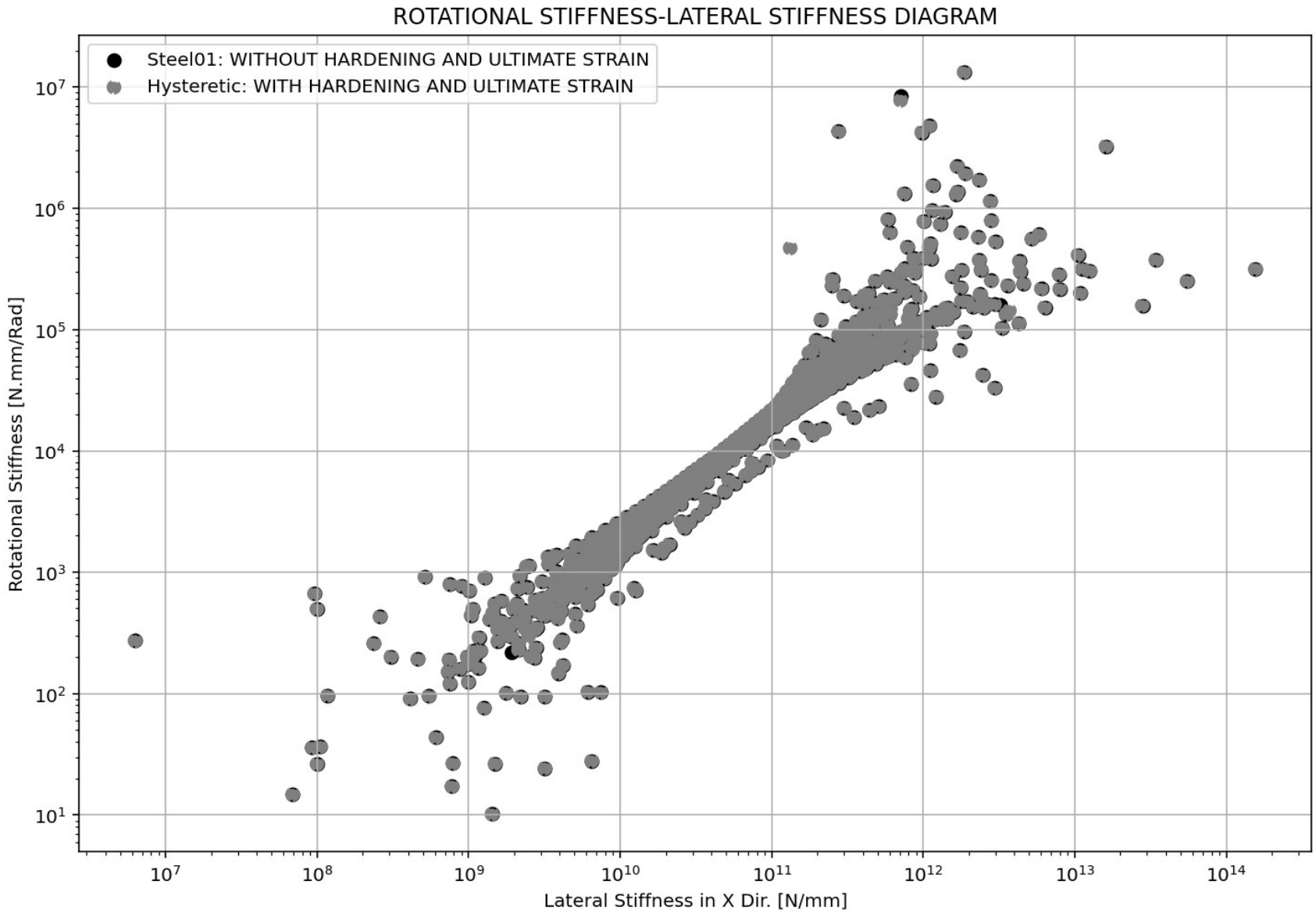

Undeformed and Deformed Shapes - DEFORMED SCALE: 100000.00
Z [mm]
X [mm]
Undeformed
Deformed
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000
8000
1
2
3
3
4
4

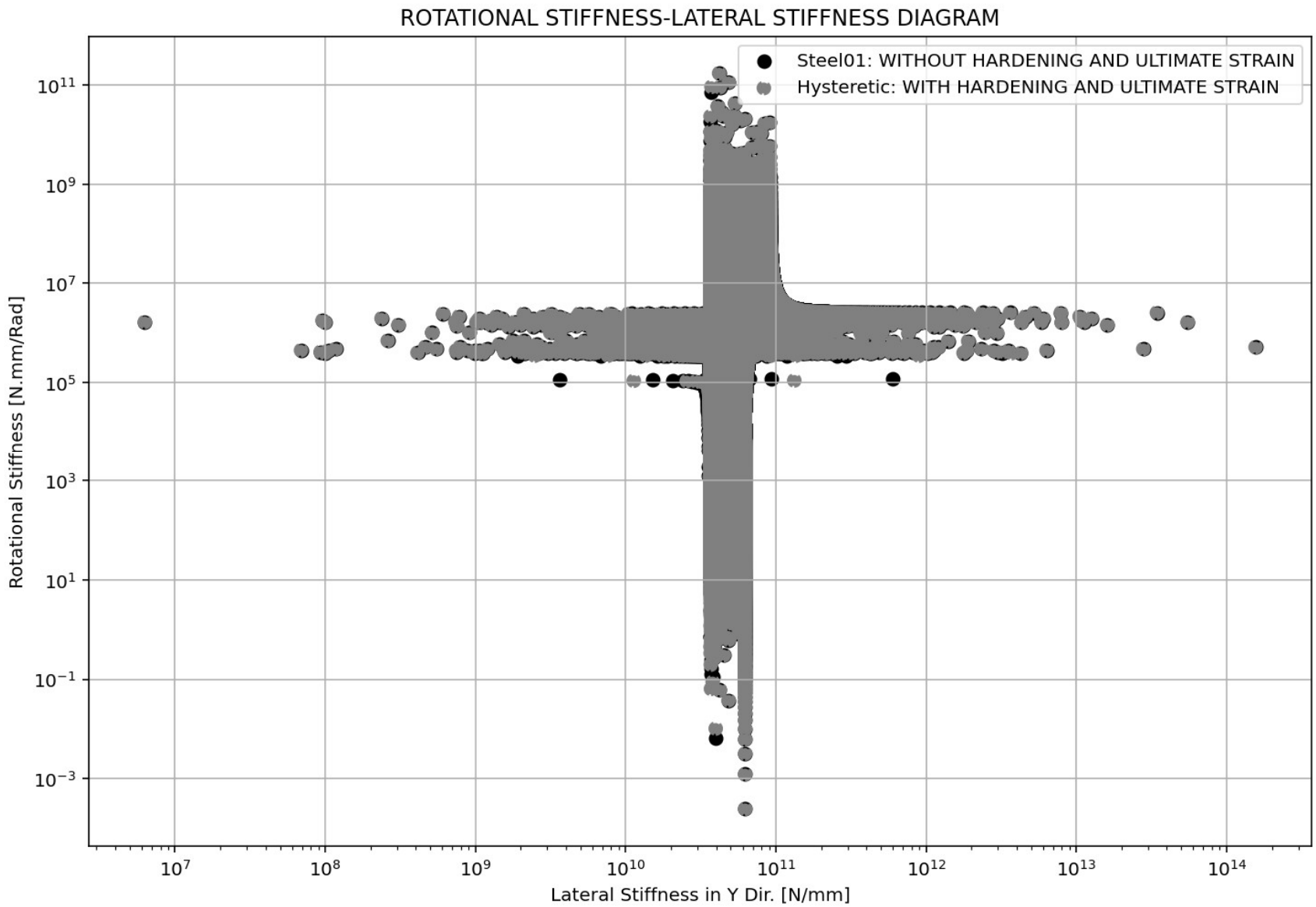

P-M Interaction
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Axial Force [N]
25000
20000
15000
10000
5000
0
−5000
−1.0
−0.5
0.0
0.5
1.0
1.5
Bending Moment [N.mm]
1e8

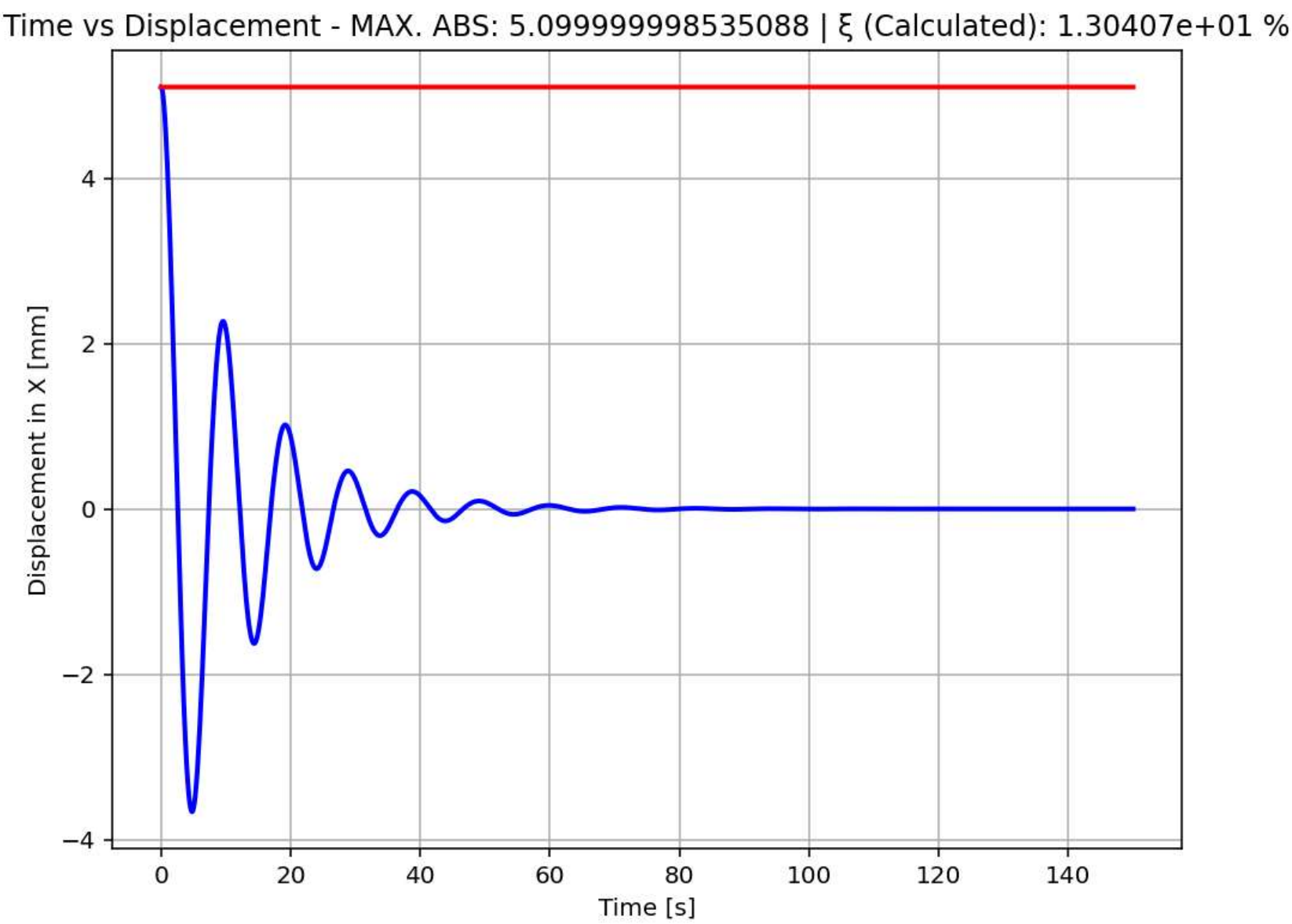

SHEAR FORCE-DISPLACEMENT DIAGRAM
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Shear Force [N]
40000
20000
0
−20000
−40000
−60000
−4
−2
0
2
4
Displacement in X [mm]

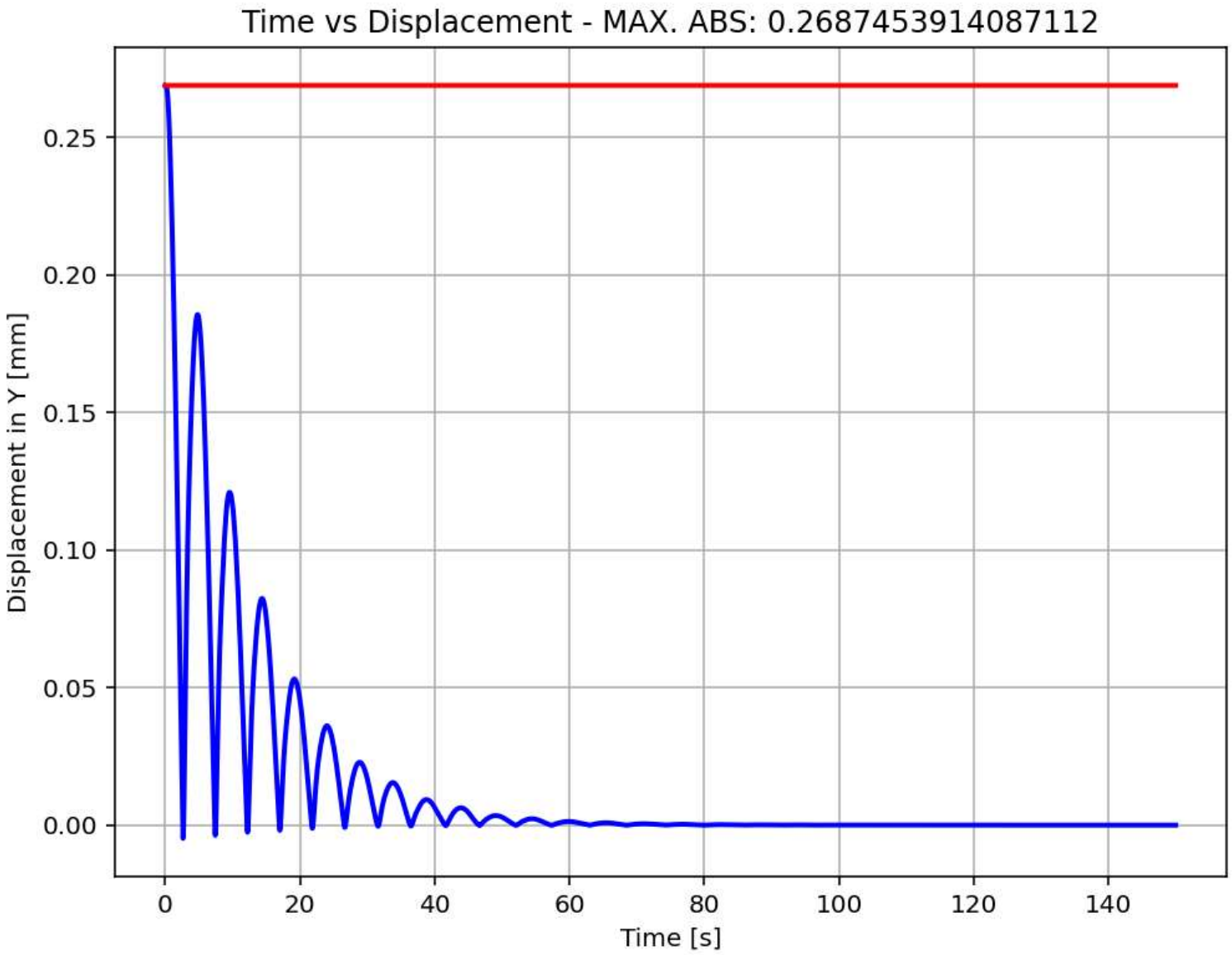

AXIAL FORCE-DISPLACEMENT DIAGRAM
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Axial Force [N]
25000
20000
15000
10000
5000
0
−5000
0.00
0.05
0.10
0.15
0.20
0.25
Displacement in Y [mm]

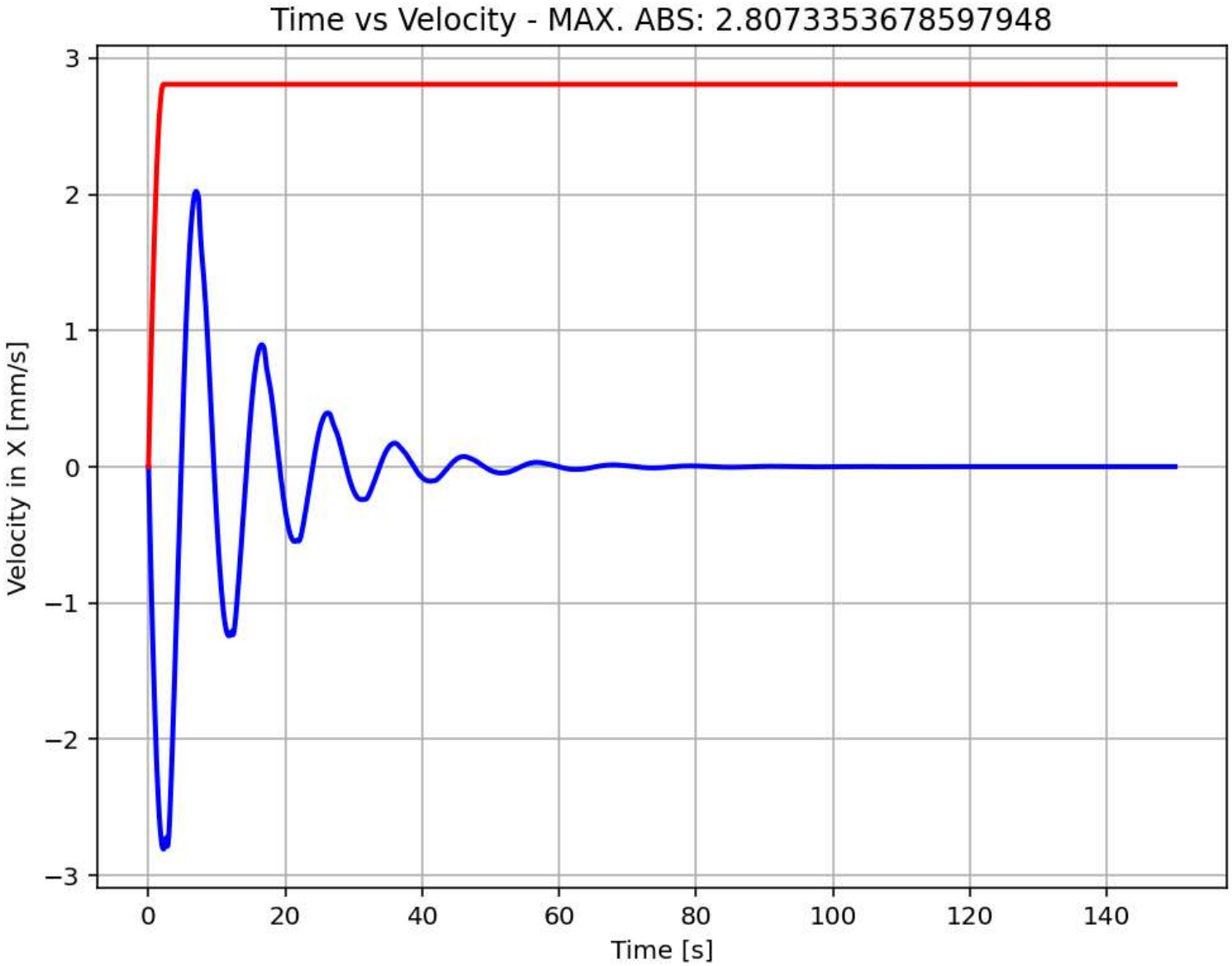

MOMENT-ROTATION DIAGRAM
1e8
1.5
1.0
0.5
0.0
−0.5
−1.0
Moment [kN.mm]
−0.0020
−0.0015
−0.0010
−0.0005
0.0000
0.0005
0.0010
0.0015
Rotation [rad]
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN

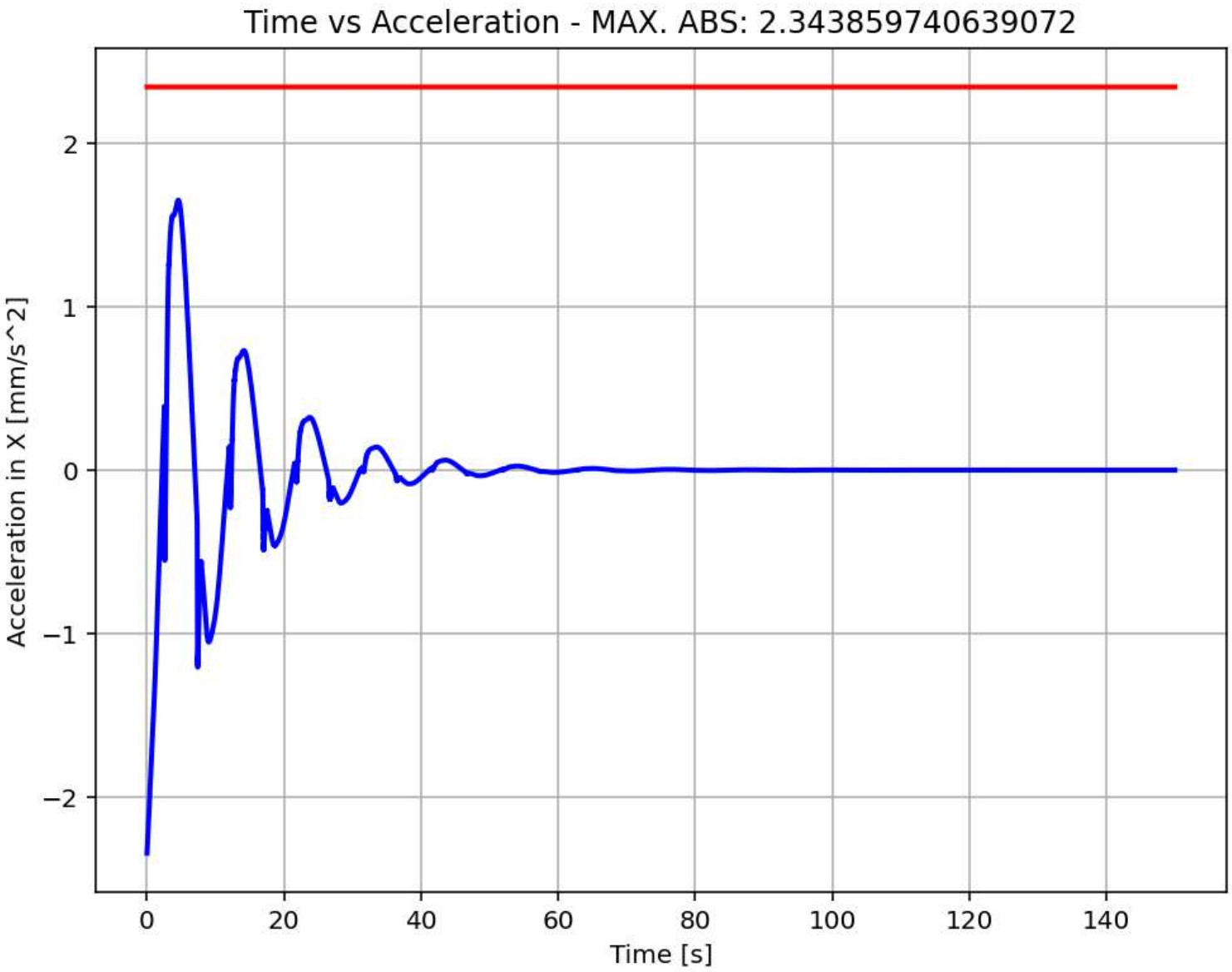

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in X Dir. [N/mm]
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
10^{7}
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}

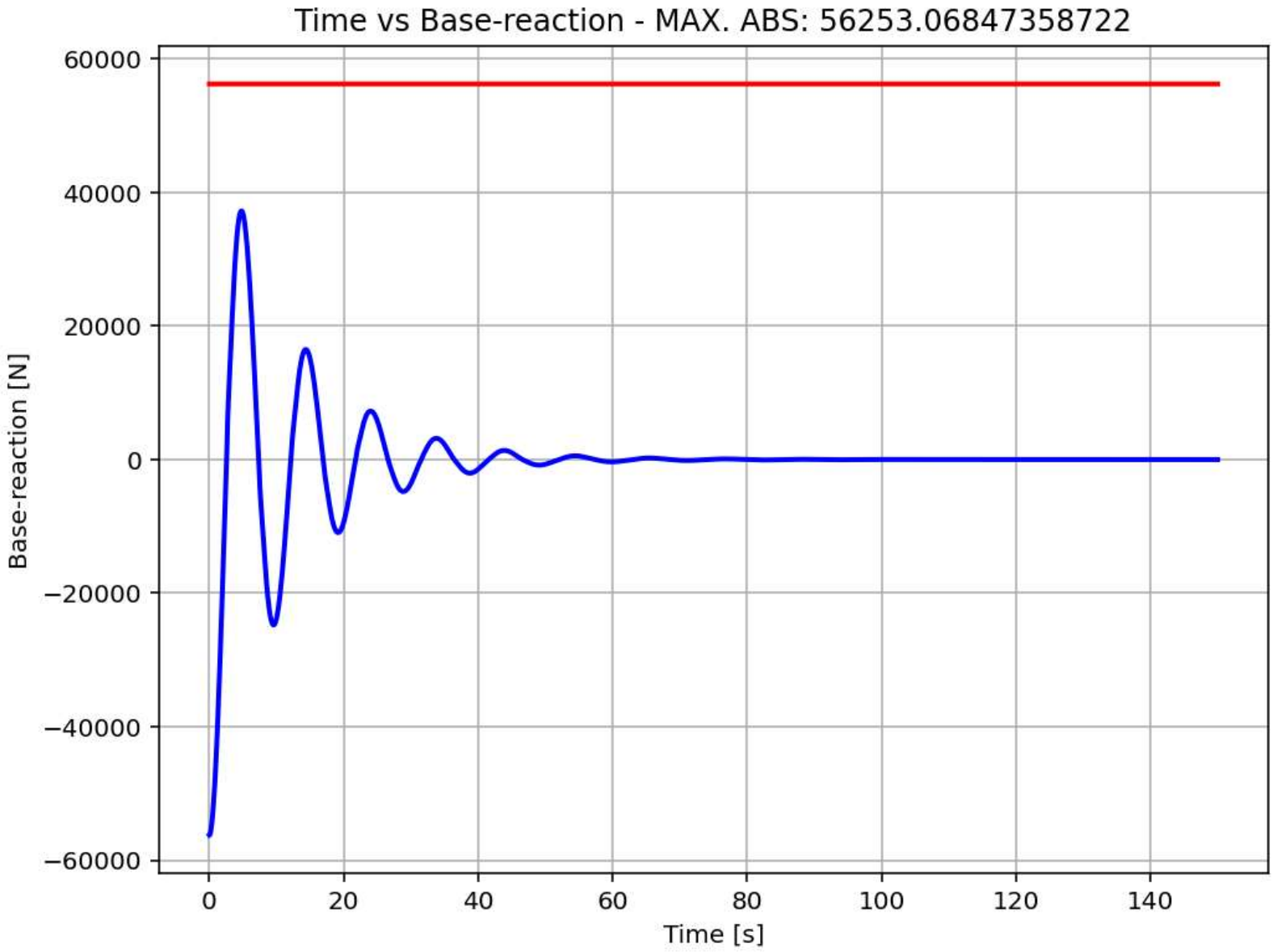

ROTATIONAL STIFFNESS-LATERAL STIFFNESS DIAGRAM
Steel01: WITHOUT HARDENING AND ULTIMATE STRAIN
Hysteretic: WITH HARDENING AND ULTIMATE STRAIN
Rotational Stiffness [N.mm/Rad]
Lateral Stiffness in Y Dir. [N/mm]
10^{11}
10^{9}
10^{7}
10^{5}
10^{3}
10^{1}
10^{-1}
10^{-3}
10^{7}
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}
10^{14}


Time vs Displacement - MAX. ABS: 5.099999998535088 | ξ (Calculated): 1.30407e+01 %
Displacement in X [mm]
Time [s]
4
2
0
−2
−4
0
20
40
60
80
100
120
140


Time vs Displacement - MAX. ABS: 0.2687453914087112
Displacement in Y [mm]
0.25
0.20
0.15
0.10
0.05
0.00
0
20
40
60
80
100
120
140
Time [s]


Time vs Velocity - MAX. ABS: 2.8073353678597948
Velocity in X [mm/s]
Time [s]
3
2
1
0
−1
−2
−3
0
20
40
60
80
100
120
140


Time vs Acceleration - MAX. ABS: 2.343859740639072
Acceleration in X [mm/s^2]
Time [s]
2
1
0
−1
−2
0
20
40
60
80
100
120
140


Time vs Base-reaction - MAX. ABS: 56253.06847358722
60000
40000
20000
0
−20000
−40000
−60000
Base-reaction [N]
0
20
40
60
80
100
120
140
Time [s]