ME 759: Nonlinear FEM
Assignment 2: 1-D Elastoplasticity

Equations used for coding

19/03/2022

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Assignment 2 – Equations used in code

ε_n = STATEV(1)
ε^p_n = STATEV(2)
β_n = STATEV(3)
α_n = STATEV(4)

1) Trial stress

$\sigma^t_{n+1} = \sigma_n + E\,\Delta\varepsilon_n \Rightarrow$ STRESS(1) = STRESS(1) + E * DSTRAN(1)

2) $\varepsilon^t_{n+1} = \varepsilon_n + \Delta\varepsilon_n$

3) Relative trial stress

$\xi^t_{n+1} = \sigma^t_{n+1} - \beta_n$, ~~β^t_{n+1}~~

4) Back stress trial $\beta^t_{n+1} = \beta_n$

5) Equivalent plastic strain trial: $\alpha^t_{n+1} = \alpha_n$

6) Plastic strain trial: $\varepsilon^{pt}_{n+1} = \varepsilon^p_n$

7) Yield function trial: $f^t_{n+1} = |\xi^t_{n+1}| - \sigma_y(\alpha_n)$

$= |\xi^t_{n+1}| - [\sigma_0 + \theta H \alpha_n]$

If $f <= 0$.:

DDSDDE = E

$\varepsilon^p_{n+1} = \varepsilon^p_n$, $\alpha_{n+1} = \alpha_n$, $\beta_{n+1} = \beta_n$

$\sigma_{n+1} = \sigma^t_{n+1}$ ~~exit~~

else:

a) $\Delta\gamma = \dfrac{f^t_{n+1}}{E+H}$

b) $\sigma_{n+1} = \sigma^t_{n+1} - \Delta\gamma * E * $ ~~$sign(\sigma^t_{n+1})$~~ $sign(\xi^t_{n+1})$

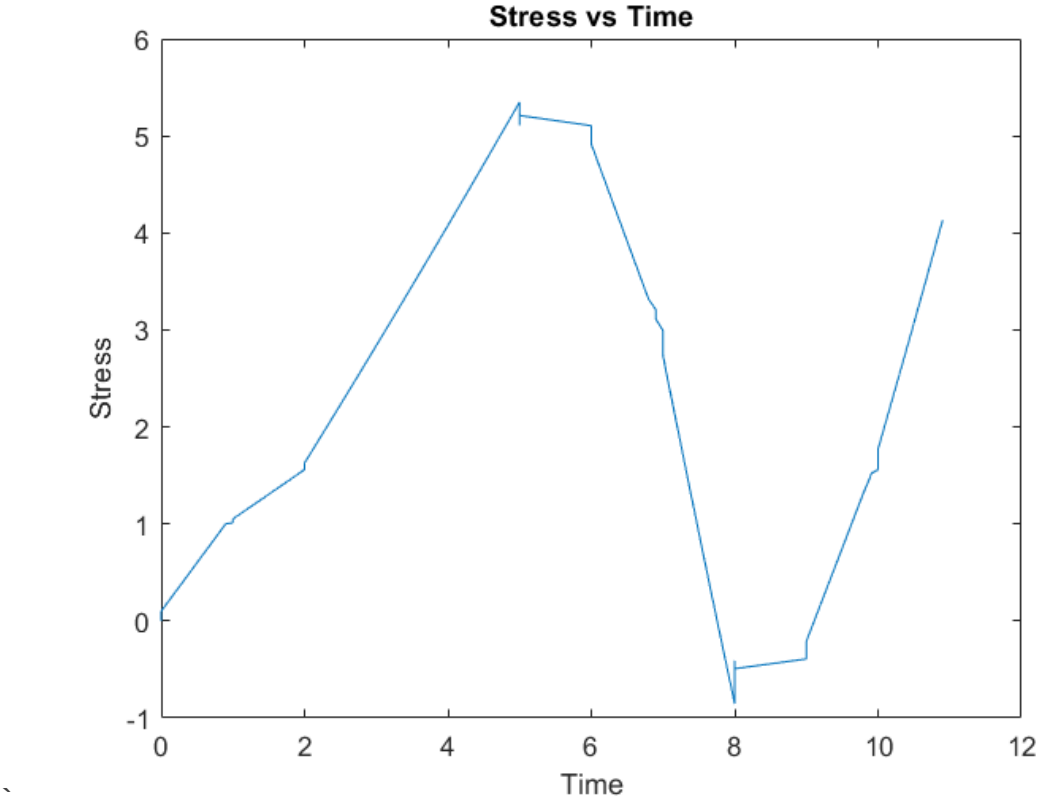
c) $\varepsilon^p_{n+1} = \varepsilon^{pt}_{n+1} + \Delta\gamma * sign($ ~~σ_n~~ (ξ^t_{n+1})

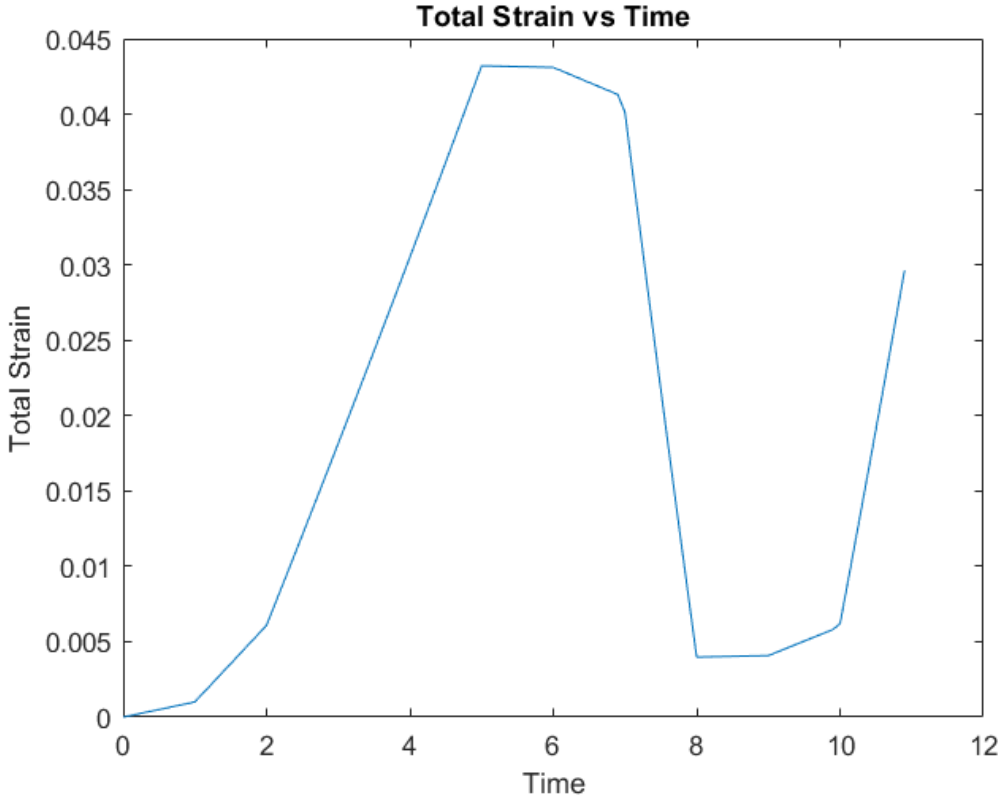
d) $\beta_{n+1} = \beta^t_{n+1} + \Delta\gamma * (1-\theta) * H * sign(\xi^t_{n+1})$

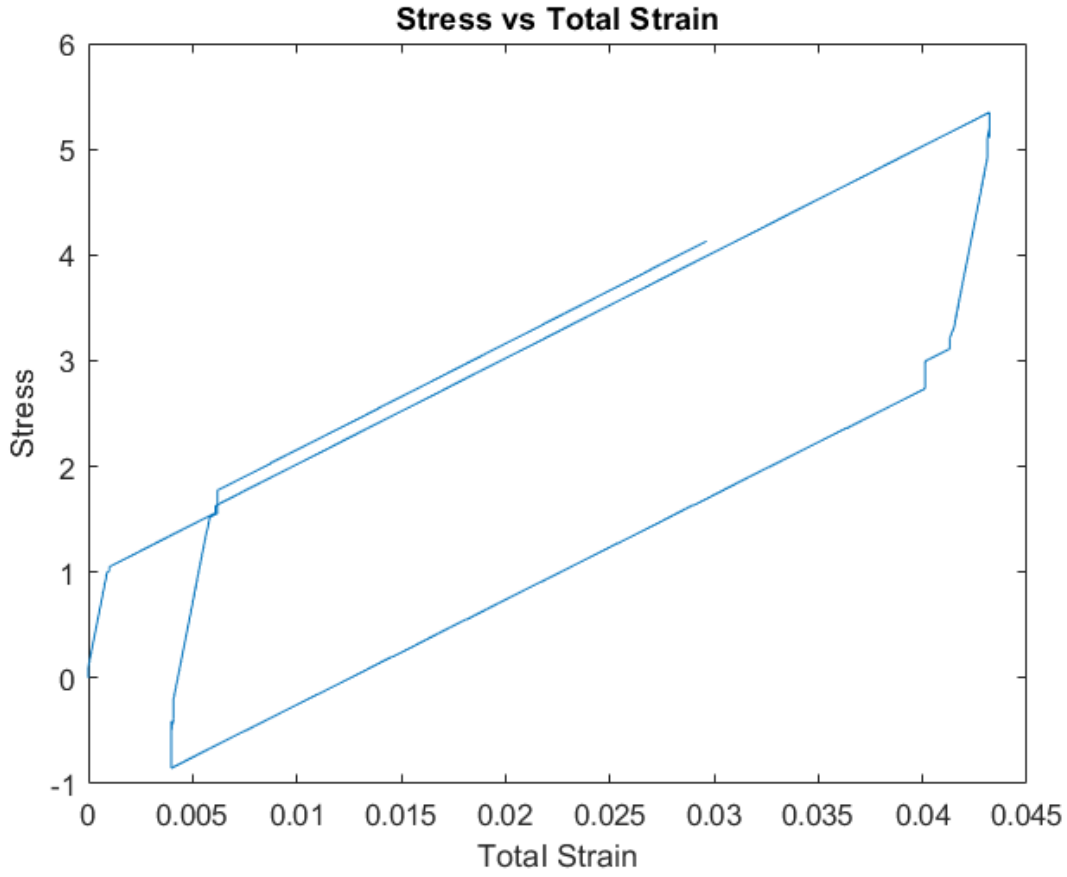
e) $DDSDDE(1,1) = \dfrac{EH}{E+H}$

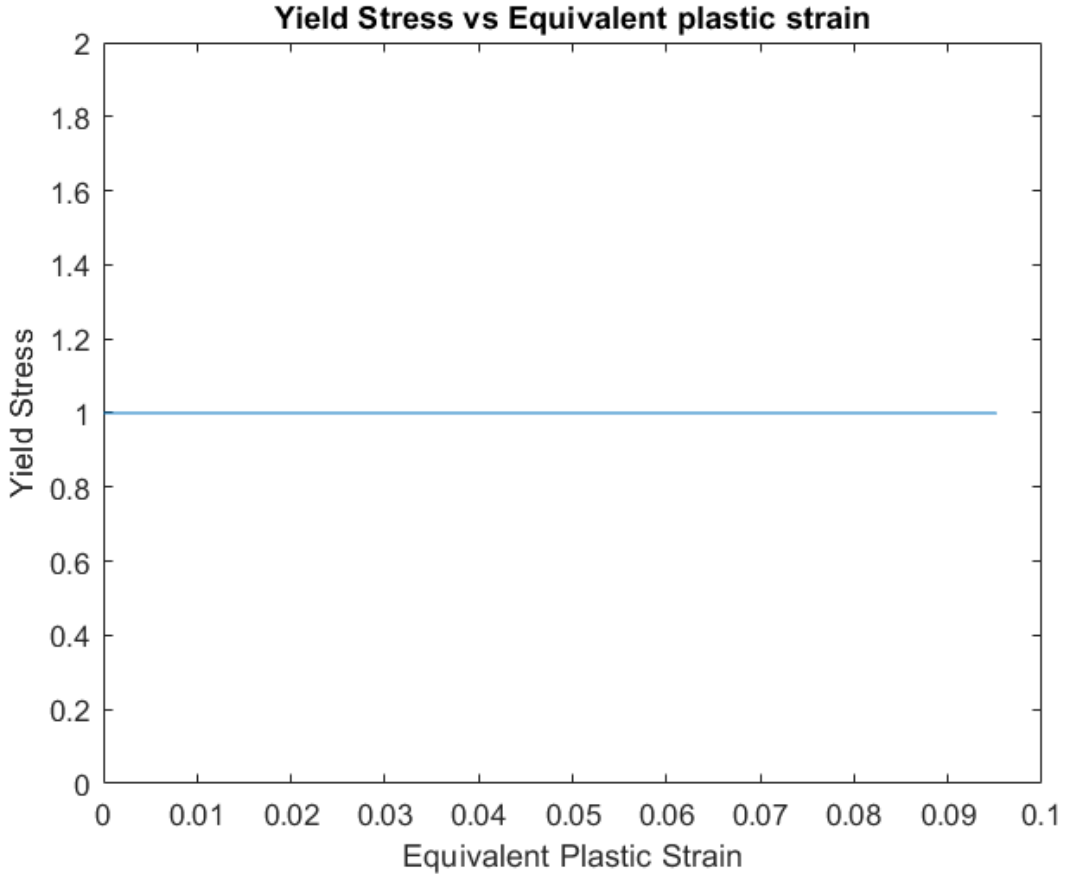
Part a

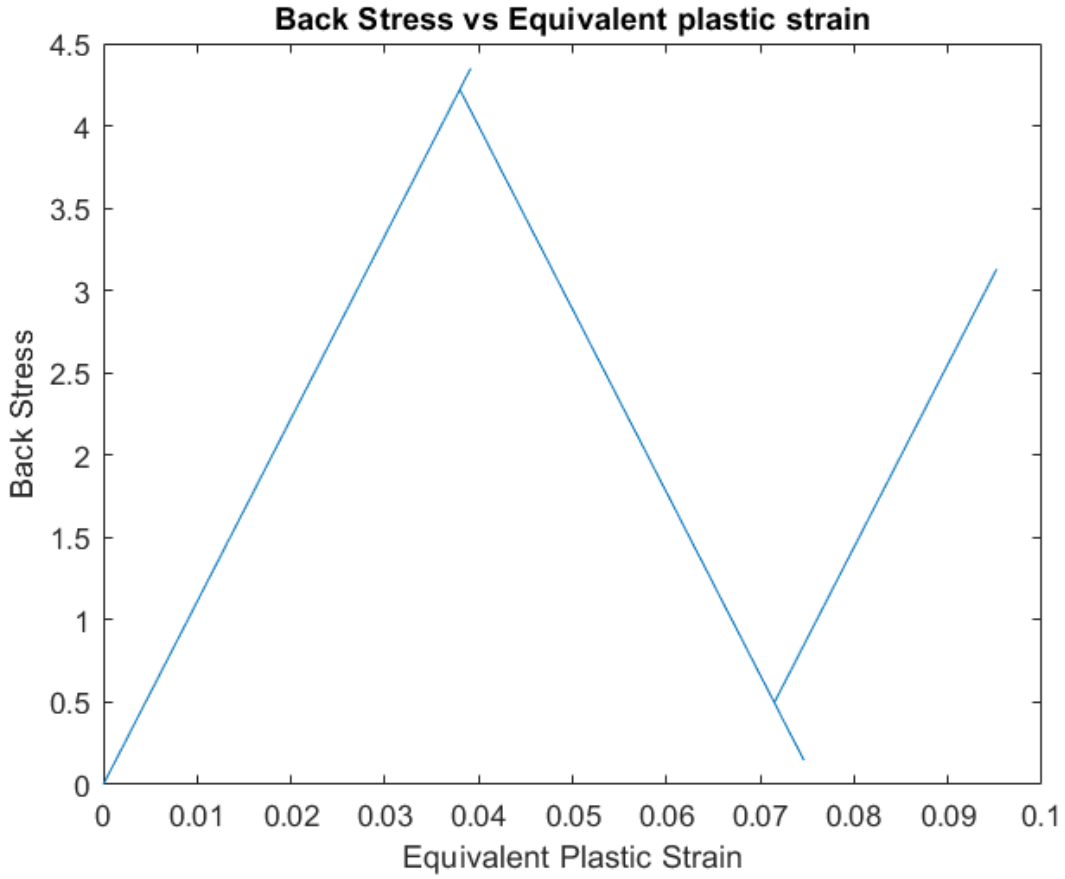
Theta = 0.0 (Pure linear kinematic hardening)



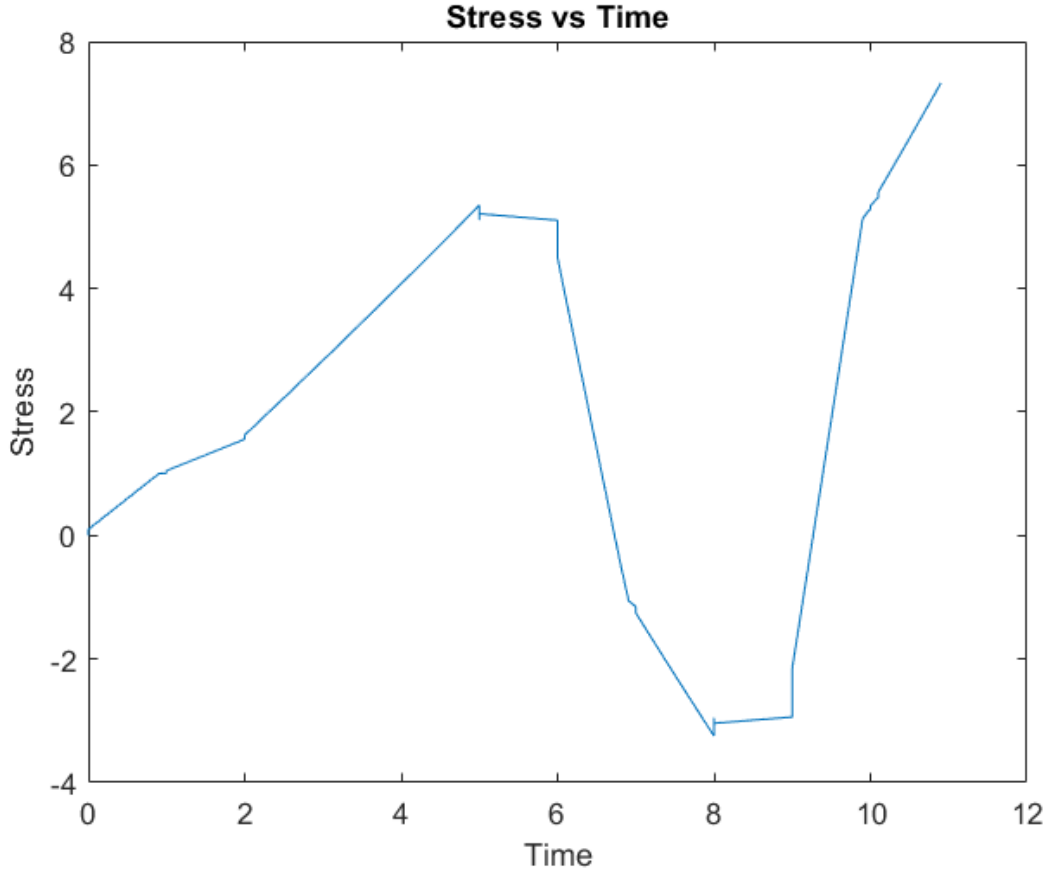


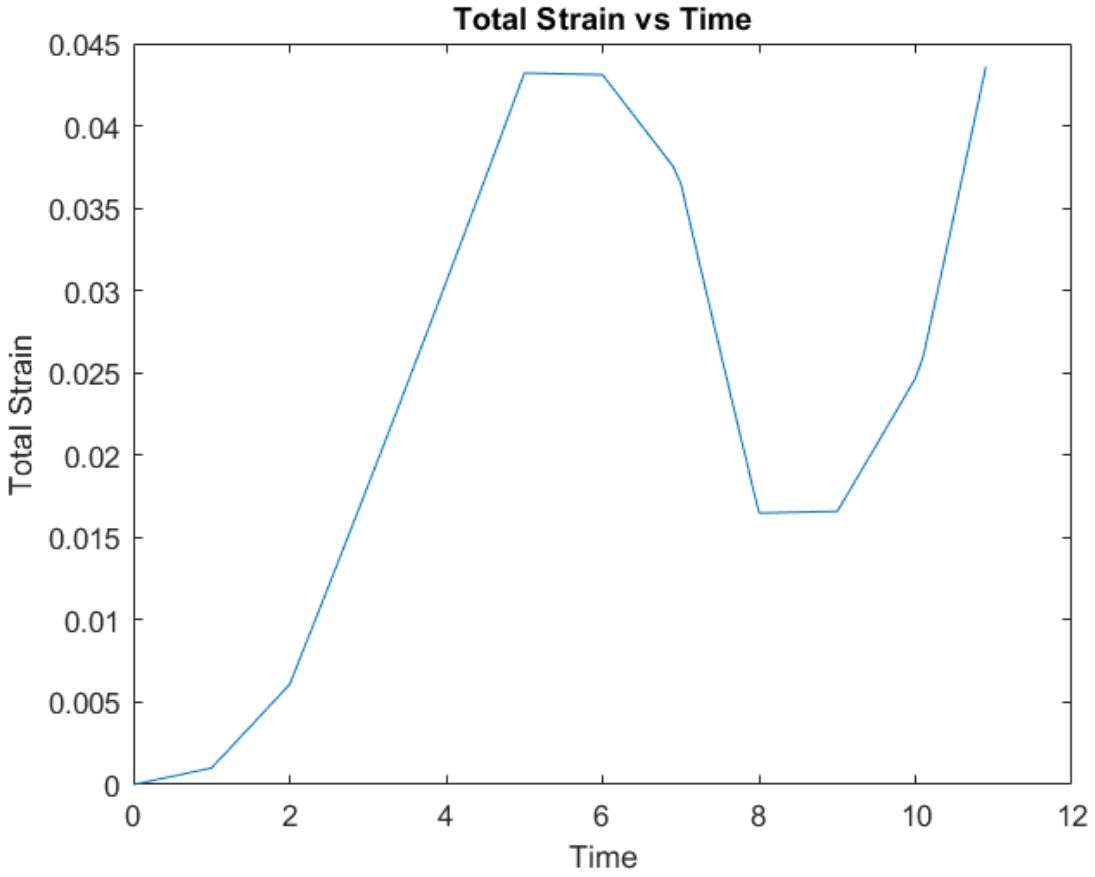

Stress vs Total Strain
Stress
Total Strain
6
5
4
3
2
1
0
-1
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045

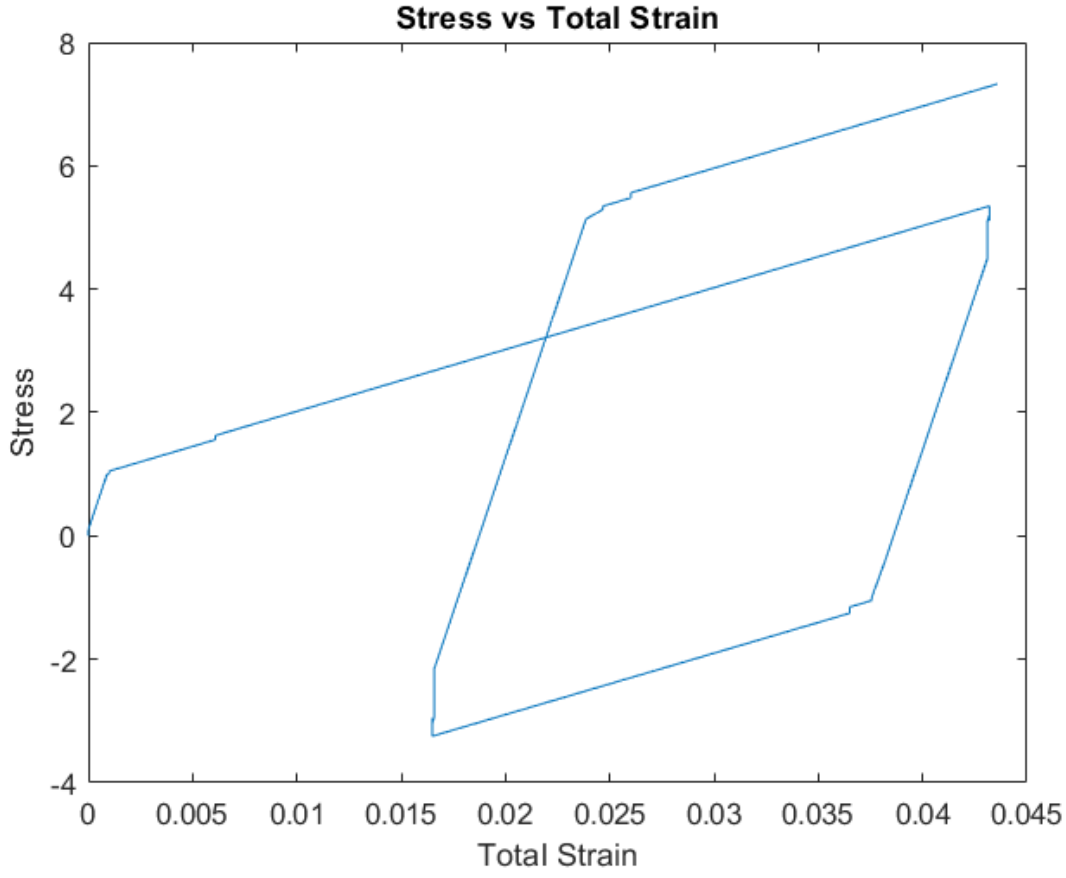

Yield Stress vs Equivalent plastic strain
Yield Stress
Equivalent Plastic Strain
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1

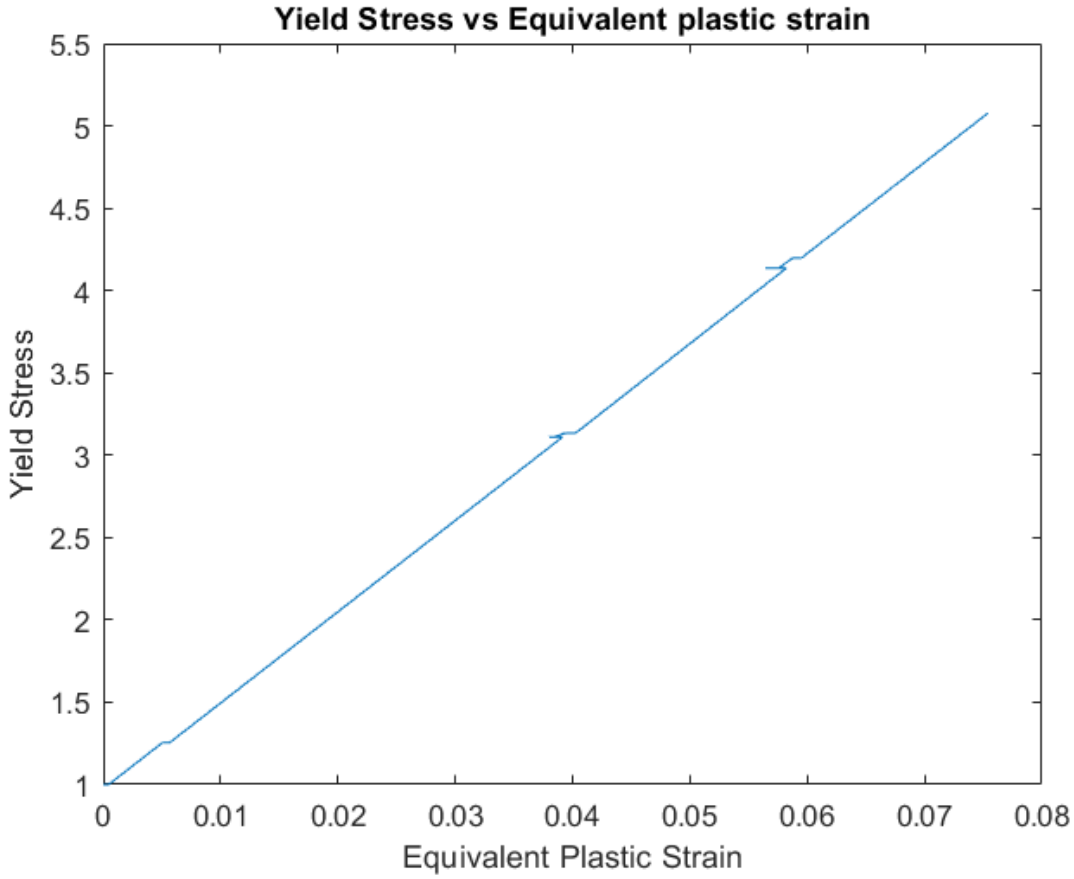


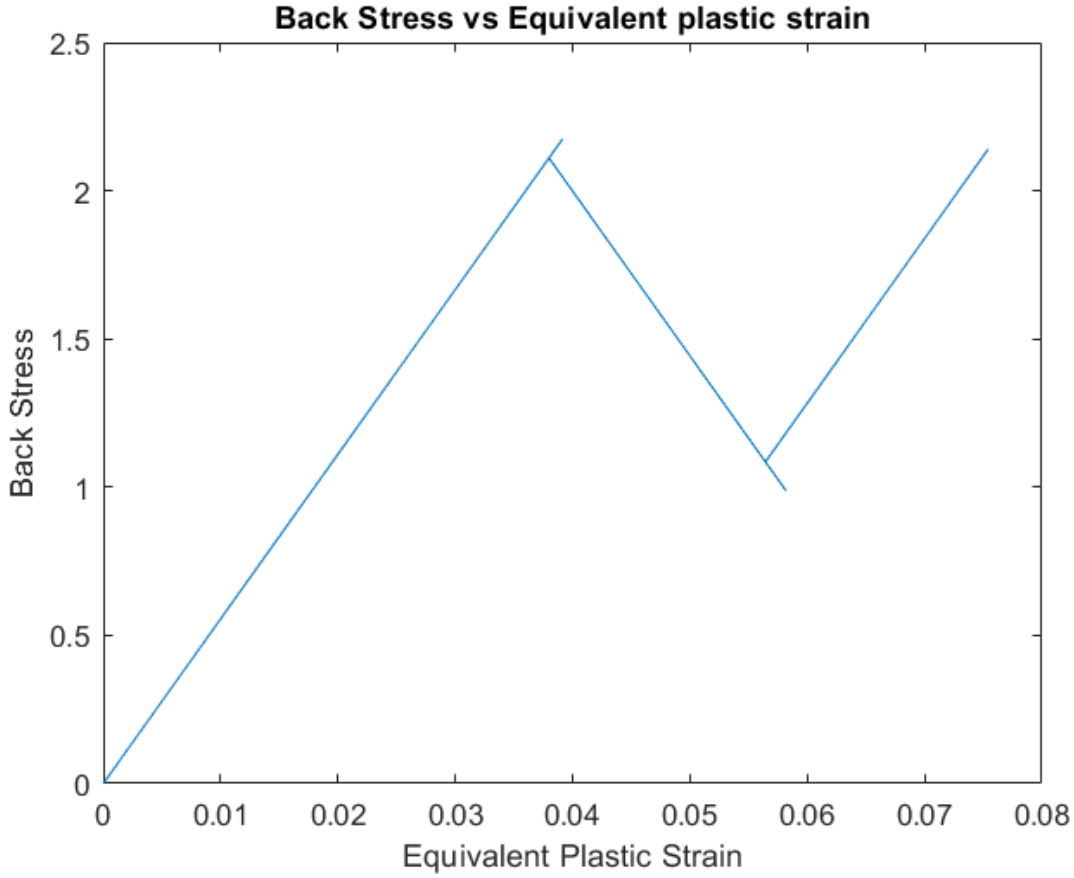
Theta = 0.5 (Combined linear isotropic-kinematic hardening)



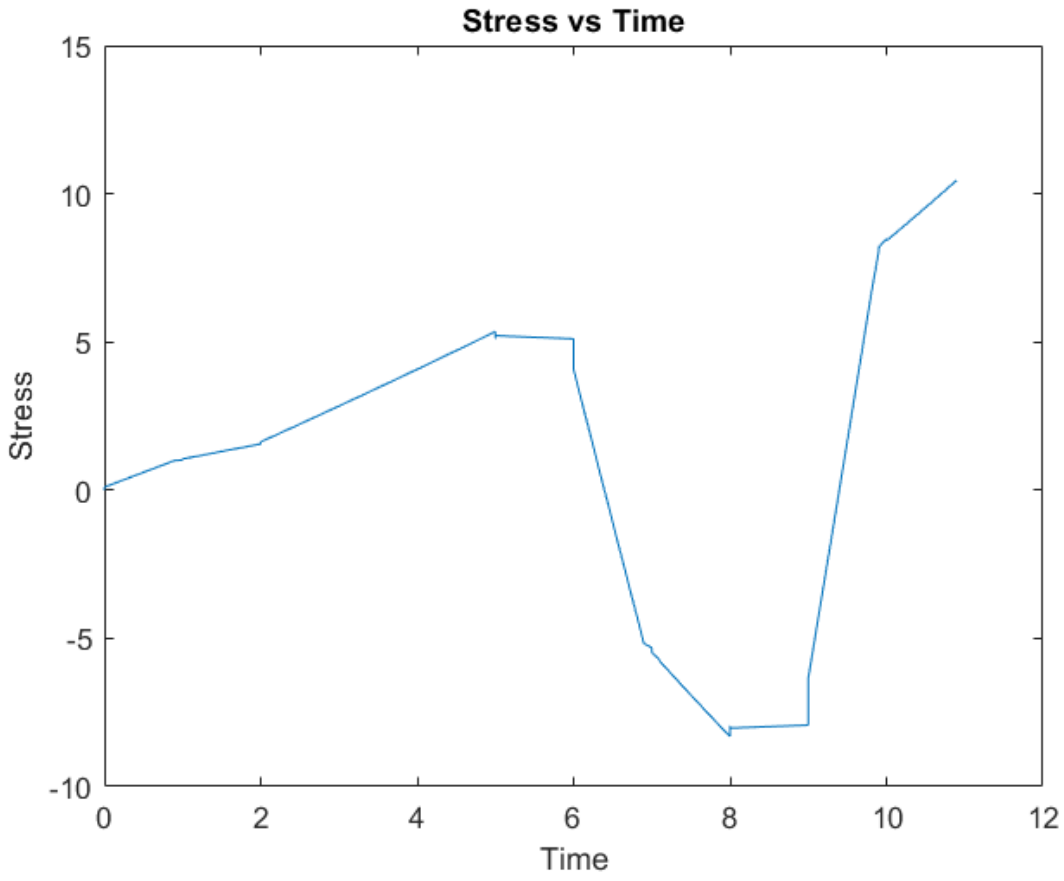

Total Strain vs Time
Total Strain
Time
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
2
4
6
8
10
12

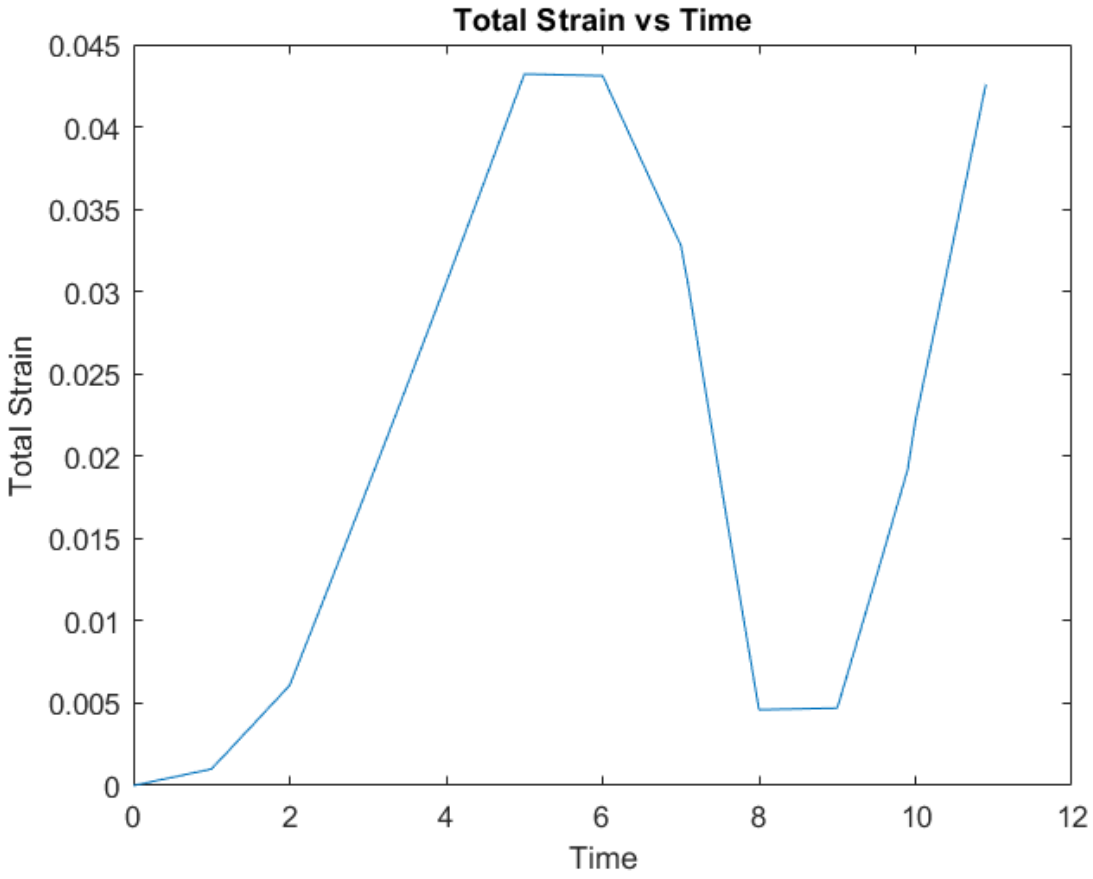

Stress vs Total Strain
Stress
Total Strain
8
6
4
2
0
-2
-4
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045

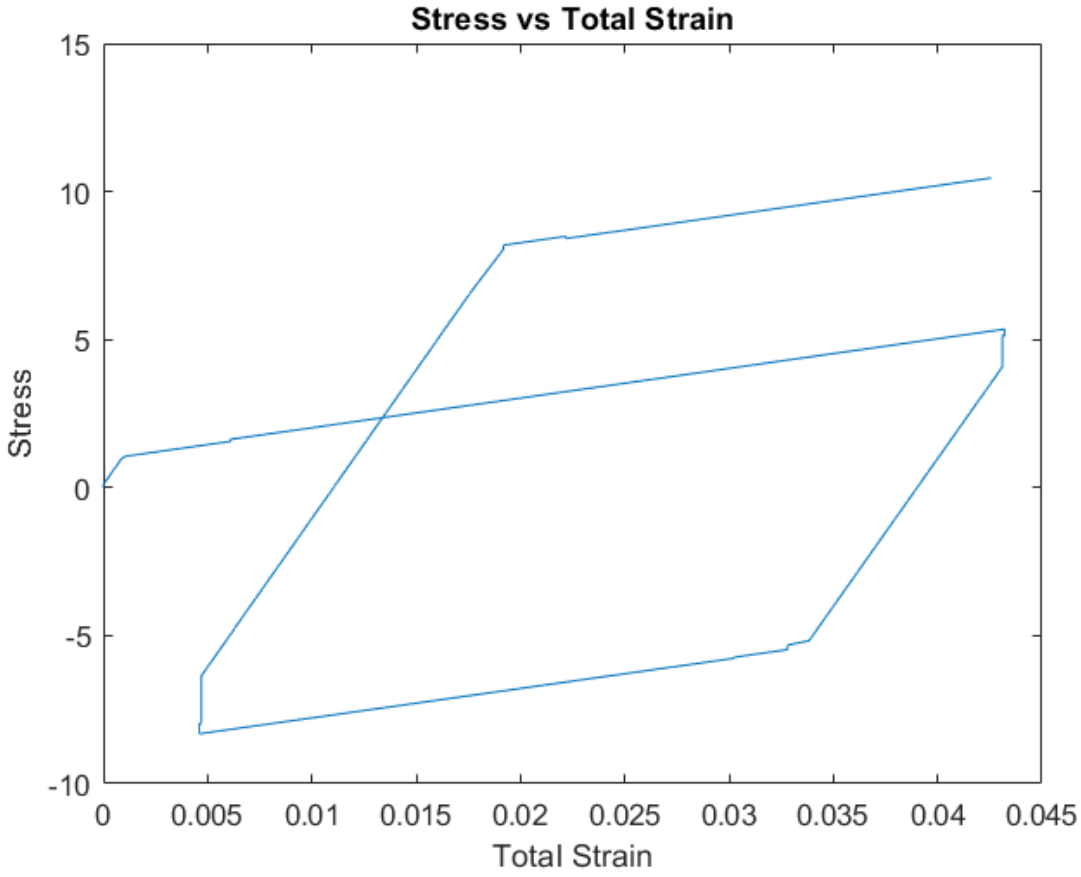

Yield Stress vs Equivalent plastic strain
Yield Stress
Equivalent Plastic Strain
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08

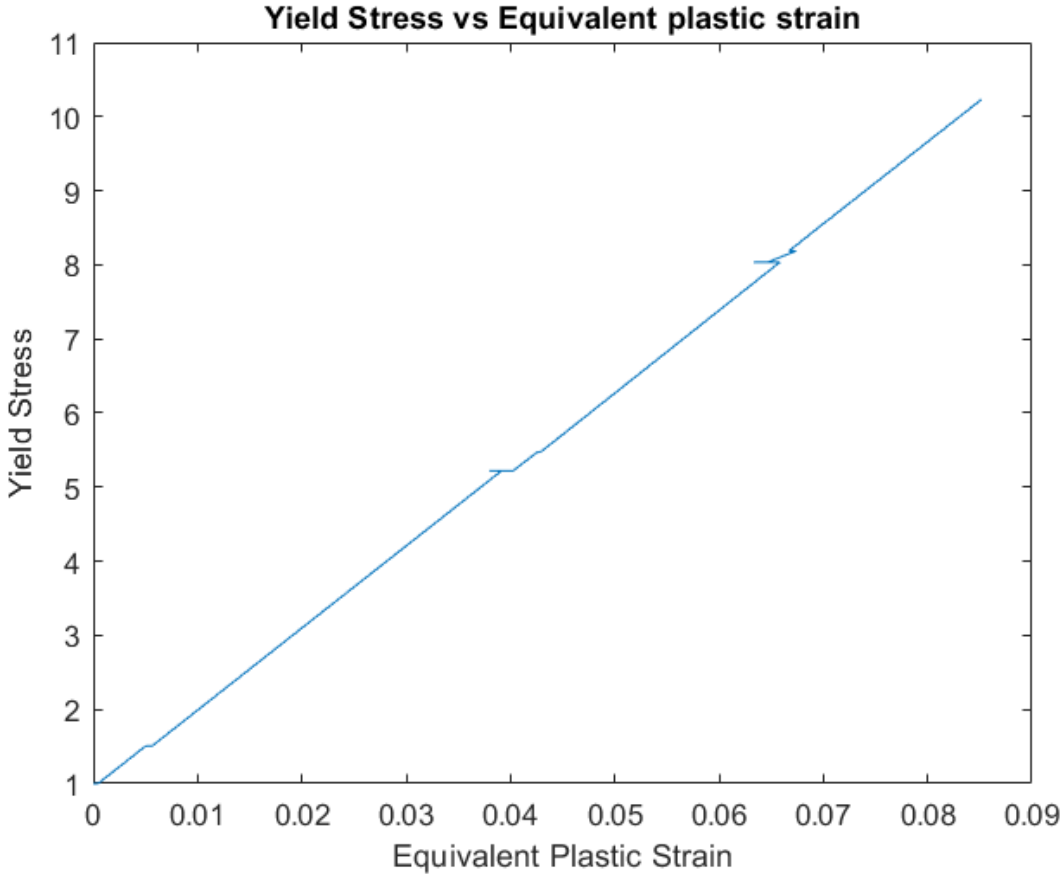

Back Stress vs Equivalent plastic strain
Back Stress
Equivalent Plastic Strain
2.5
2
1.5
1
0.5
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08

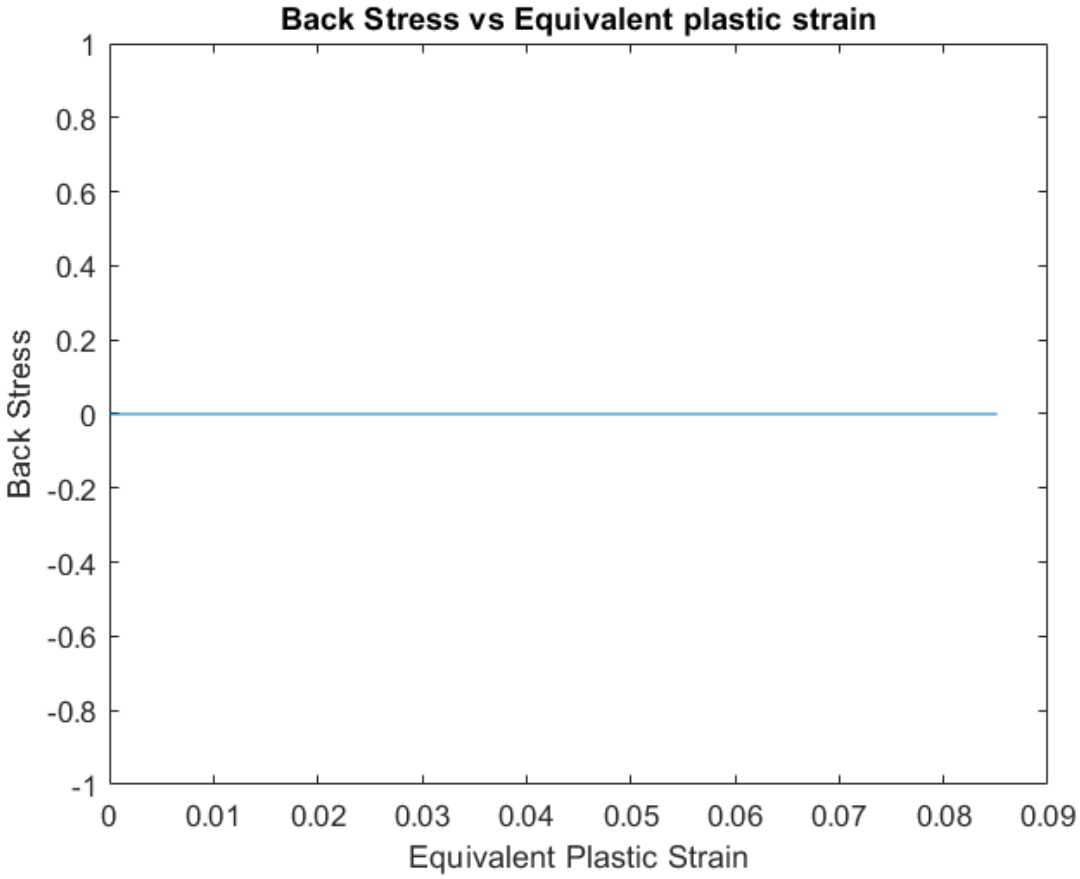
Theta = 1.0 (Pure linear isotropic hardening)






Stress vs Total Strain
Stress
Total Strain
15
10
5
0
-5
-10
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045


Yield Stress vs Equivalent plastic strain
Yield Stress
Equivalent Plastic Strain
11
10
9
8
7
6
5
4
3
2
1
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09



Observations:

We get zero back stress as for pure isotropic hardening, there is not back stress term in equations.

Part b

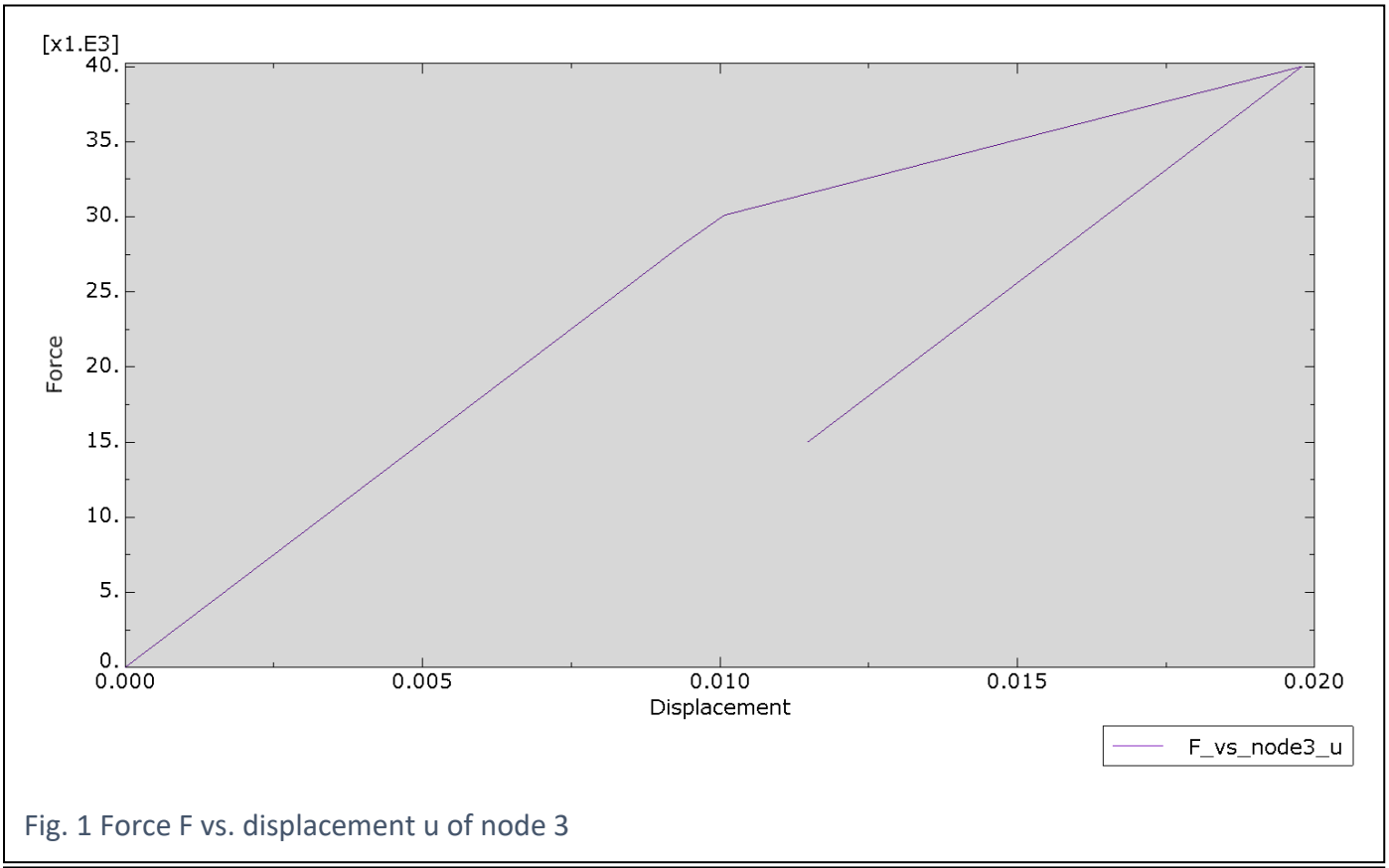
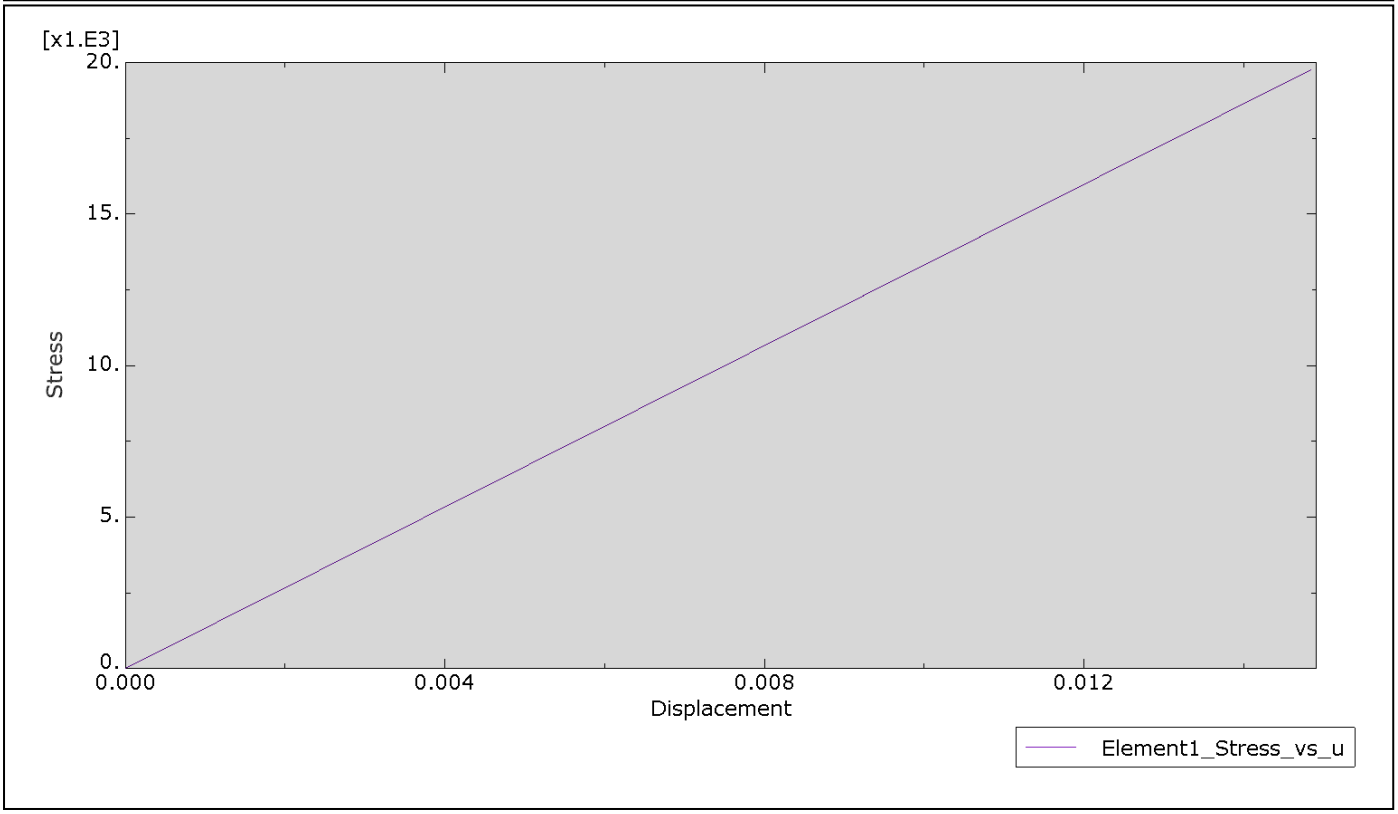


Fig. 1 Force F vs. displacement u of node 3



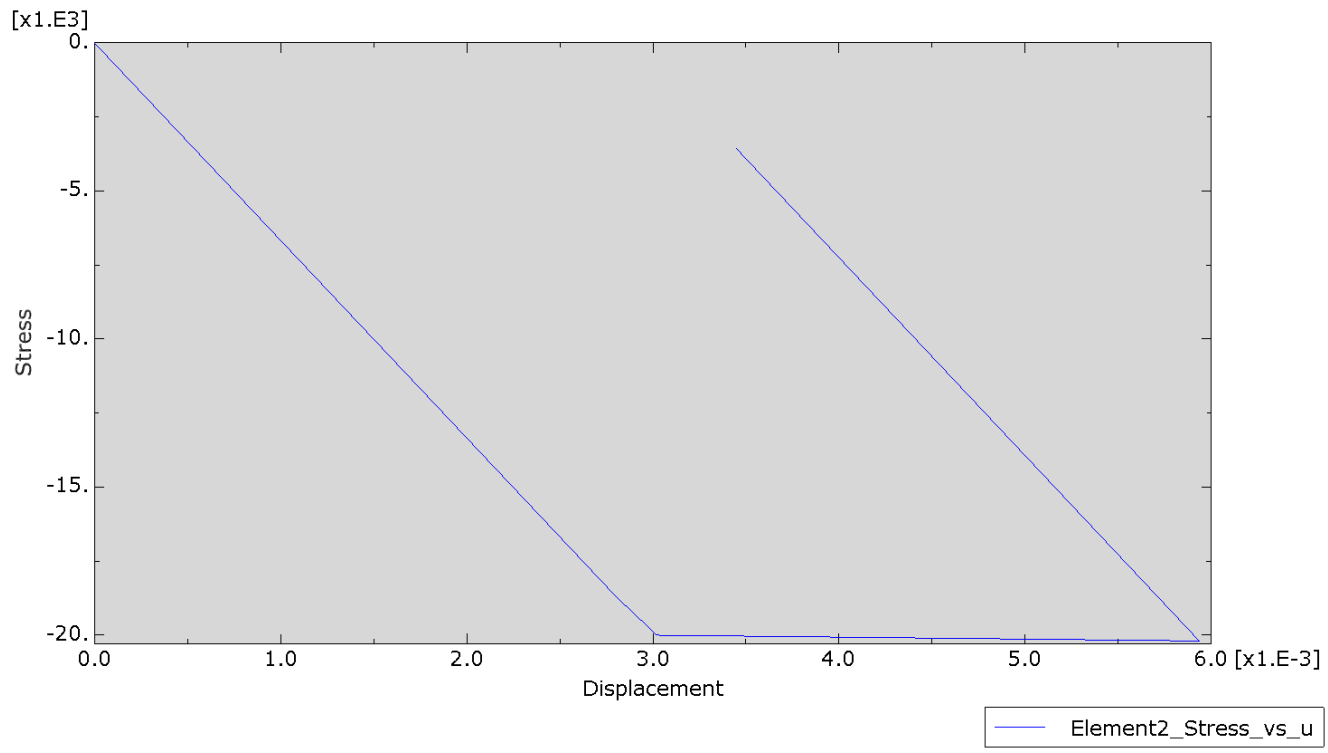


Fig. 3 Stress in elements 2 vs displacement u

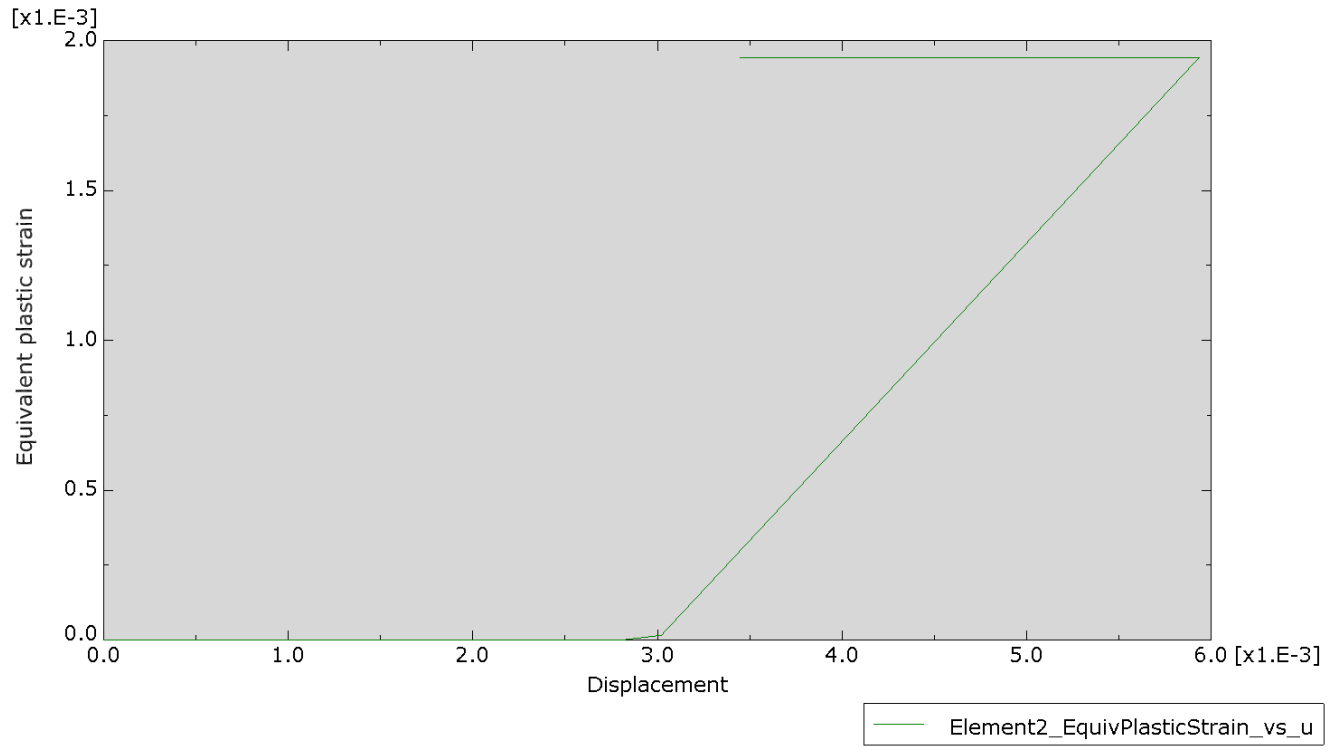


Fig. 4 Equivalent plastic strain vs displacement u in element 2