Machined T-Bar FEA

4/4/14

Purpose

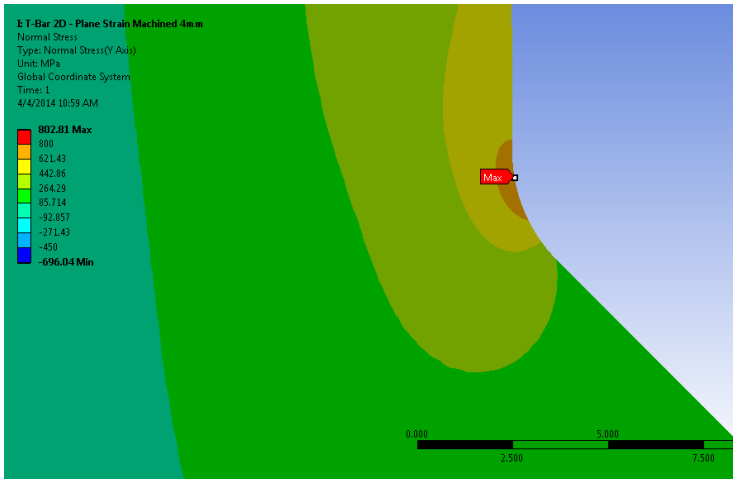
- Clarify and confirm stress level at stress concentration in Machined T- Bar specimen
  - Plane strain vs. Plane stress vs. 3D
  - Mesh sensitivity
  - Geometry sensitivity (toe radius)
- Provide necessary information to conduct advanced fatigue analysis
  - Precision
    - Small stress difference can cause large change in fatigue life
  - Linear and Non-linear stress analysis (residual stress)
  - Stress profile through thickness

Model

Plane Strain & Plane Stress

- Stress constant across thickness
- Both produce same result

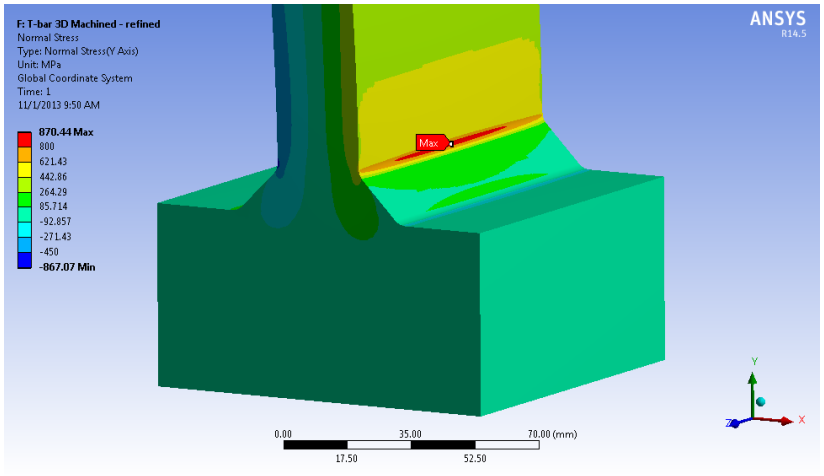
Peak YY Stress	Bending Stress	Stress Concentration
803	485	1.66



3D

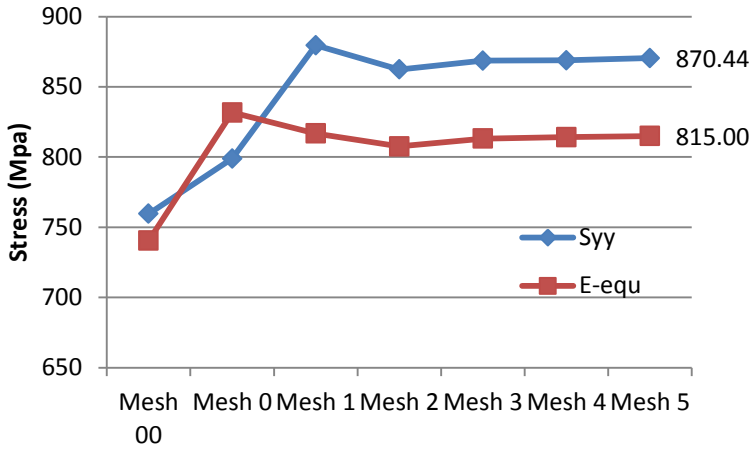
- Stress **NOT** constant across thickness
  - Higher in center
    - 7.7% higher than plane stress
  - Lower at edge

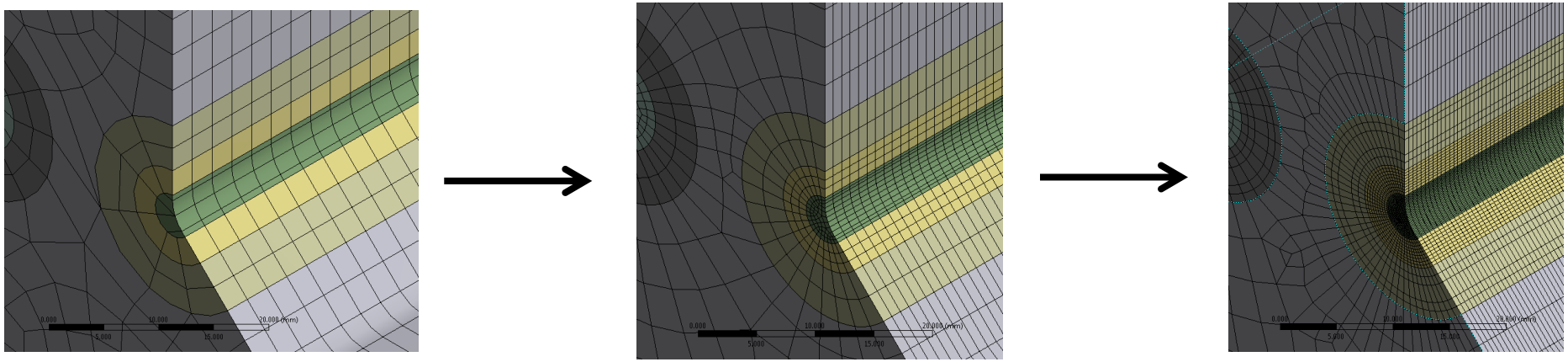
Peak YY Stress	Bending Stress	Stress Concentration
870	524	1.66



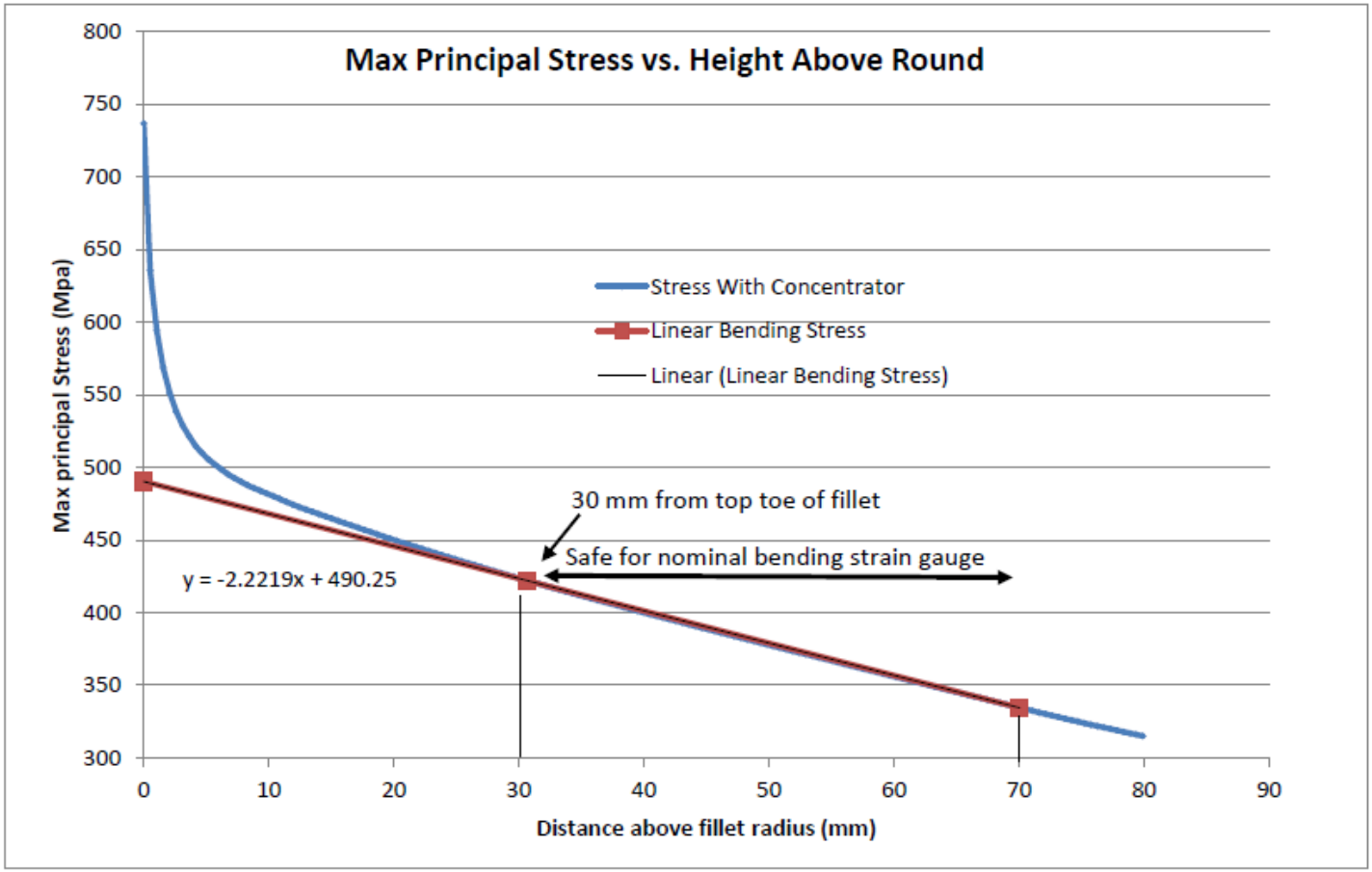
Mesh Sensitivity

- What is an adequate mesh?
  - Enough resolution to capture concentrator
    - High stress gradients = dense mesh
    - Convergence



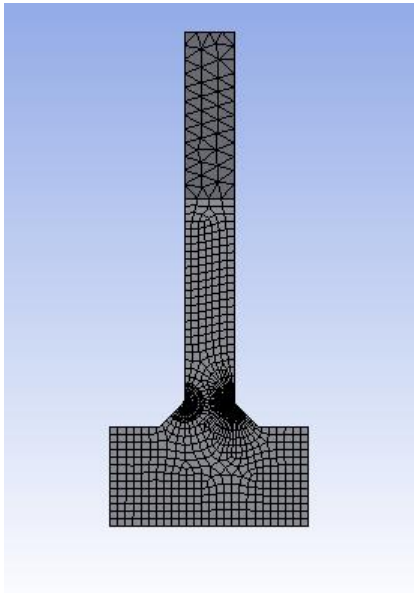


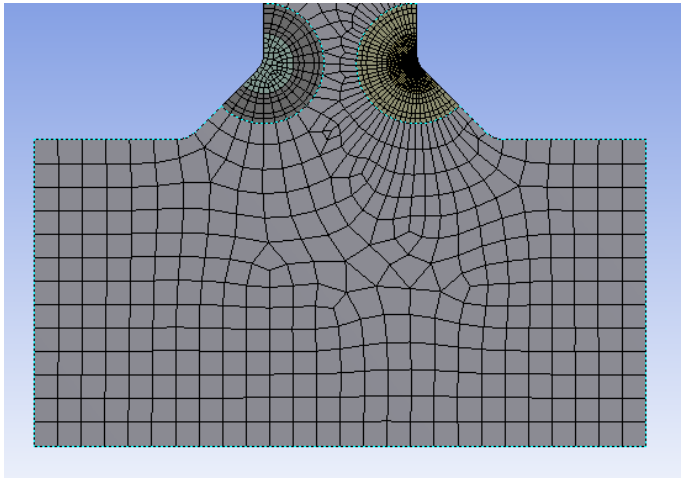
Stress Gradient

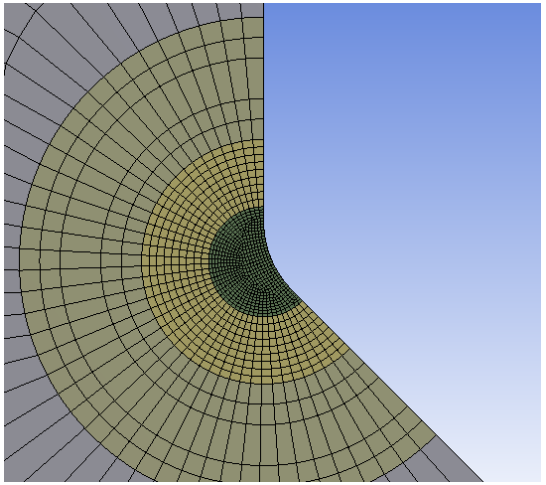


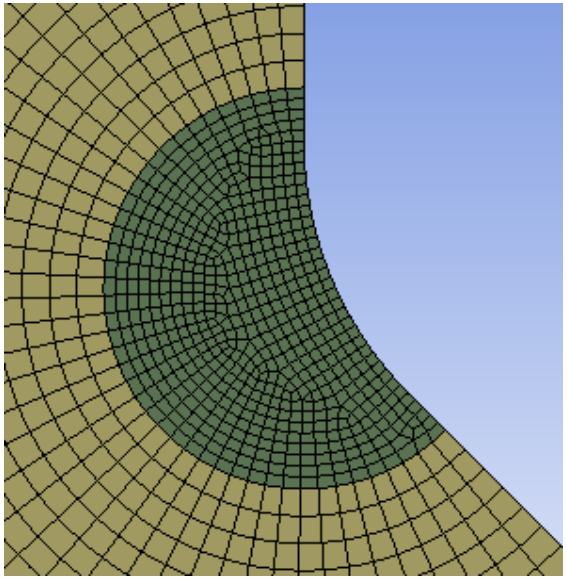
Look how steep the slope is near the radius – need dense mesh to capture with accuracy

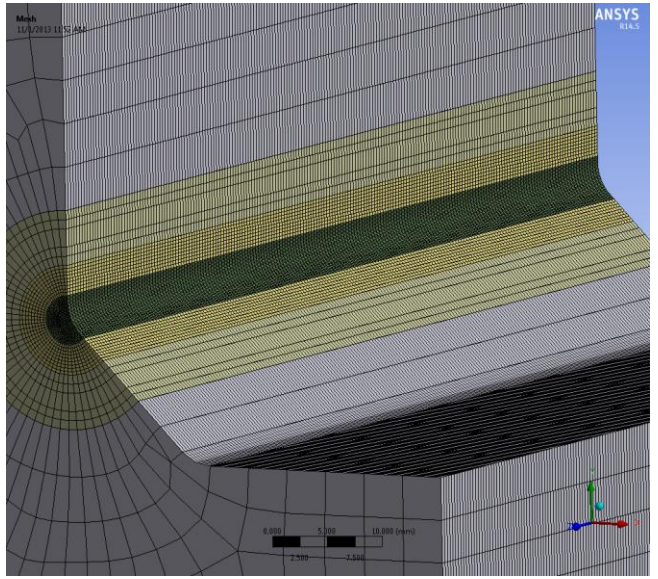
Mesh









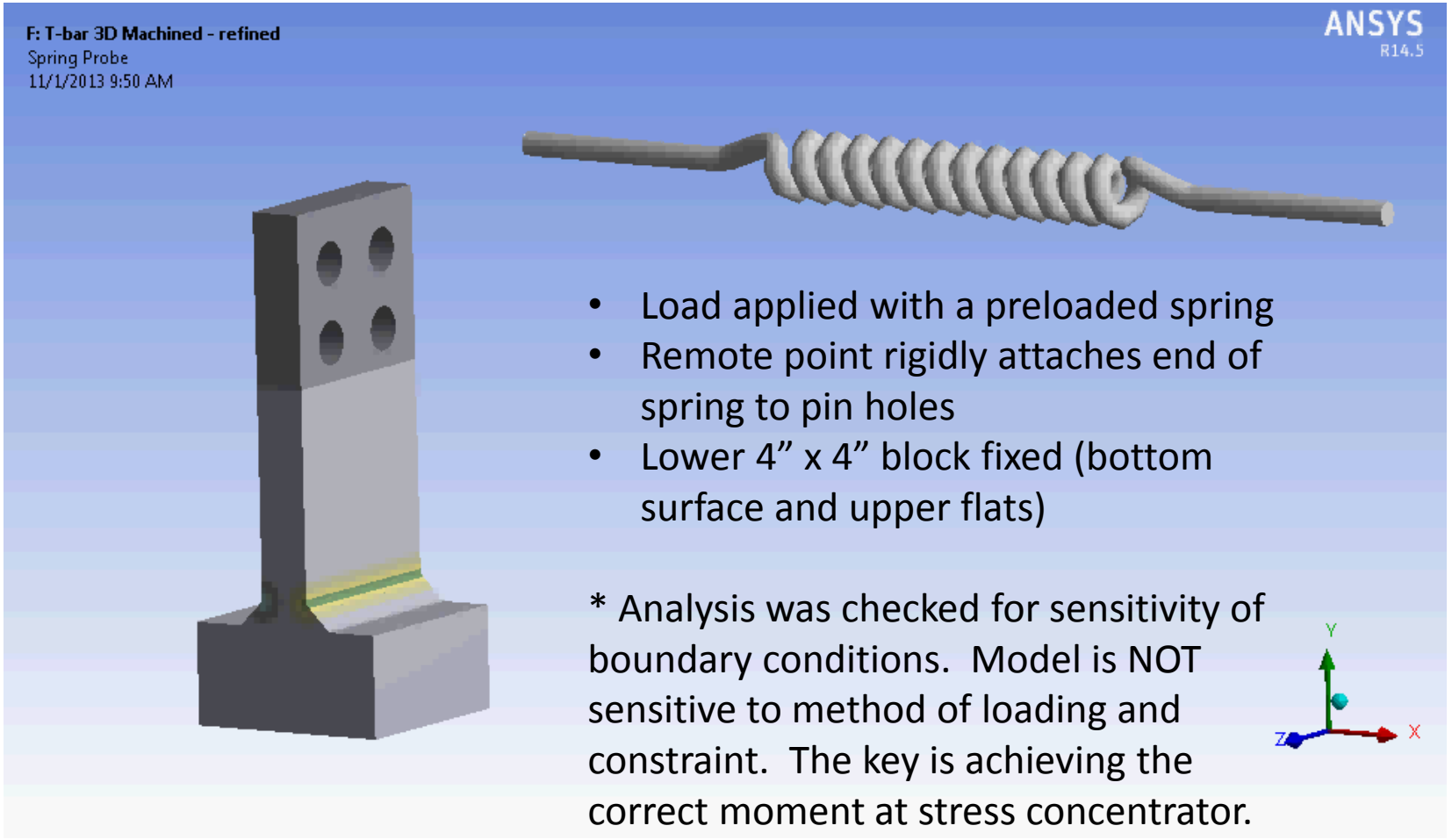


Overkill?

- ~430,000 Elements
- ~1,700,000 Nodes
- 4 min runtime

Maybe - but at very little cost.

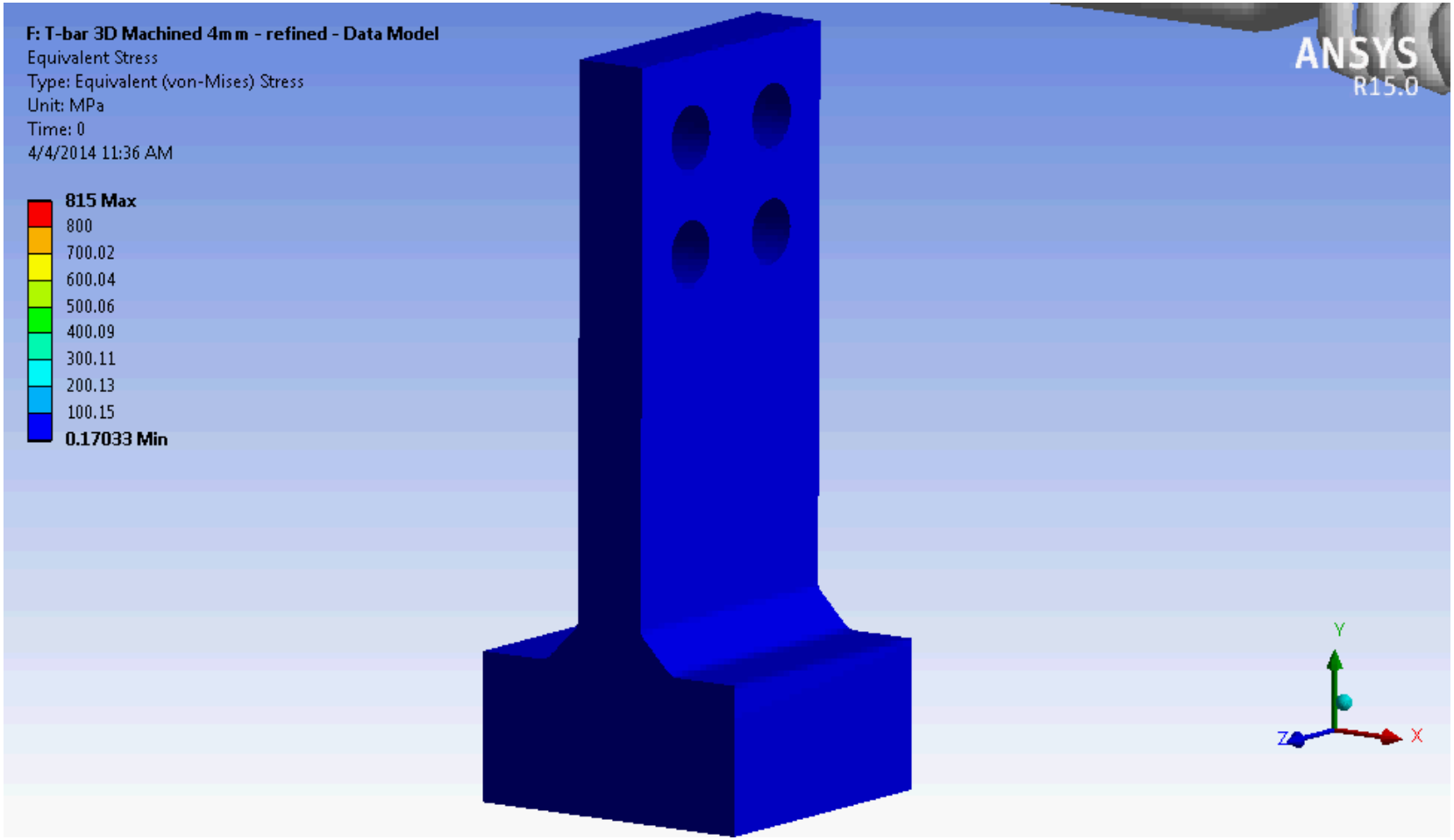
Boundary Conditions



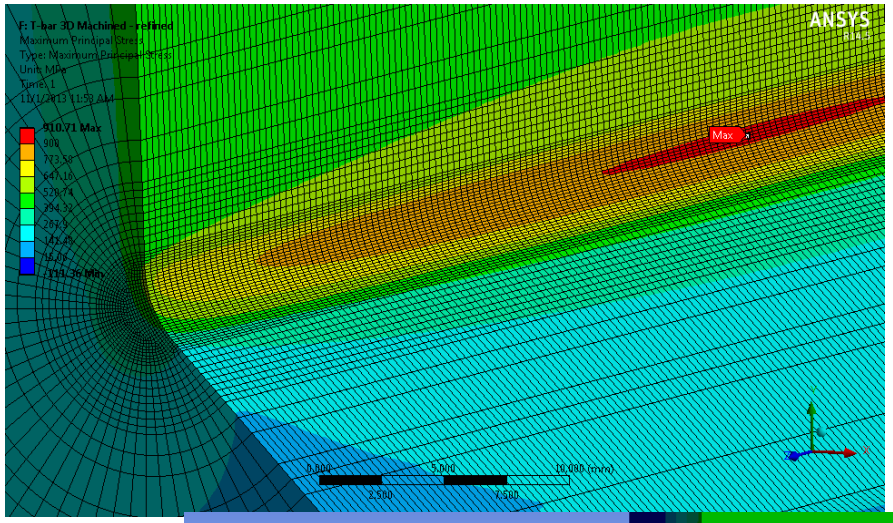
- Load applied with a preloaded spring
- Remote point rigidly attaches end of spring to pin holes
- Lower 4” x 4” block fixed (bottom surface and upper flats)

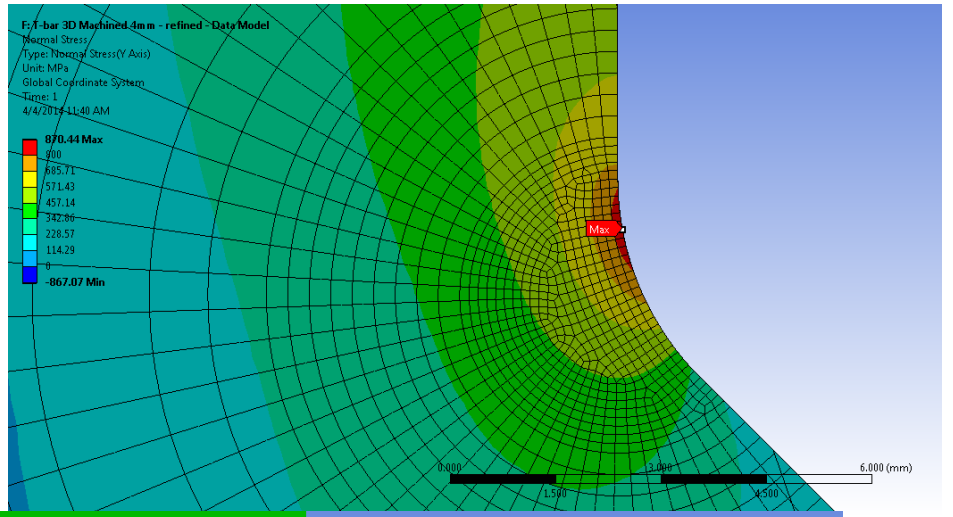
* Analysis was checked for sensitivity of boundary conditions. Model is NOT sensitive to method of loading and constraint. The key is achieving the correct moment at stress concentrator.

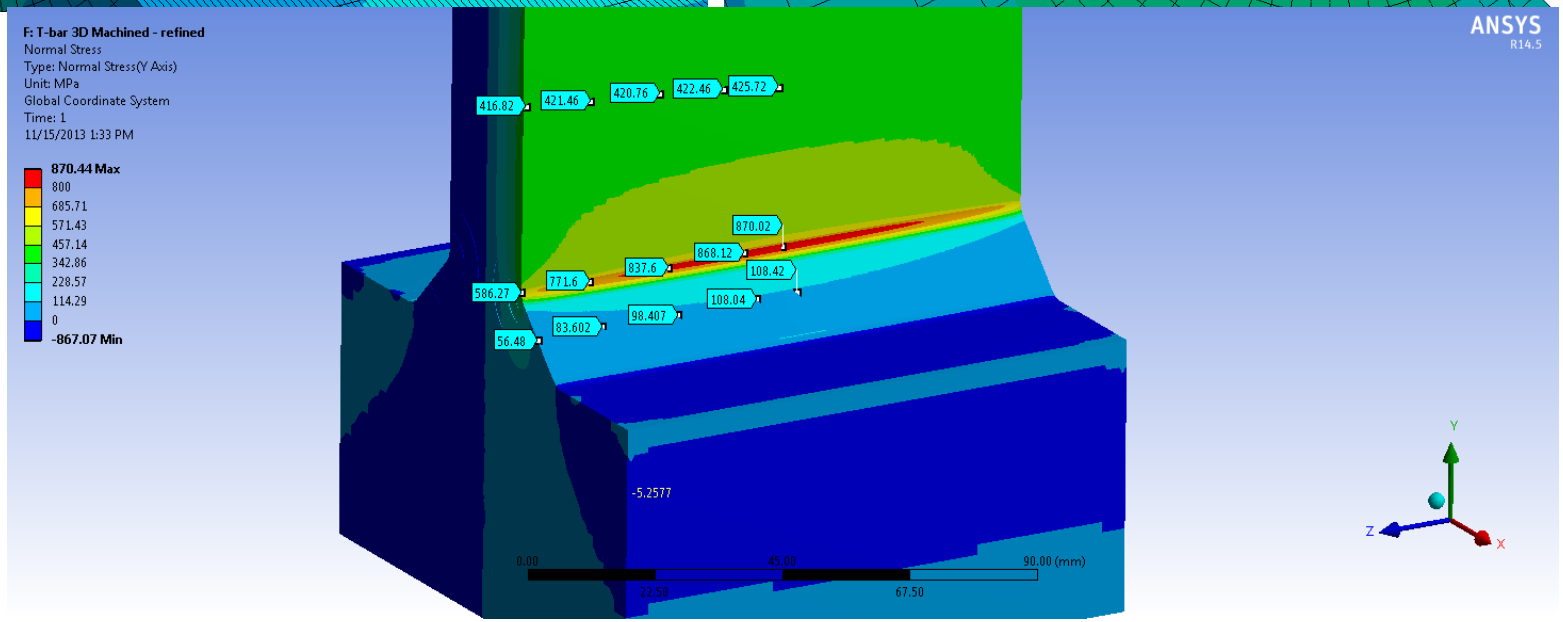
Results


F: T-bar 3D Machined 4mm - refined - Data Model
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 0
4/4/2014 11:36 AM
815 Max
800
700.02
600.04
500.06
400.09
300.11
200.13
100.15
0.17033 Min
ANSYS
R15.0
Y
Z
X

Results


F: T-bar 3D Machined - refined
Maximum Principal Stress
Type: Maximum Principal Stress
Unit: MPa
Time: 1
11/1/2013 11:58 AM
910.71 Max
900
773.58
647.16
520.74
394.32
267.9
141.48
15.06
-111.36 Min
Max
ANSYS
0.000
5.000
10.000 (mm)
2.500
7.500


F: T-bar 3D Machined 4mm - refined - Data Model
Normal Stress
Type: Normal Stress(Y Axis)
Unit: MPa
Global Coordinate System
Time: 1
4/4/2014 11:40 AM
870.44 Max
800
685.71
571.43
457.14
342.86
228.57
114.29
0
-867.07 Min
Max
0.000
3.000
6.000 (mm)
1.500
4.500

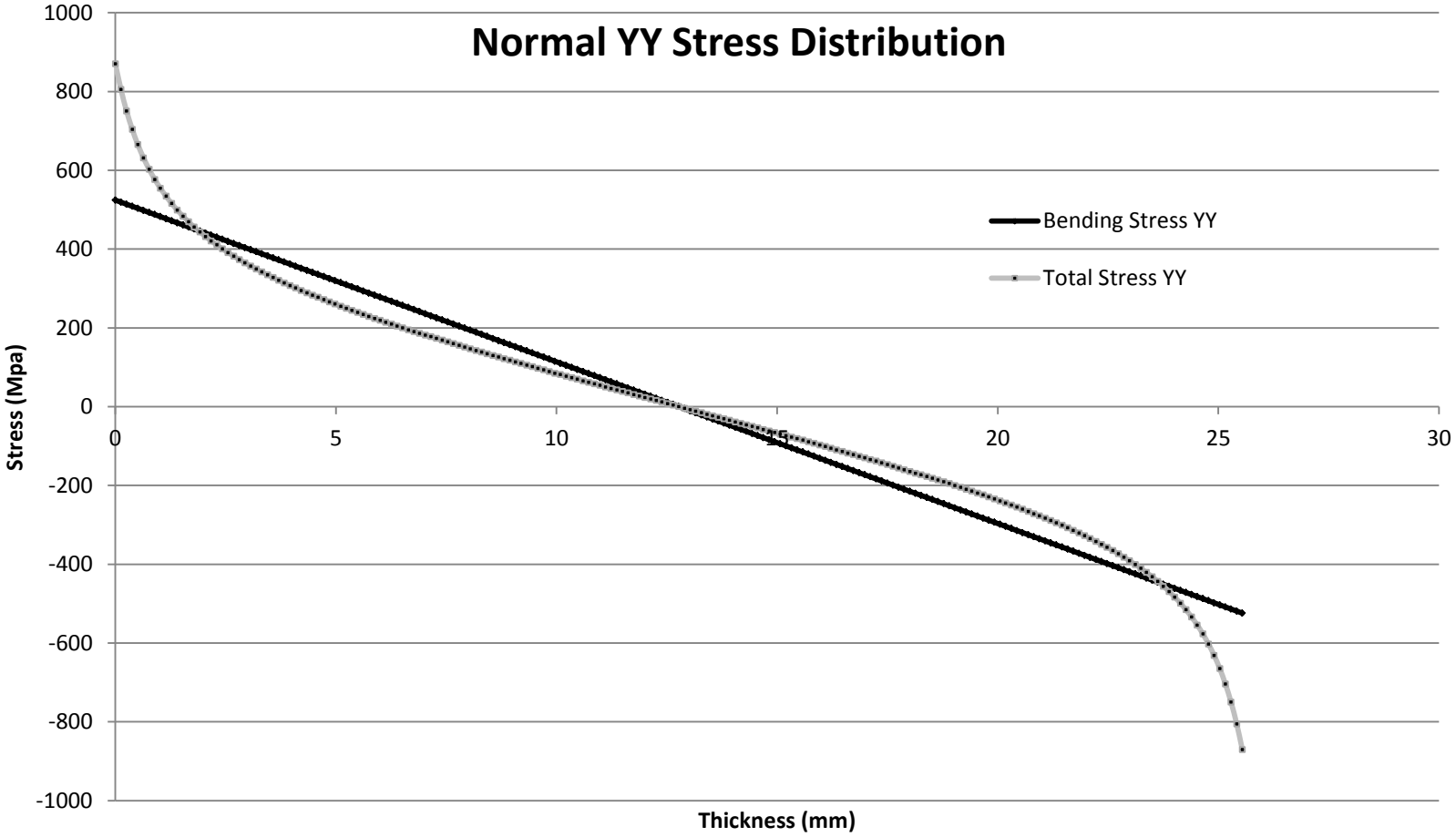

F: T-bar 3D Machined - refined
Normal Stress
Type: Normal Stress(Y Axis)
Unit: MPa
Global Coordinate System
Time: 1
11/15/2013 1:33 PM
870.44 Max
800
685.71
571.43
457.14
342.86
228.57
114.29
0
-867.07 Min
ANSYS
R14.5
416.82
421.46
420.76
422.46
425.72
870.02
868.12
837.6
771.6
586.27
108.42
108.04
98.407
83.602
56.48
-5.2577
0.00
45.00
90.00 (mm)
22.50
67.50
Y
Z
X

Radius Sensitivity

Radius	Normal Stress - Peak	Difference from 4 mm	Bending Stress	Stress concentration - FEA	Stress Concentration - efatigue.com
3	943.42	8.6 %	525.2	1.80	1.80
3.25	922.28	6.2 %	525.4	1.76	1.76
3.5	902.14	3.9%	524.8	1.72	1.72
3.75	885.55	2.0 %	524.3	1.69	1.69
4	868.47	0	524.9	1.65	1.65
4.25	853.79	-1.7	523.3	1.63	1.63
4.5	840.72	-3.2 %	521.3	1.61	1.60
4.75	830.56	-4.4 %	522.84	1.59	1.58
5	819.58	-5.6 %	521.89	1.57	1.56

* Radius sensitivity run with intermediate mesh

Stress distribution through thickness at center of specimen



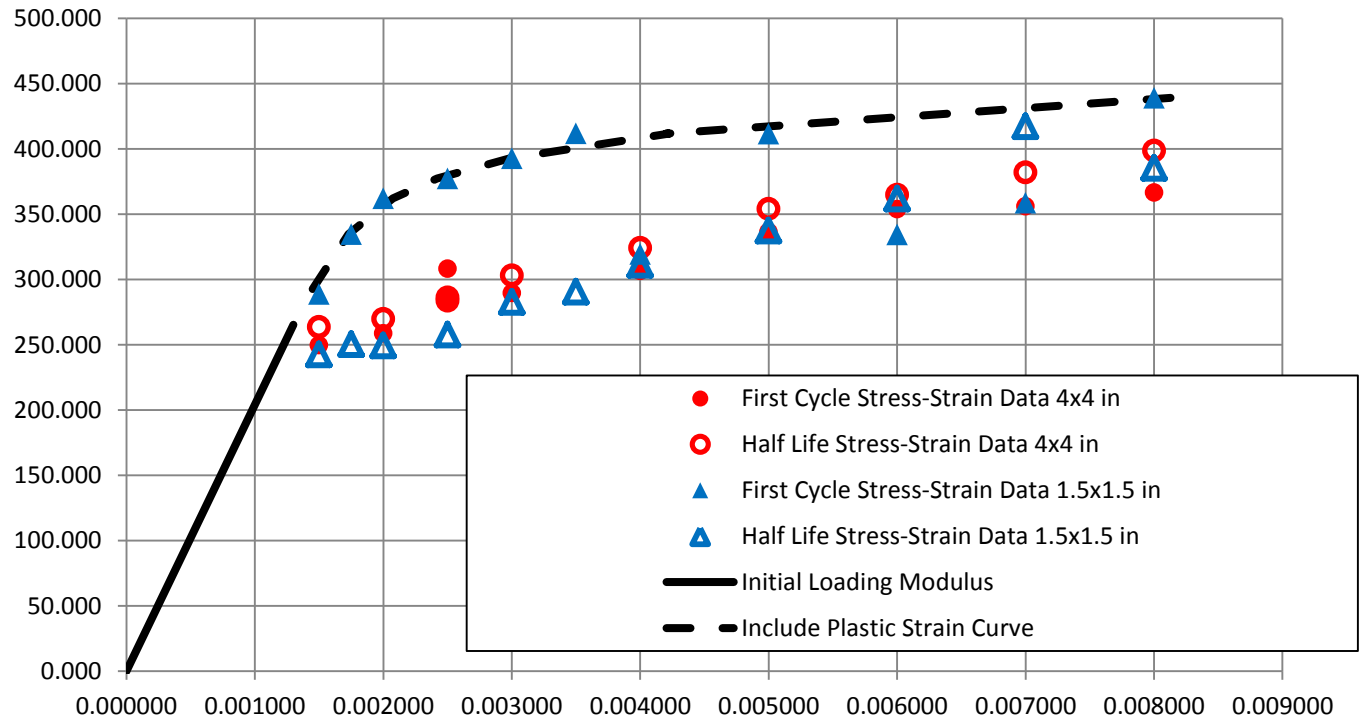
Full Tensor Results

30 mm above Fillet Tangent Point										
	S-XX	S-YY	S-ZZ	S-XY	S-YZ	S-XZ	S-Equ	S1	S2	S3
Plane Strain	0	425	128	0	0	0	378	425	128	0
Plane Stress	0	425	0	0	0	0	425	425	0	0
3D	0	424	61	0	0	0	397	424	61	0
	e-XX	e-YY	e-ZZ	e-XY	e-YZ	e-XZ	e-Equ	e1	e2	e3
Plane Strain	-0.000869	0.002027	0.000000	-0.000001	0.000000	0.000000	0.001980	0.002027	0.000000	-0.000869
Plane Stress	-0.000668	0.002228	-0.000668	-0.000001	0.000000	0.000000	0.002228	0.002228	-0.000668	-0.000668
3D	-0.000762	0.002126	-0.000349	-0.000004	0.000000	0.000000	0.002081	0.002126	-0.000349	-0.000762

Max Concentration (~1.3mm below fillet tangent point)										
	S-XX	S-YY	S-ZZ	S-XY	S-XZ	S-YZ	S-Equ	S1	S2	S3
Plane Strain	21	803	247	-128	0	0	731	823	247	0
Plane Stress	21	803	0	-128	0	0	823	823	0	0
3D	23	870	242	-139	0	0	798	892	242	1
	e-XX	e-YY	e-ZZ	e-XY	e-XZ	e-YZ	e-Equ	e1	e2	e3
Plane Strain	-0.001542	0.003786	0.000000	-0.001747	0.000000	0.000000	0.003834	0.003925	0.000000	-0.001681
Plane Stress	-0.001153	0.004174	-0.001295	-0.001747	0.000000	0.000000	0.004314	0.004314	-0.001293	-0.001295
3D	-0.001629	0.004141	-0.000133	-0.001894	0.000000	0.000000	0.004186	0.004293	-0.000133	-0.001781

3D effects only present at concntrator

Nonlinear Material Characterization



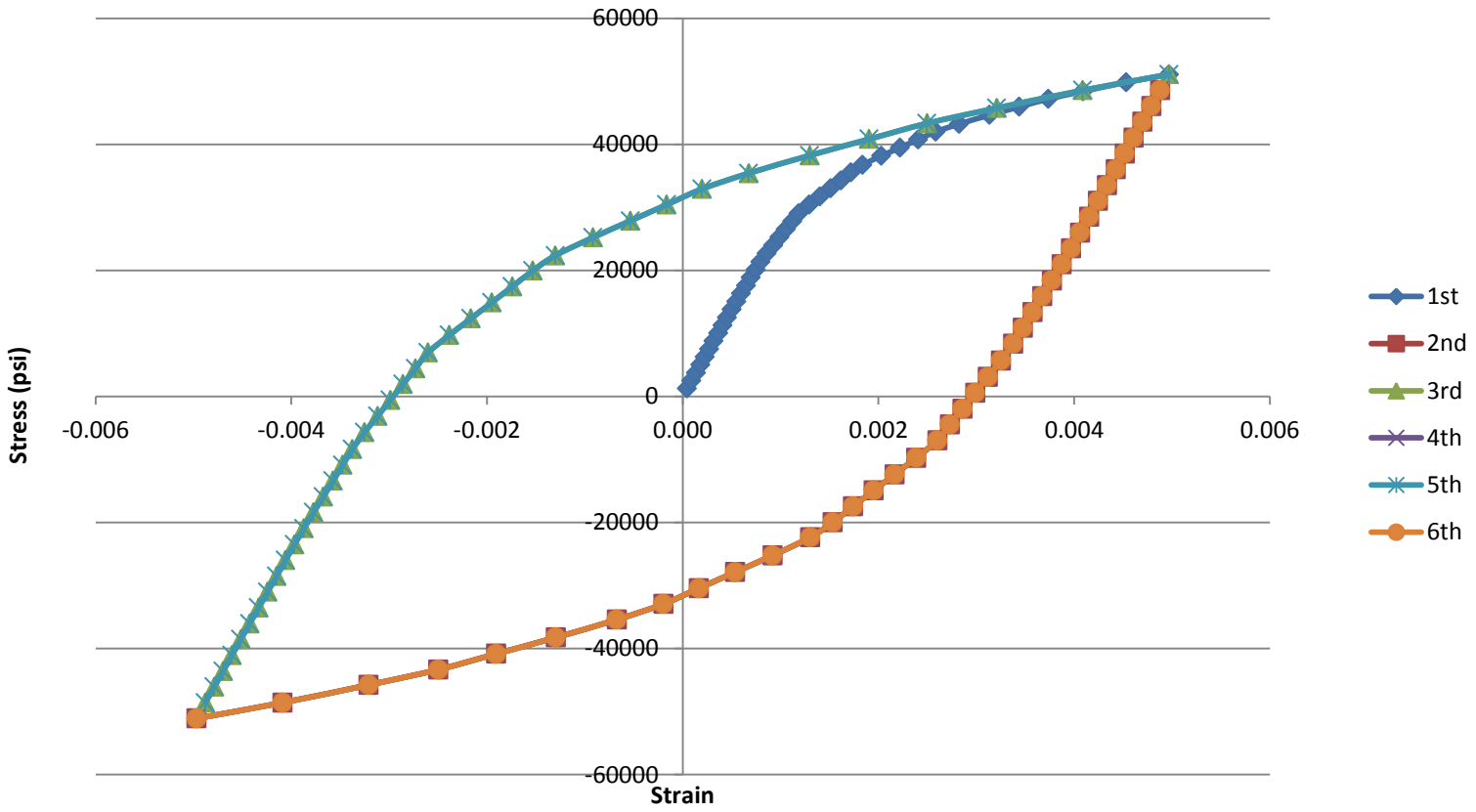
Monotonic

E	n	K	Yield Stress
204,052	0.0643	610.43	251.1

Cyclic

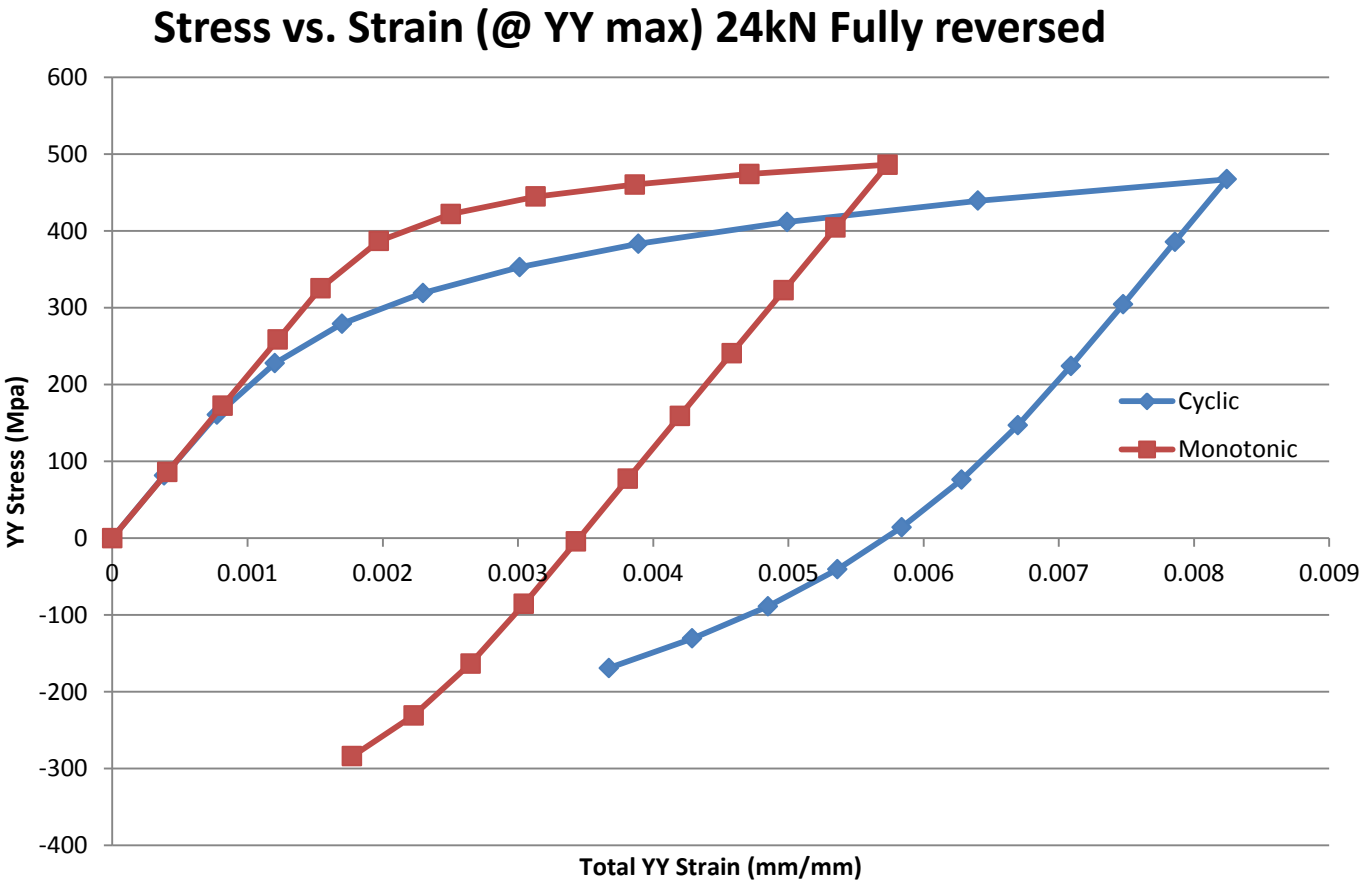
E	Sys	K'	n'
190786	324.12	991.4	0.1799

Nonlinear Material Model

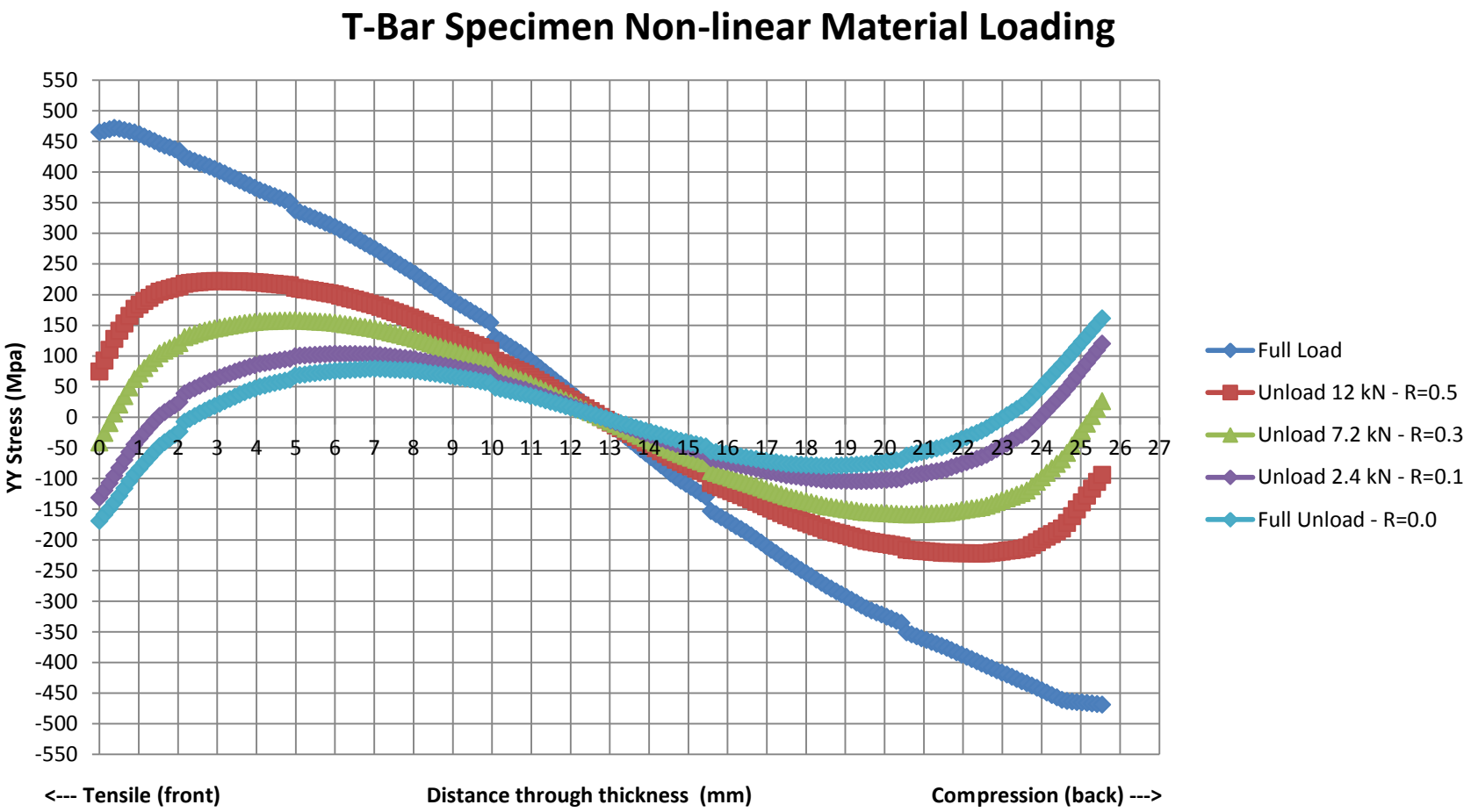


Kinematic Hardening – Yield surface translates (accounts for cyclic loading)

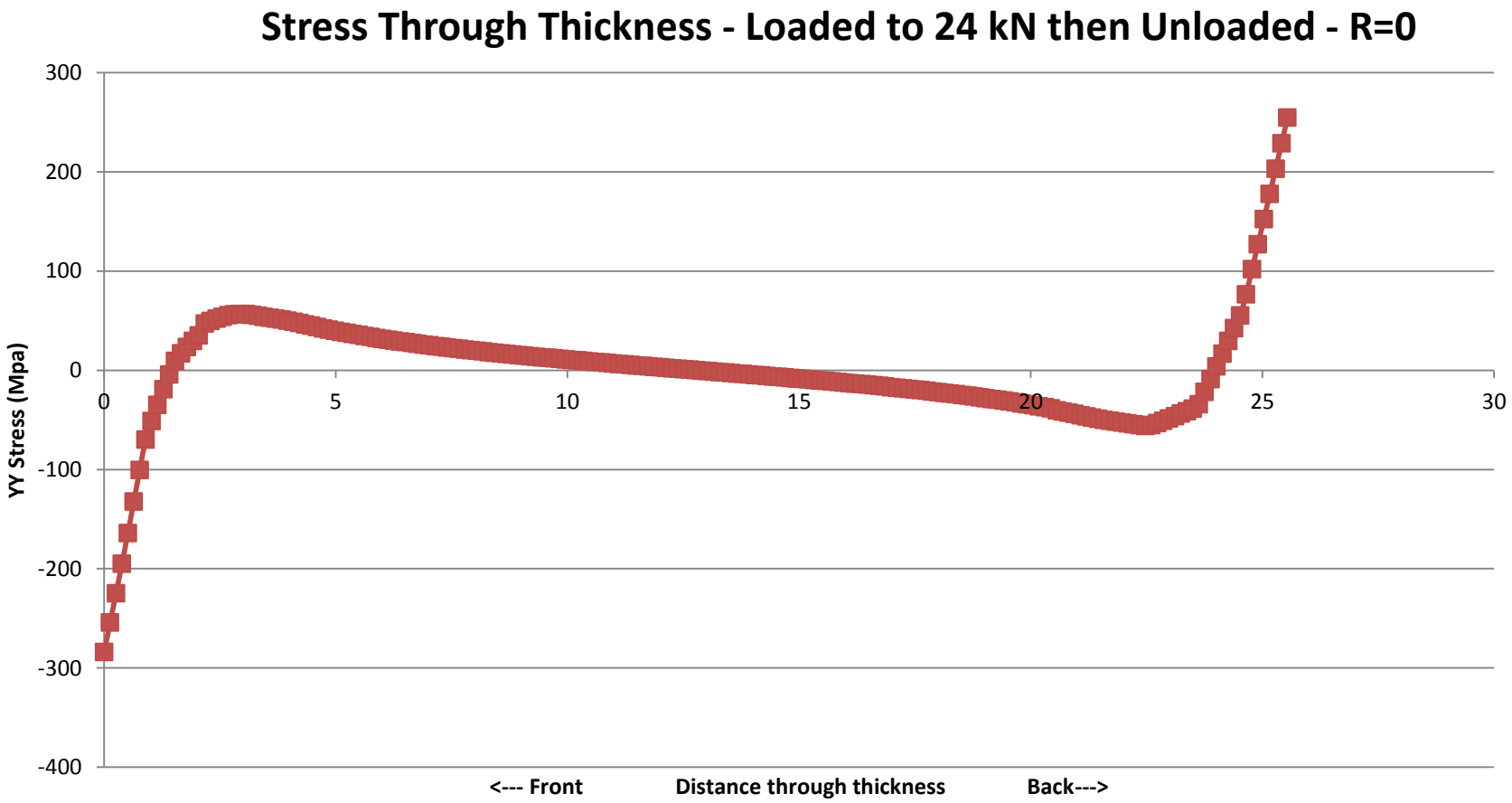
Cyclic vs. Monotonic 24 kN



24 kN Nonlinear Results - Cyclic

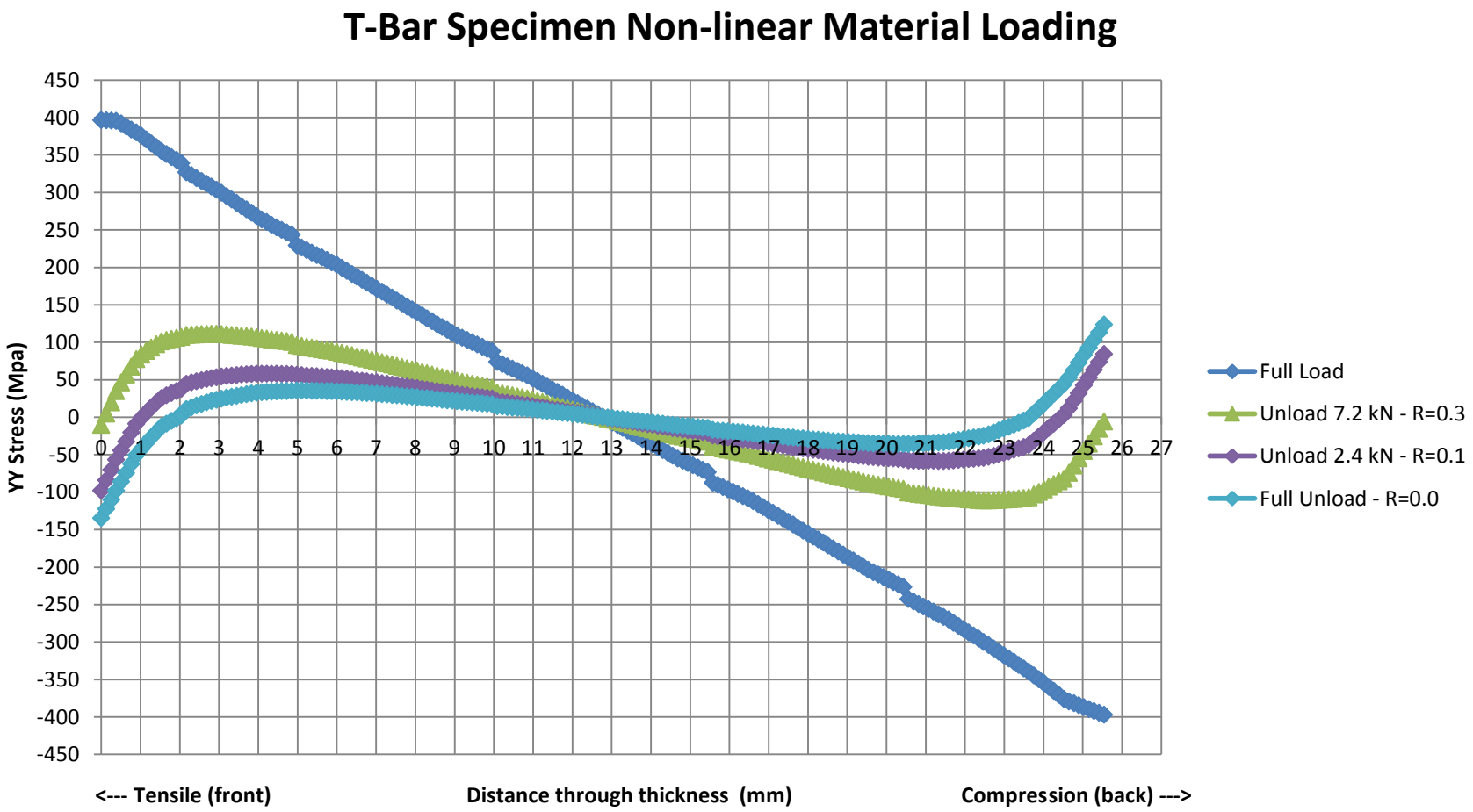


24 kN Nonlinear Results - Monotonic

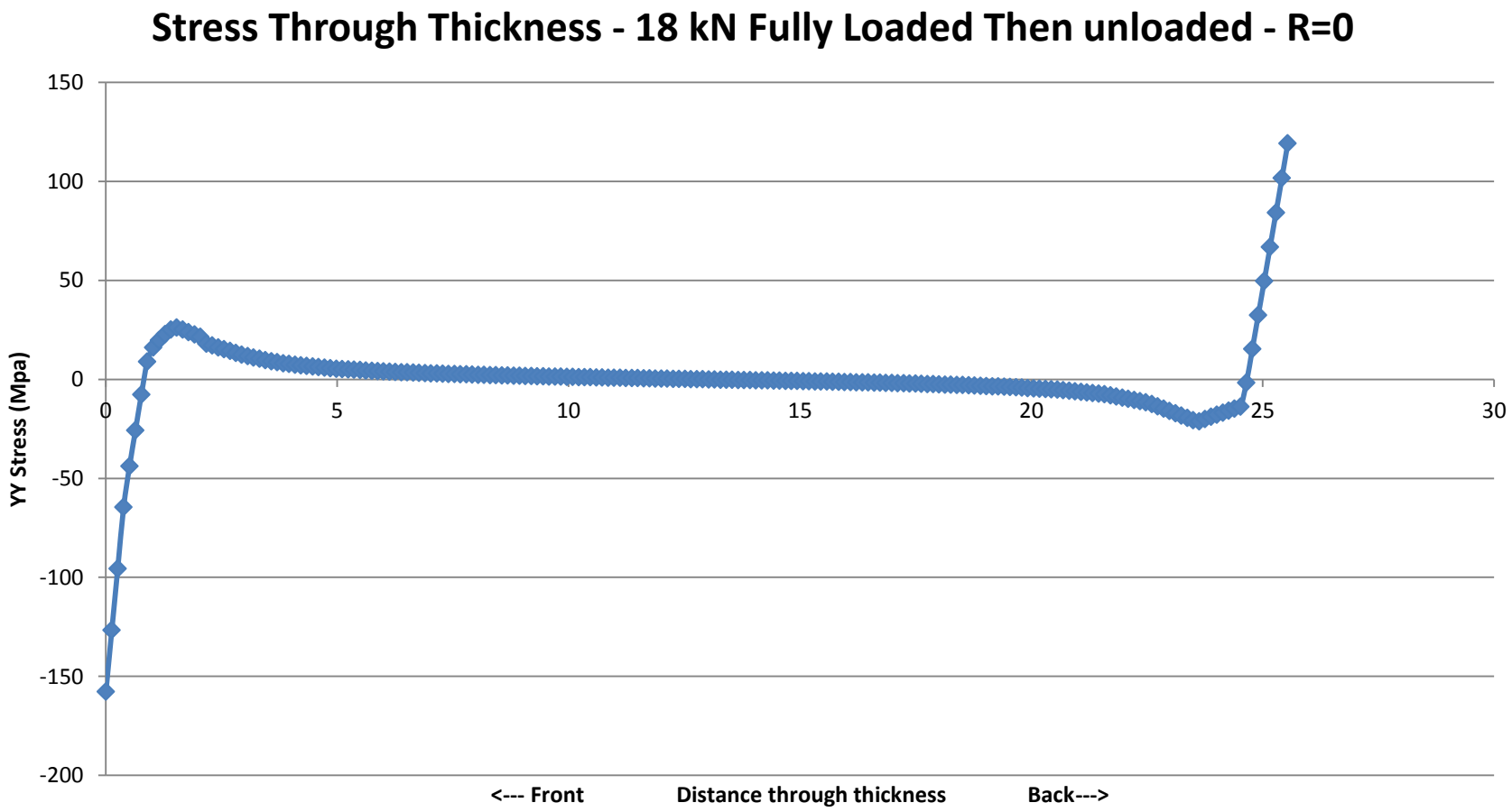


Elastic stress push lengthened material (yielded) shut – causes compressive residual stress on the tension side.

18 kN Nonlinear Results - Cyclic



18 kN Nonlinear Results - Monotonic



Use of Data for Fatigue Analysis

- Tom take over from here
  - Hysteresis loops
  - Etc.