TELECOMMUNICATIONS INDUSTRY FOUNDATION

Illustrative Examples

Mount to Tower Interaction Calculations and Finite Element Analysis Models

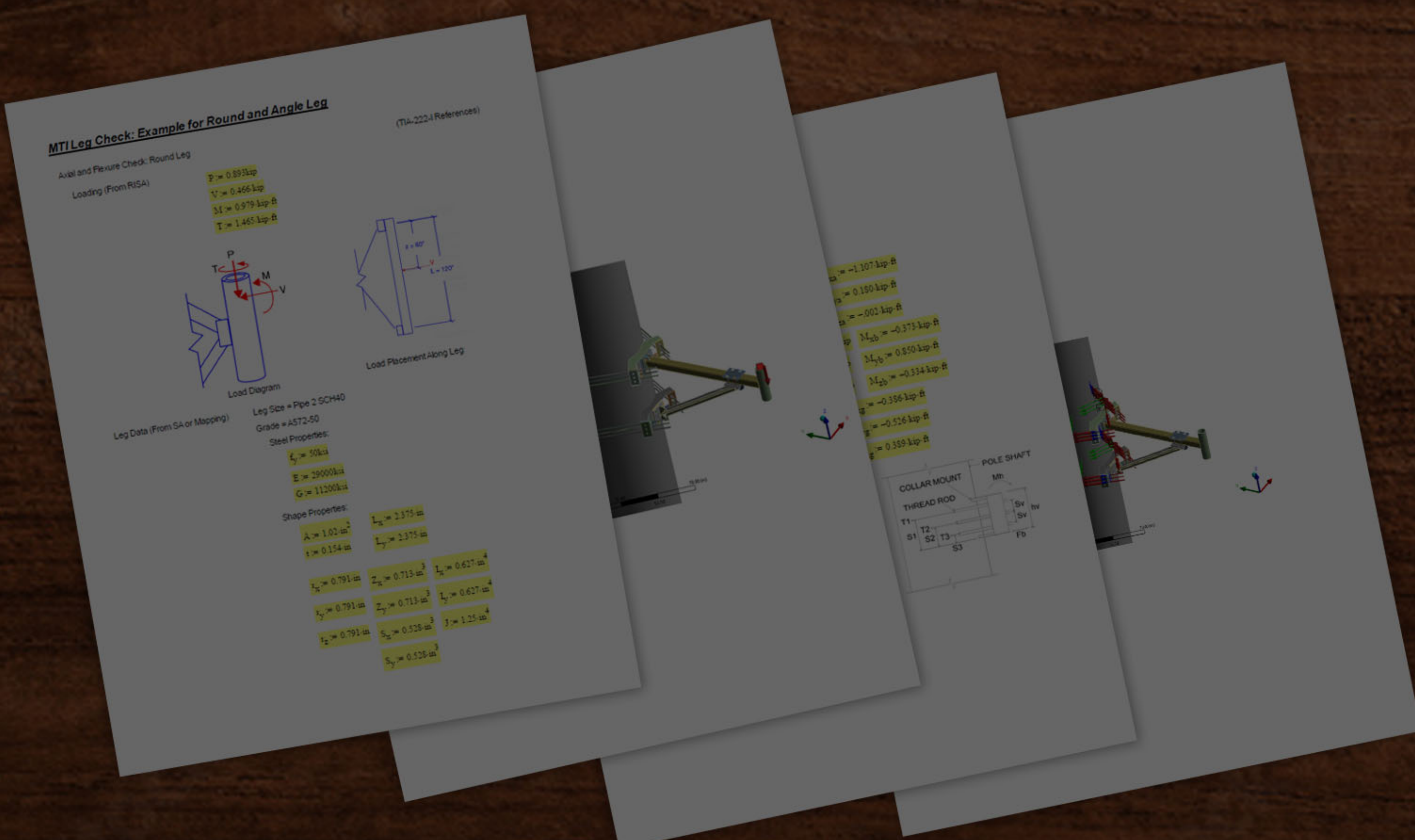

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Exhibit 1

Example calculation of an angle-leg tower analyzed for mount reactions from a sector frame

MTI Leg Check: Example for Round and Angle Leg

Axial and Flexure Check: Round Leg

(TIA-222-I References)

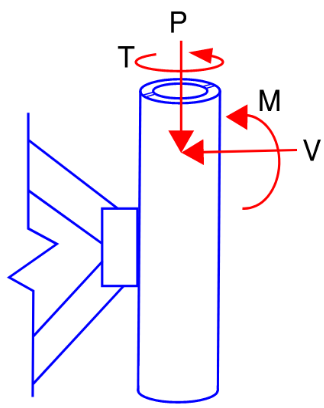
Loading (From RISA)

$P := 0.893\text{kip}$

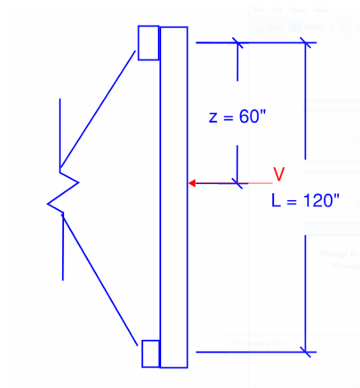
$V := 0.466 \cdot \text{kip}$

$M := 0.979 \cdot \text{kip} \cdot \text{ft}$

$T := 1.465 \cdot \text{kip} \cdot \text{ft}$



Load Diagram



Load Placement Along Leg

Leg Data (From SA or Mapping)

Leg Size = Pipe 2 SCH40

Grade = A572-50

Steel Properties:

$f_y := 50\text{ksi}$

$E := 29000\text{ksi}$

$G := 11200\text{ksi}$

Shape Properties:

$A := 1.02 \cdot \text{in}^2$ $\quad L_x := 2.375 \cdot \text{in}$

$t := 0.154 \cdot \text{in}$ $\quad L_y := 2.375 \cdot \text{in}$

$r_x := 0.791 \cdot \text{in}$ $\quad Z_x := 0.713 \cdot \text{in}^3$ $\quad I_x := 0.627 \cdot \text{in}^4$

$r_y := 0.791 \cdot \text{in}$ $\quad Z_y := 0.713 \cdot \text{in}^3$ $\quad I_y := 0.627 \cdot \text{in}^4$

$r_z := 0.791 \cdot \text{in}$ $\quad S_x := 0.528 \cdot \text{in}^3$ $\quad J := 1.25 \cdot \text{in}^4$

$S_y := 0.528 \cdot \text{in}^3$

$K := 1$

$L := 120 \cdot in$

$\phi := 0.9$

$z := 60 \cdot in$

Leg Capacities (Calculated)

$$f_e := \frac{\pi^2 \cdot E}{\left(\frac{K \cdot L}{r_z}\right)^2} = 12.436 \cdot ksi \qquad (4.5.4.2)$$

$$f_{cr} := 0.877 \cdot f_e = 10.907 \cdot ksi \qquad (4.5.4.2)$$

$$Pn := f_{cr} \cdot A = 11.125 \cdot kip \qquad (4.5.4.2)$$

$$Mn := \left(Z_x \cdot f_y\right) = 2.971 \cdot kip \cdot ft \qquad (4.7.2)$$

$$P_e := \frac{\pi^2 \cdot E \cdot I_x}{(K \cdot L)^2} = 12.462 \cdot kip \qquad (4.8.1)$$

$$\beta := \frac{1}{\left(1 - \frac{P}{P_e}\right)} = 1.077 \qquad (4.8.1)$$

Utilization Calculations:

Compression Utilization:

$$Cu := \frac{P}{\phi \cdot Pn} = 0.089$$

Flexure Utilization:

$$Bu := \frac{M + 0.7\left[\frac{2 \cdot V \cdot \left[(L - z)^2\right] \cdot z^2}{L^3}\right]}{\phi \cdot Mn} = 0.519$$

Interaction Utilization:

$$Tu := \frac{Cu}{2} + (\beta \cdot Bu) = 0.603 \qquad (4.8.1.1)$$

Capacity Check:

$$Check := \begin{cases} \text{"OK"} & \text{if } Tu < 1 \\ \text{"No Good"} & \text{otherwise} \end{cases}$$

Check = "OK"

Torsion and Shear Check: Angle Leg

Loading (From RISA)

$P := 0.893\text{kip}$

$V := 0.466 \cdot \text{kip}$

$M := 0.979 \cdot \text{kip} \cdot \text{ft}$

$T := 1.465 \cdot \text{kip} \cdot \text{in}$

Leg Data (From SA)

Leg Size = 60 Degree 4"x4"x1/4"

Grade = A572-50

Steel Properties:

$f_y := 50\text{ksi}$ $\quad K := 1$

$E := 29000\text{ksi}$ $\quad b := 4 \cdot \text{in}$

$G := 11200\text{ksi}$

$L := 120\text{in}$ $\quad z := 12 \cdot \text{in}$ $\quad t := 0.25 \cdot \text{in}$

$A := 1.9375 \cdot \text{in}^2$

$J := 0.0404 \cdot \text{in}^4$

$C_w := 0.0701 \cdot \text{in}^6$

$\alpha := \frac{z}{L} = 0.1$

$$a := \left[\frac{(E \cdot C_w)}{G \cdot J}\right]^{\frac{1}{2}} = 0.177\,\text{ft}$$

(16.5.1-Torsional Stiffness 1)

$$\theta_L := \left(\frac{T \cdot L}{G \cdot J}\right) \cdot (1 - \alpha) \cdot \left(\frac{z}{L}\right) + \frac{a}{L} \cdot \left(\frac{\sinh\left(\alpha \cdot \frac{L}{a}\right)}{\tanh\left(\frac{L}{a}\right)} - \cosh\left(\alpha \cdot \frac{L}{a}\right)\right) \cdot \sinh\left(\frac{z}{a}\right) = 0.026 \cdot \text{rad}$$

$$\theta_{PL} := \left(\frac{T \cdot L}{G \cdot J}\right) \cdot \left[\left(\frac{1-\alpha}{L}\right) + \frac{\alpha}{L}\left(\frac{\sinh\left(\alpha \cdot \frac{L}{a}\right)}{\tanh\left(\frac{L}{a}\right)} \cdot \cosh\left(\frac{z}{a}\right) - \cosh\left(\frac{\alpha \cdot L}{a}\right) \cdot \cosh\left(\frac{z}{a}\right)\right)\right] = 2.752 \times 10^{-3} \cdot \frac{rad}{in}$$

$$Vut := 1.2 \cdot A \cdot G \cdot t \cdot \theta_{PL} = 17.916 \cdot kip$$

(16.5.1-Torsional Stiffness 2)

$$Vu := Vut + V \cdot \frac{A}{b \cdot t} = 18.819 \cdot kip$$

(16.5.1-Torsional Stiffness 3)

(16.5.1-Torsional Stiffness 4)

$$Vn := 0.6 \cdot f_y \cdot (A) = 58.125 \cdot kip$$

$$\phi := 0.9$$

$$Capacity := \frac{Vu}{\phi \cdot Vn} = 0.36$$

$$Check := \begin{cases} \text{"OK"} & \text{if } \frac{Vu}{\phi \cdot Vn} < 1 \\ \text{"No Good"} & \text{otherwise} \end{cases}$$

$$Check = \text{"OK"}$$

MTI Collar Check

Loading (From RISA)

Alpha

$\theta_a := 180°$

$F_{xa} := -.06318kip$ $M_{xa} := -1.107 \cdot kip \cdot ft$

$F_{ya} := -2.67071kip$ $M_{ya} := 0.180 \cdot kip \cdot ft$

$F_{za} := 6.42122kip$ $M_{za} := -.002 \cdot kip \cdot ft$

Beta

$\theta_b := 60°$

$F_{xb} := -1.25025kip$ $M_{xb} := -0.373 \cdot kip \cdot ft$

$F_{yb} := 1.08555kip$ $M_{yb} := 0.850 \cdot kip \cdot ft$

$F_{zb} := 1.53866kip$ $M_{zb} := -0.334 \cdot kip \cdot ft$

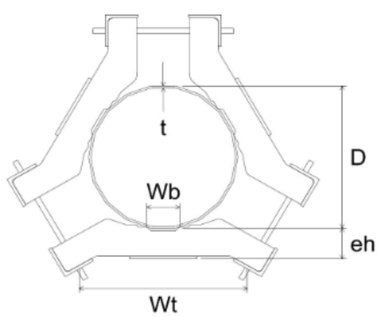
Gamma

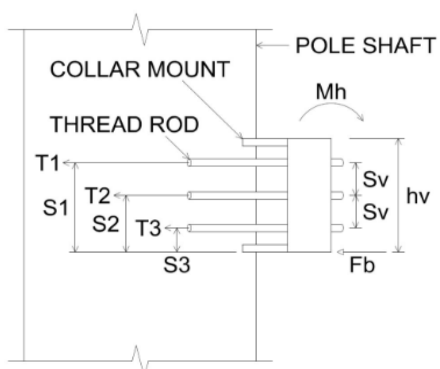
$\theta_g := 300°$

$F_{xg} := 1.36633kip$ $M_{xg} := -0.386 \cdot kip \cdot ft$

$F_{yg} := 1.20414kip$ $M_{yg} := -0.526 \cdot kip \cdot ft$

$F_{zg} := 1.50055kip$ $M_{zg} := 0.389 \cdot kip \cdot ft$





Collar Data:

Threaded Rod Qty: $Q_{tr} := 2$

Collar Height: $h_v := 11.5in$

Threaded Rod Vertical Spacing: $s_v := 9.5in$

Threaded Rod Width: $W_t := 23in$

Threaded Rod Considered: 1/2" A307

Diameter: $d_{tr} := 0.5in$

Yield Strength: $f_{ytr} := 36ksi$ $f_{utr} := 60ksi$

Threaded Rod Vertical Height: $s_{v1} := 10.5in$ $s_{v2} := 1in$

Bearing Width: $W_b := 7.5in$

$$R2 := \frac{s_{v2}}{s_{v1}} = 0.095$$ (16.5.1 - Tension Collar 1.i.i)

Pole Data:

Pole Offset: $e_h := 6in$

Pole Diameter: $D := 17.3in$

Pole Thickness: $t := 0.1875in$

Pole Strength: $f_{yp} := 65ksi$

Max Reactions (Calculated):

$M_{ma} := 2.560 \cdot kip \cdot ft$

$M_{mb} := -0.442 \cdot kip \cdot ft$

$M_{mg} := -0.458 \cdot kip \cdot ft$

Max Moment: $M_h := \frac{2.560}{12} \cdot in \cdot kip$

Capacity Calculations:

$$\delta := \frac{6 \cdot M_h}{\left(\cos\left(\frac{\pi}{6}\right)\right)\left[\left[s_{v2} \cdot (R2 - 1)\right] + \frac{\left[(5 - R2) \cdot \left(R2 \cdot s_{v2} + s_{v1}\right)\right]}{1 + R2}\right]} = 0.032 \cdot kip$$ (16.5.1 - Tension Collar 1.i.ii)

$$T1 := \delta \frac{5 - R2}{1 + R2} = 0.142 \cdot kip$$ (16.5.1 - Tension Collar 1.i.iii)

$$T2 := R2 \cdot (T1 + \delta) - \delta = -0.015 \cdot kip$$ (16.5.1 - Tension Collar 1.i.iv)

$\phi := 0.65$ (16.5.4.iii.ii)

$\phi_p := 0.9$ (16.5.1 - Tension Collar 1.iv.ii)

Threaded Rod Capacity:

$$Rn := \phi \cdot f_{utr} \cdot \frac{\pi}{4} \cdot \left(d_{tr} - \frac{0.9743 in}{13} \right)^2 = 5.534 \cdot kip$$

Utilization Calculations:

Threaded Rod Utilization:

$$Utr := \frac{T1}{Rn} = 0.026$$

$$Check := \begin{vmatrix} \text{"OK"} & \text{if } Utr < 1 \\ \text{"No Good"} & \text{otherwise} \end{vmatrix} \qquad Check = \text{"OK"}$$

Pole Utilization:

$$Bp := 2 \cdot \cos\left(\frac{\pi}{6}\right) \cdot (T1 + T2) = 0.22 \cdot kip$$

$$Rnp := \left[\phi_p \cdot f_{yp} \cdot t^2 \cdot \frac{5.5}{\left(1 - \frac{0.81 \cdot W_b}{D}\right)} \right] = 17.433 \cdot kip$$

(16.5.1 - Tension Collar 1.i.iv)

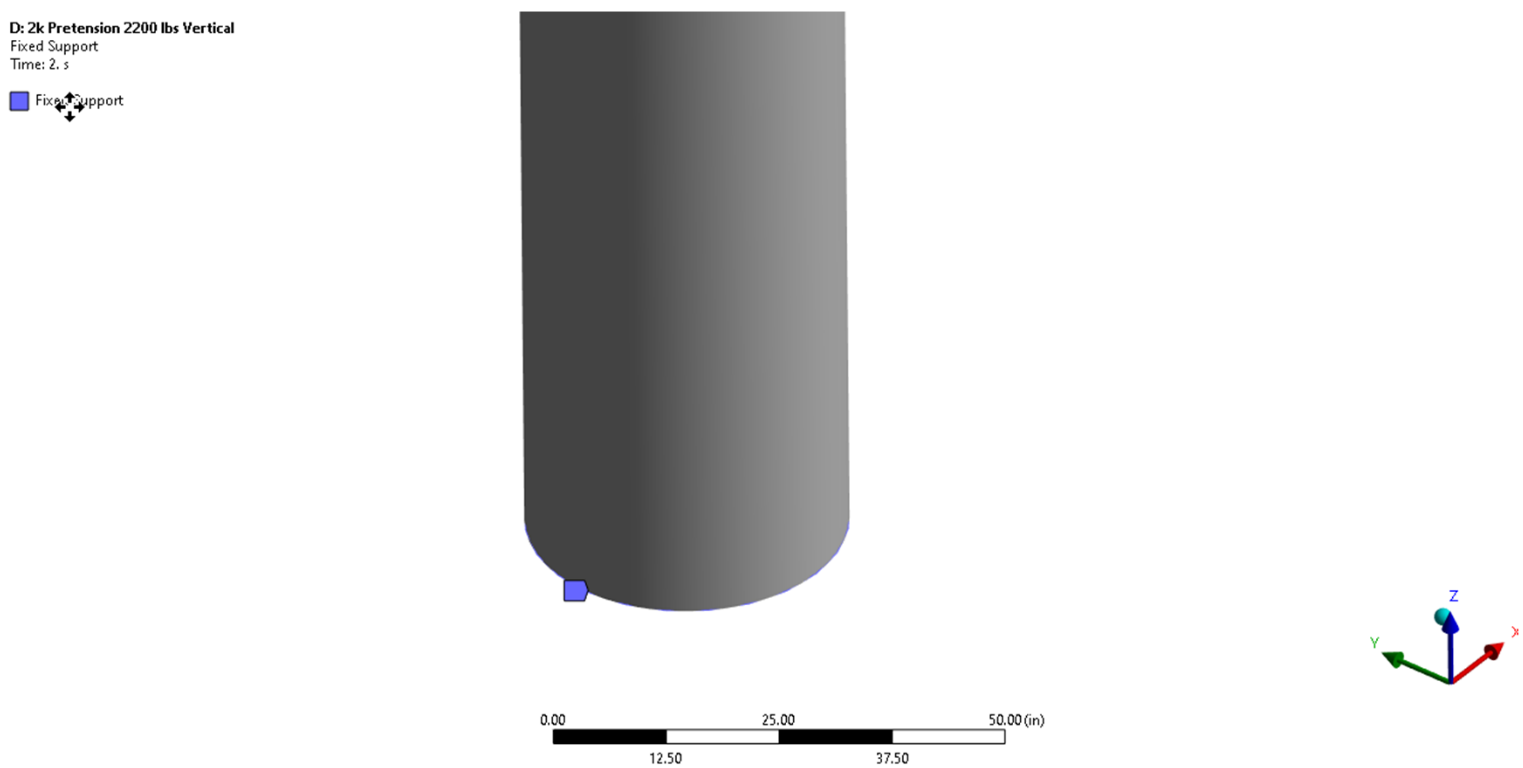
$$Up := \frac{Bp}{Rnp} = 0.013$$

$$Check := \begin{vmatrix} \text{"OK"} & \text{if } Up < 1 \\ \text{"No Good"} & \text{otherwise} \end{vmatrix} \qquad Check = \text{"OK"}$$

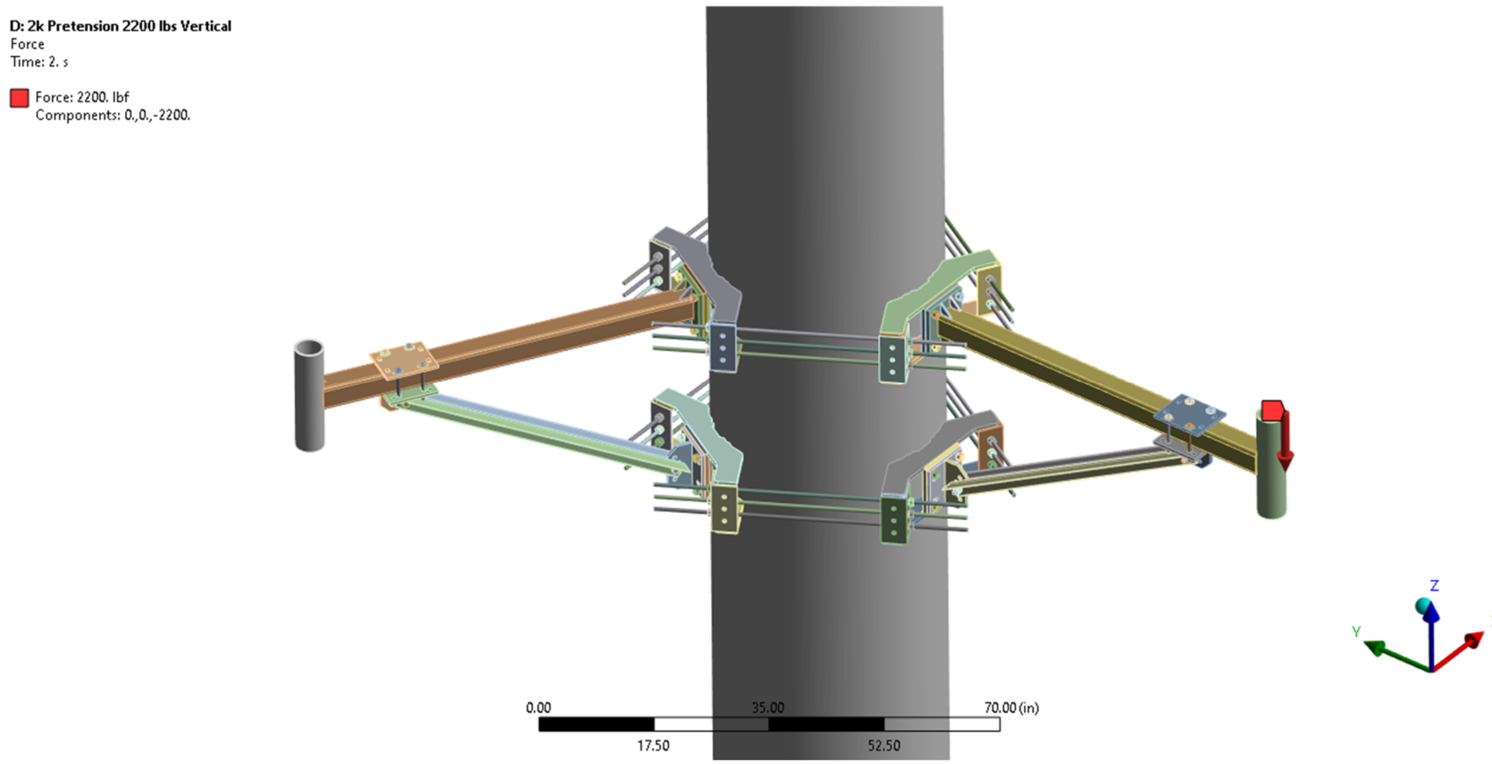
Exhibit 2

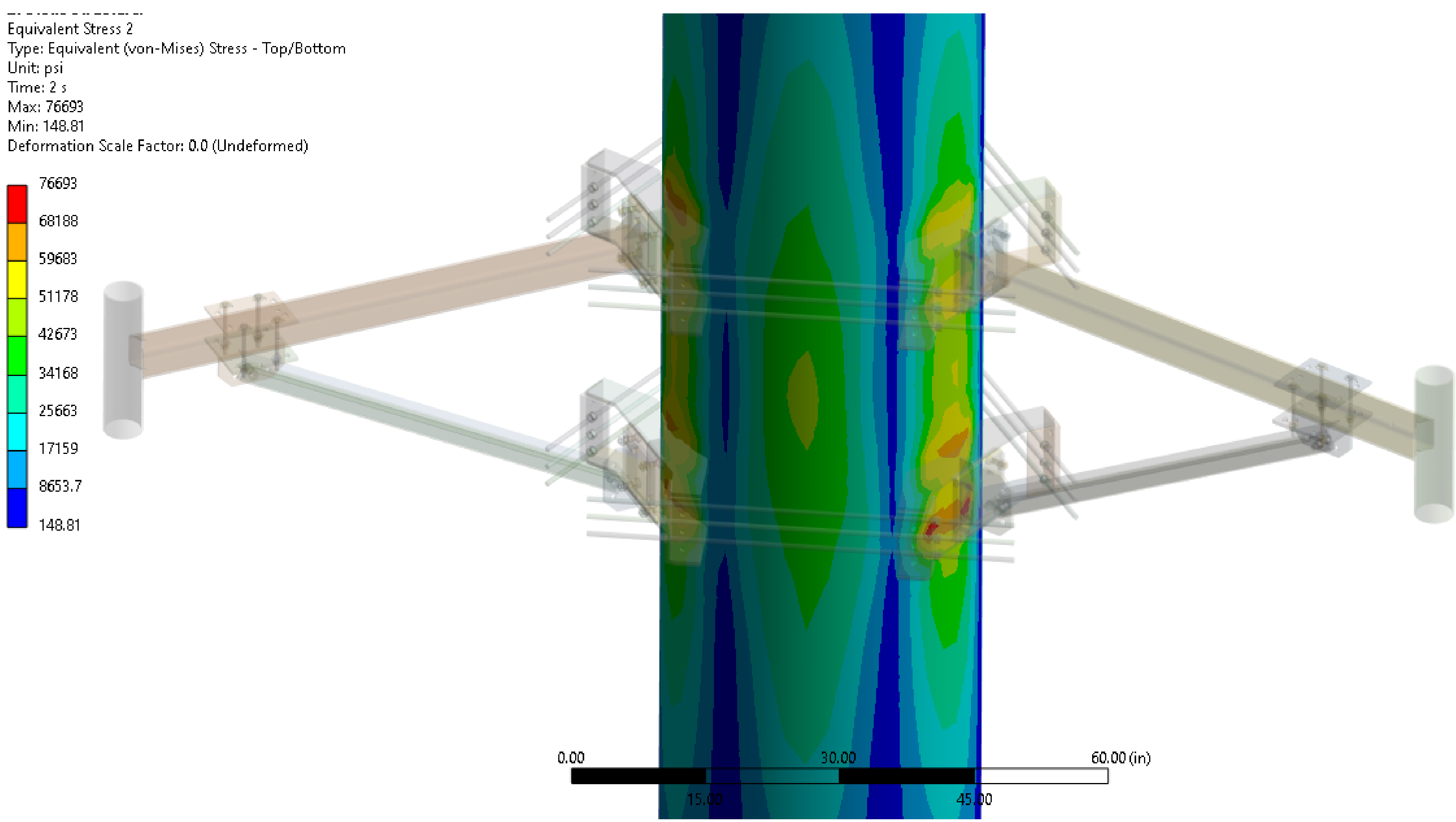
Finite element analysis results showing the reduction of stress in a monopole when a kicker kit is added

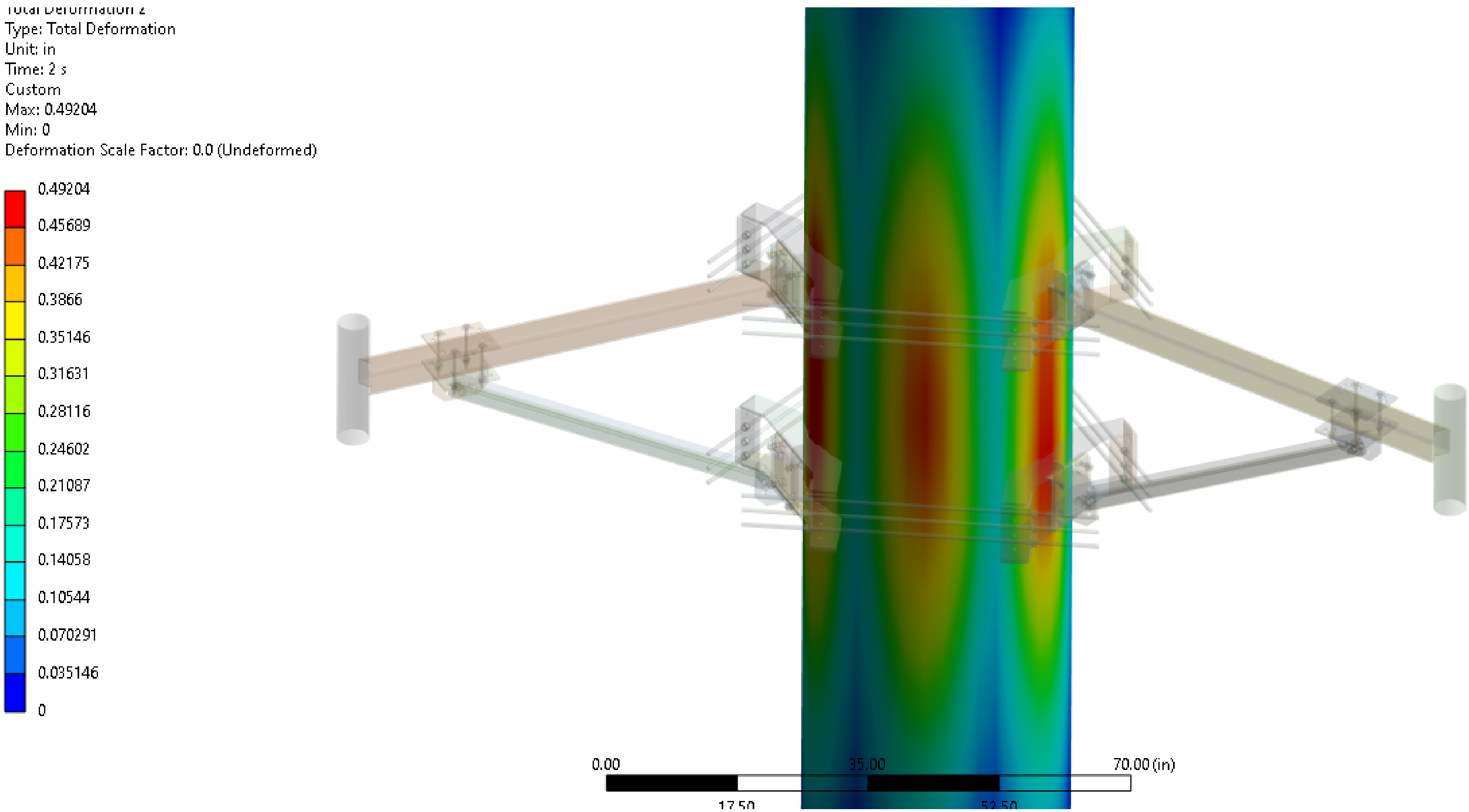
4800 pretension. 2200 lbs vertical. Dual Collar


D: 2k Pretension 2200 lbs Vertical
Fixed Support
Time: 2. s
Fixed Support
0.00
25.00
50.00 (in)
12.50
37.50
Z
Y
X

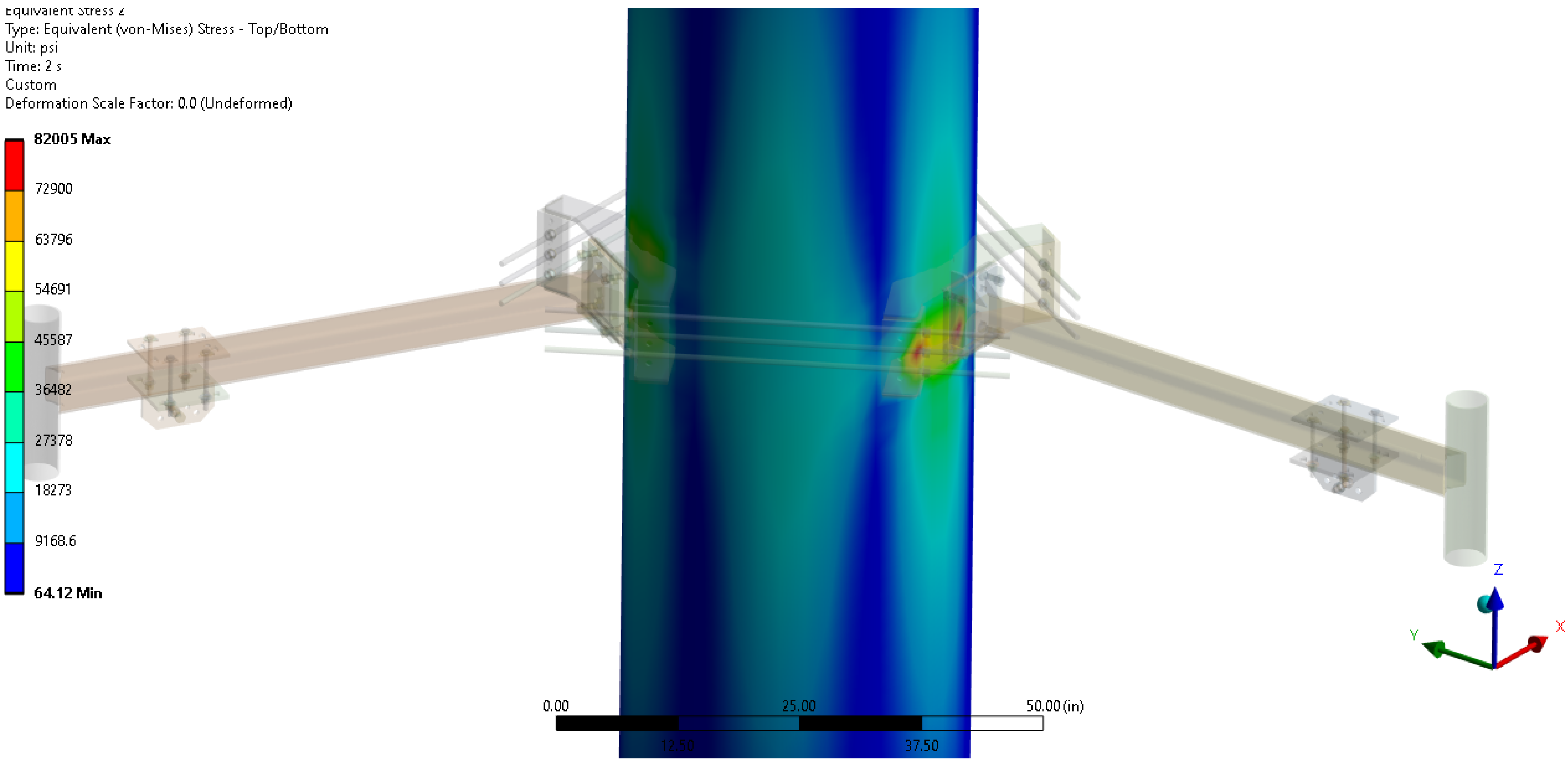
5.Ft standoff arm 2200 lb vertical

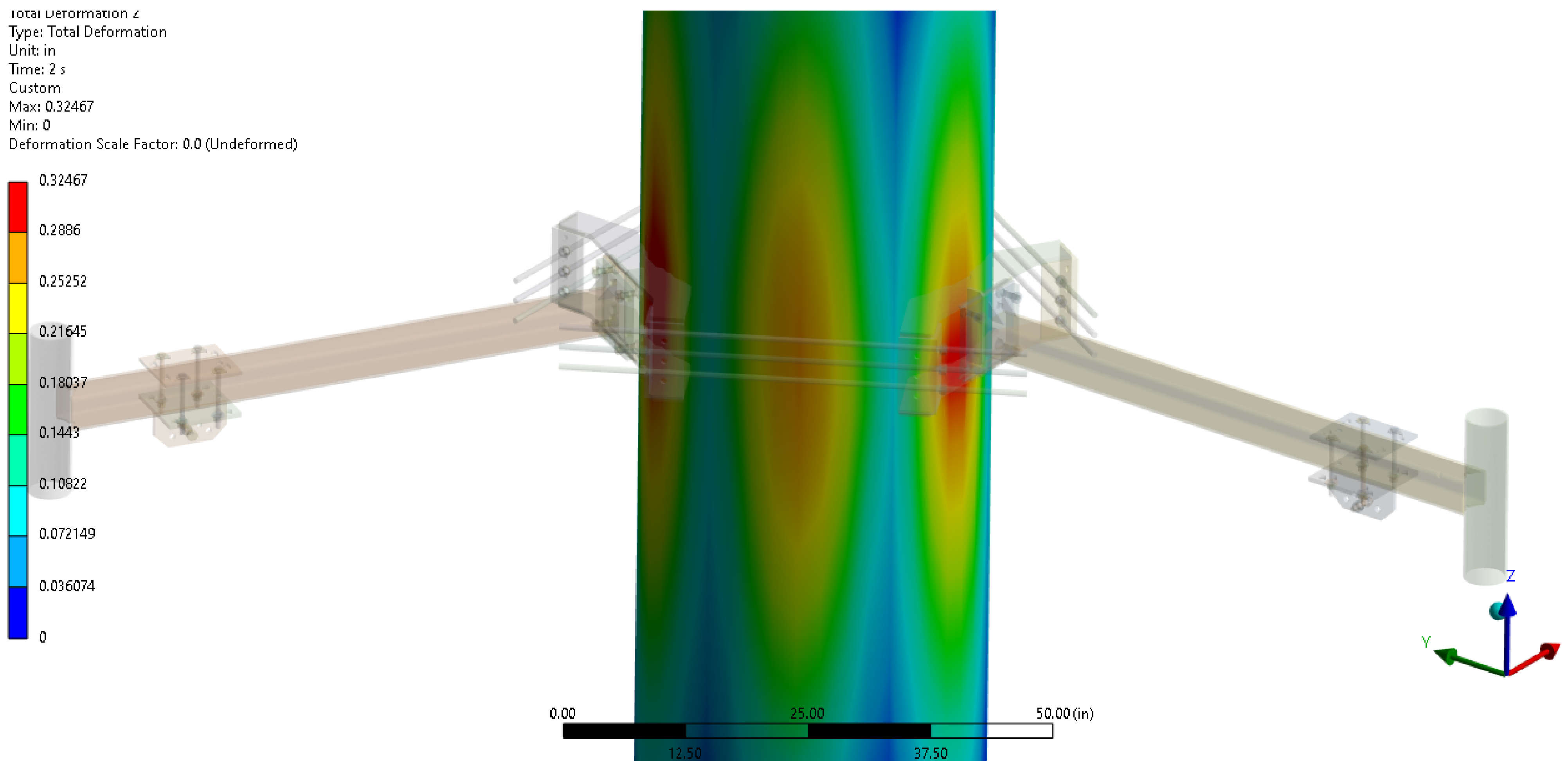



Equivalent Stress 2
Type: Equivalent (von-Mises) Stress - Top/Bottom
Unit: psi
Time: 2 s
Max: 76693
Min: 148.81
Deformation Scale Factor: 0.0 (Undeformed)
76693
68188
59683
51178
42673
34168
25663
17159
8653.7
148.81
0.00
15.00
30.00
45.00
60.00 (in)


Type: Total Deformation
Unit: in
Time: 2 s
Custom
Max: 0.49204
Min: 0
Deformation Scale Factor: 0.0 (Undeformed)
0.49204
0.45689
0.42175
0.3866
0.35146
0.31631
0.28116
0.24602
0.21087
0.17573
0.14058
0.10544
0.070291
0.035146
0
0.00
35.00
70.00 (in)
17.50
52.50

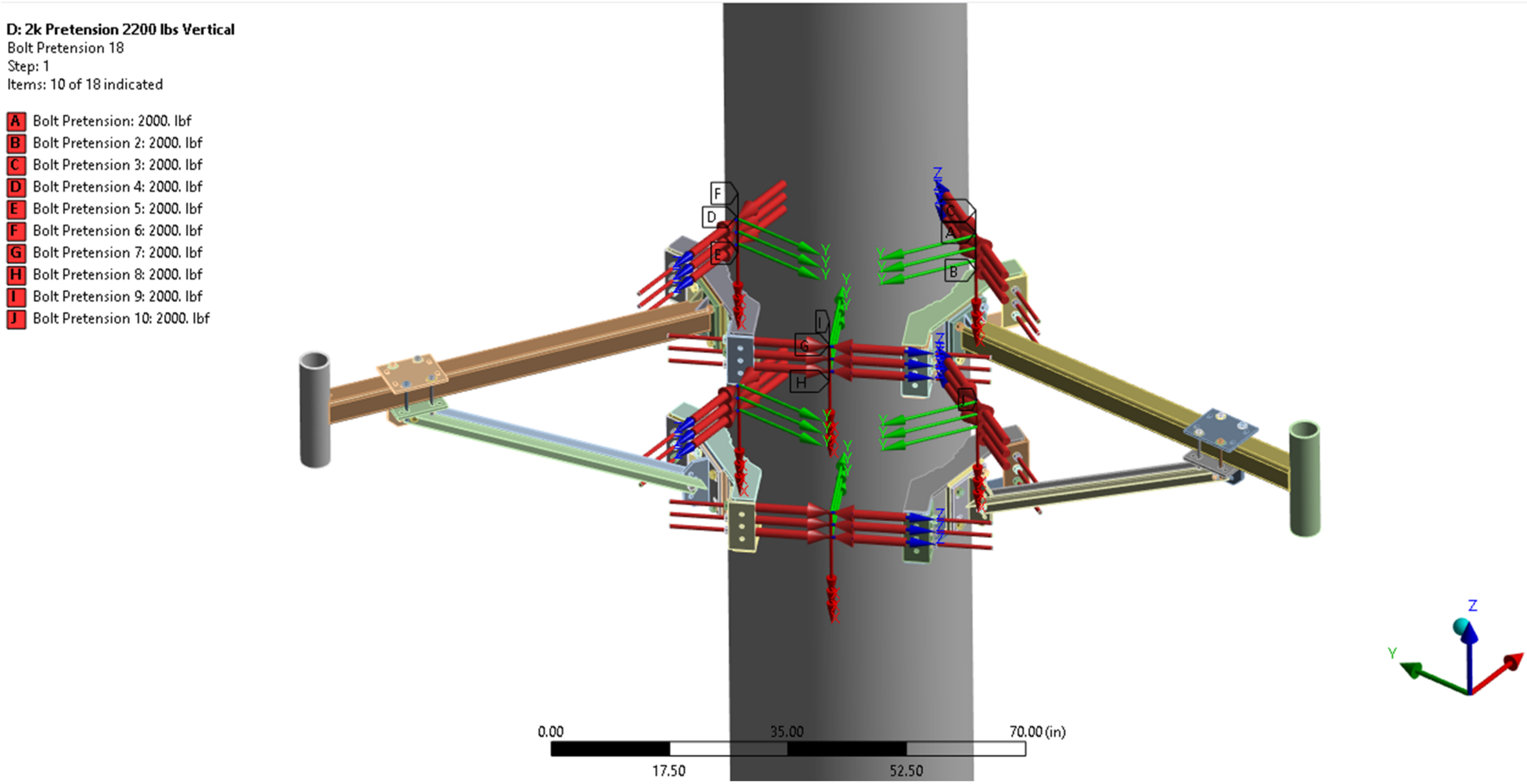
4800 pretension. 2200 lbs vertical. Single collar

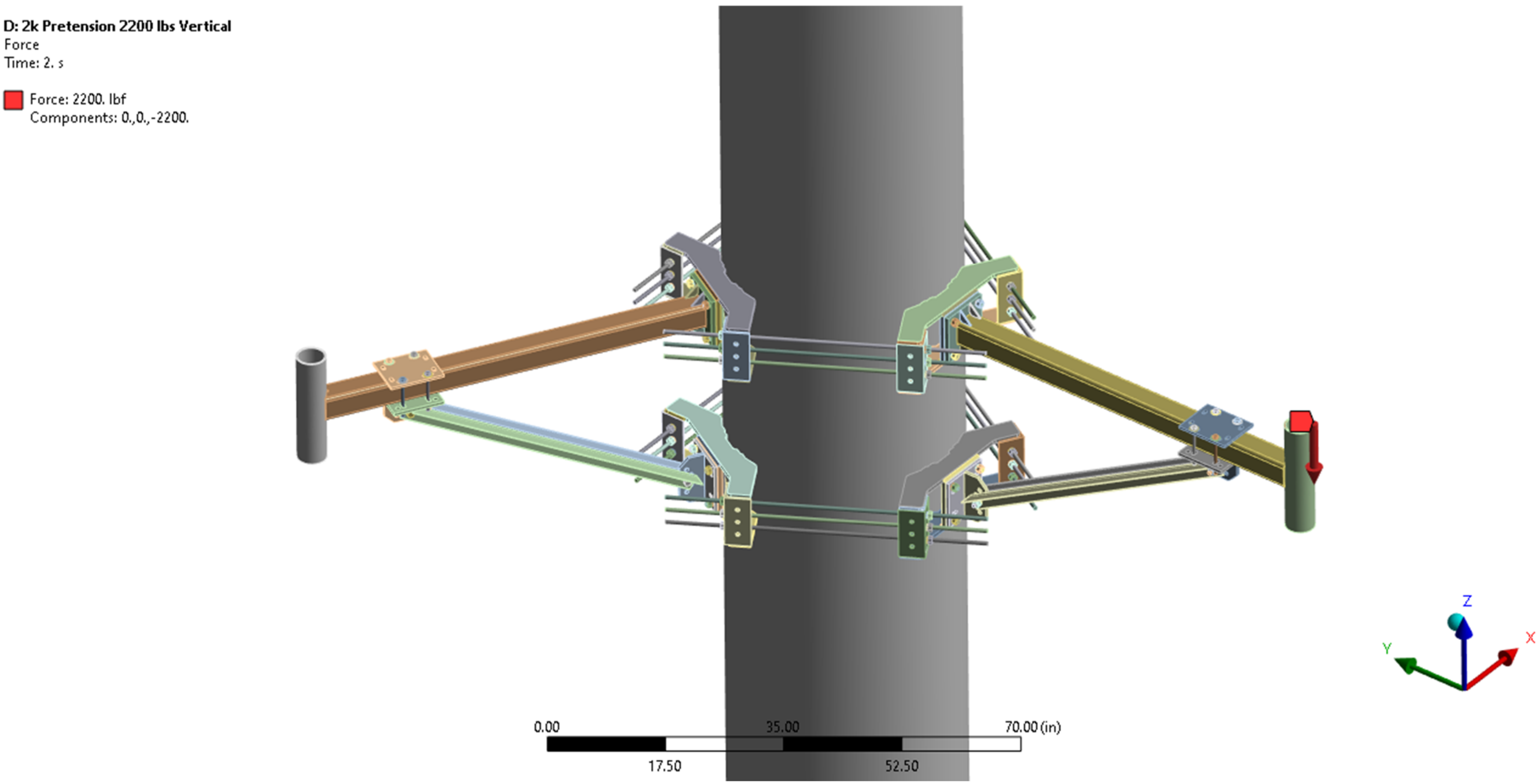

Equivalent Stress 2
Type: Equivalent (von-Mises) Stress - Top/Bottom
Unit: psi
Time: 2 s
Custom
Deformation Scale Factor: 0.0 (Undeformed)
82005 Max
72900
63796
54691
45587
36482
27378
18273
9168.6
64.12 Min
0.00
25.00
50.00 (in)
12.50
37.50
Z
Y
X

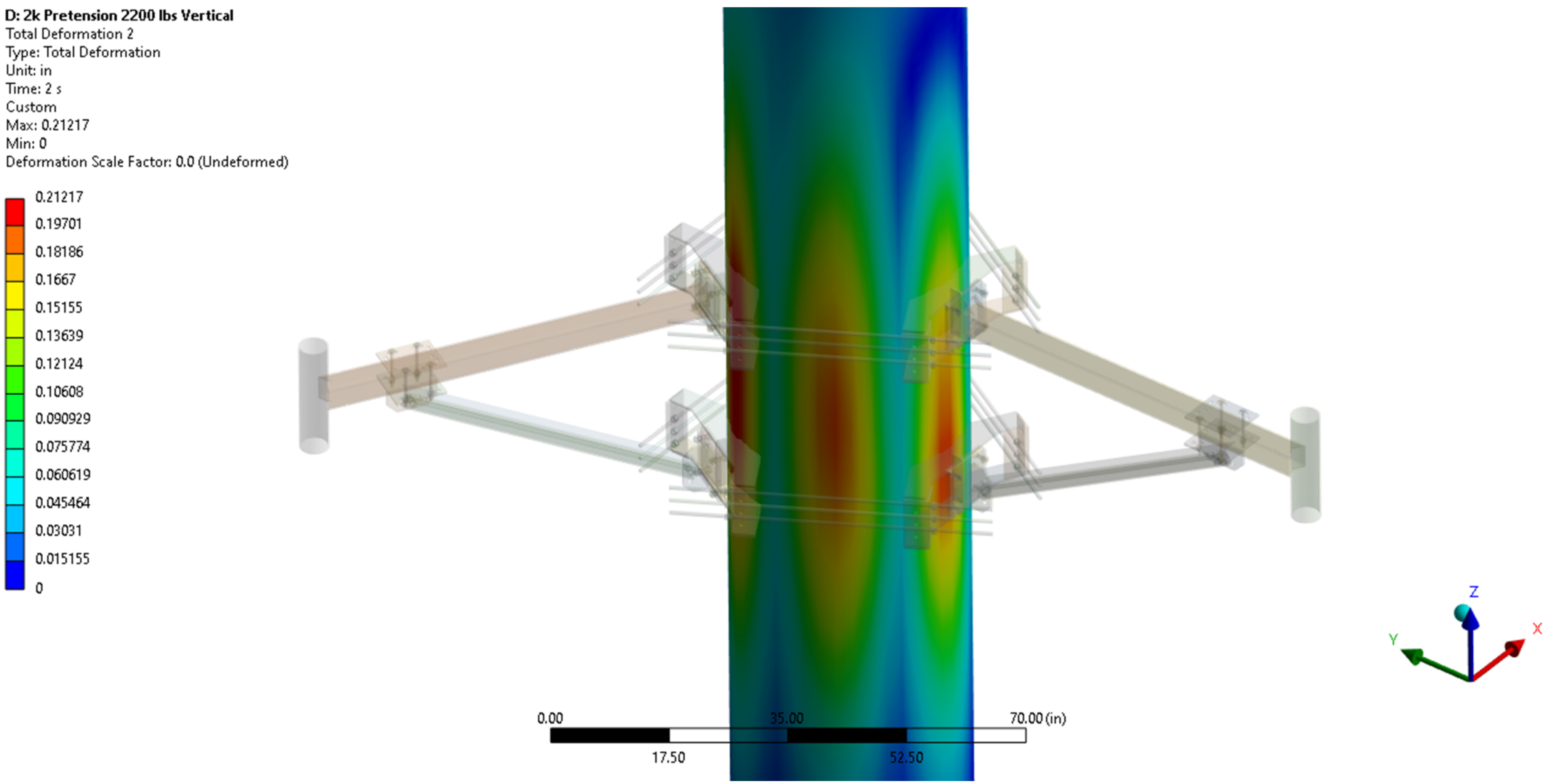


Total Deformation 2
Type: Total Deformation
Unit: in
Time: 2 s
Custom
Max: 0.32467
Min: 0
Deformation Scale Factor: 0.0 (Undeformed)
0.32467
0.2886
0.25252
0.21645
0.18037
0.1443
0.10822
0.072149
0.036074
0
0.00
25.00
50.00 (in)
12.50
37.50
Z
Y
X

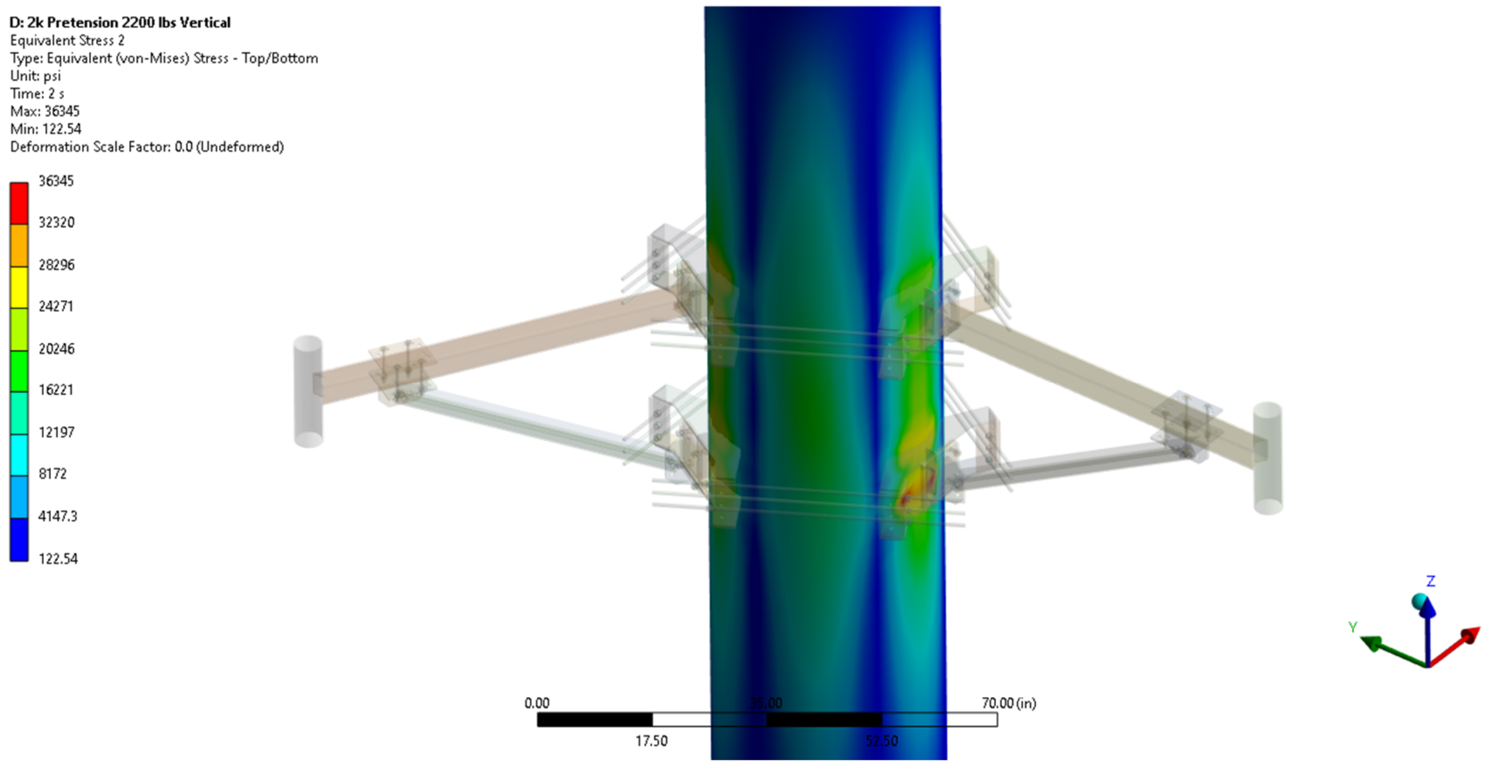
2000 pretension. 2200 lbs vertical. Dual collar


D: 2k Pretension 2200 lbs Vertical
Bolt Pretension 18
Step: 1
Items: 10 of 18 indicated
A Bolt Pretension: 2000. lbf
B Bolt Pretension 2: 2000. lbf
C Bolt Pretension 3: 2000. lbf
D Bolt Pretension 4: 2000. lbf
E Bolt Pretension 5: 2000. lbf
F Bolt Pretension 6: 2000. lbf
G Bolt Pretension 7: 2000. lbf
H Bolt Pretension 8: 2000. lbf
I Bolt Pretension 9: 2000. lbf
J Bolt Pretension 10: 2000. lbf
0.00
35.00
70.00 (in)
17.50
52.50

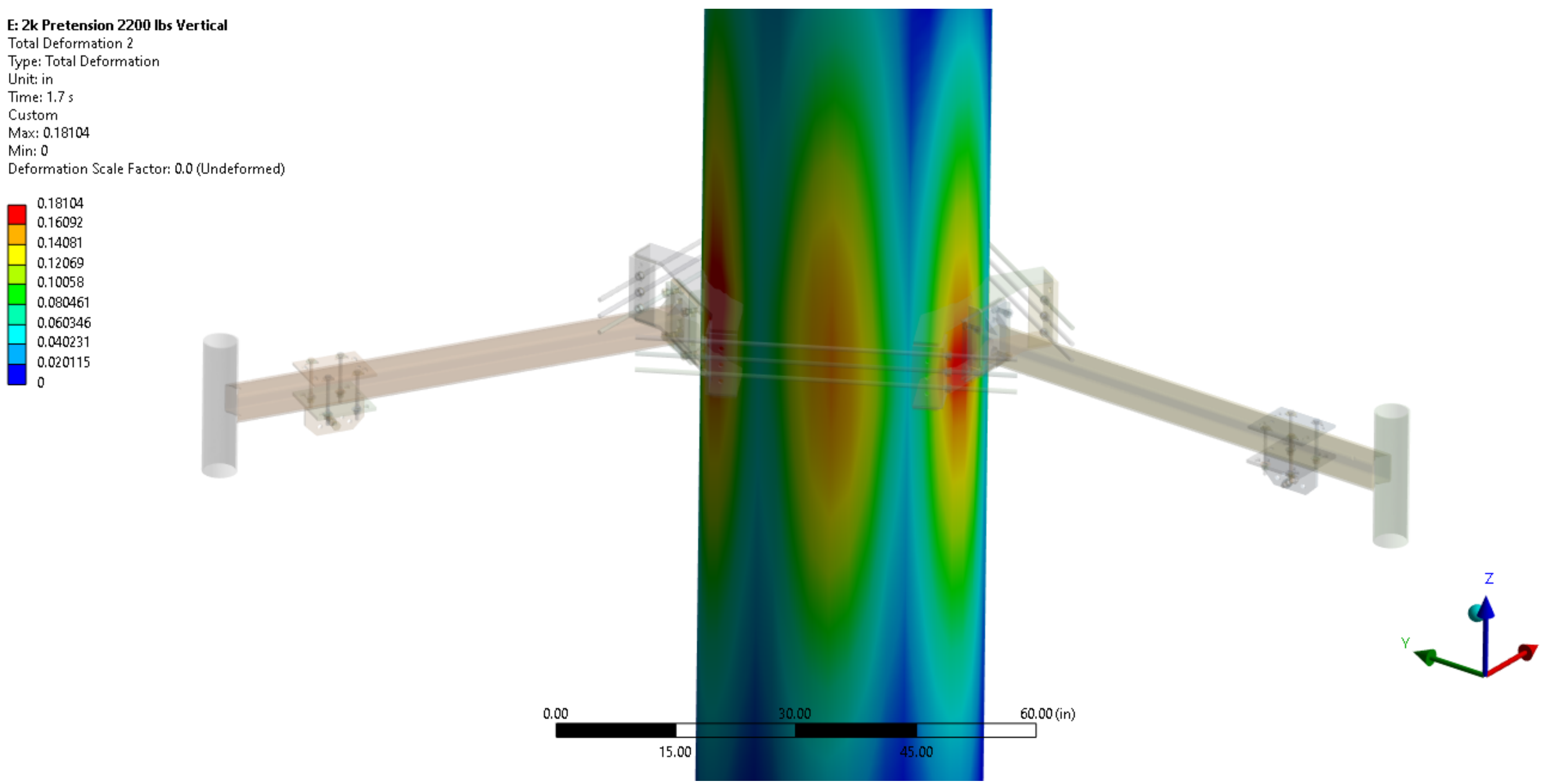

D: 2k Pretension 2200 lbs Vertical
Force
Time: 2. s
Force: 2200. lbf
Components: 0.,0.,-2200.
0.00
35.00
70.00 (in)
17.50
52.50
Z
Y
X

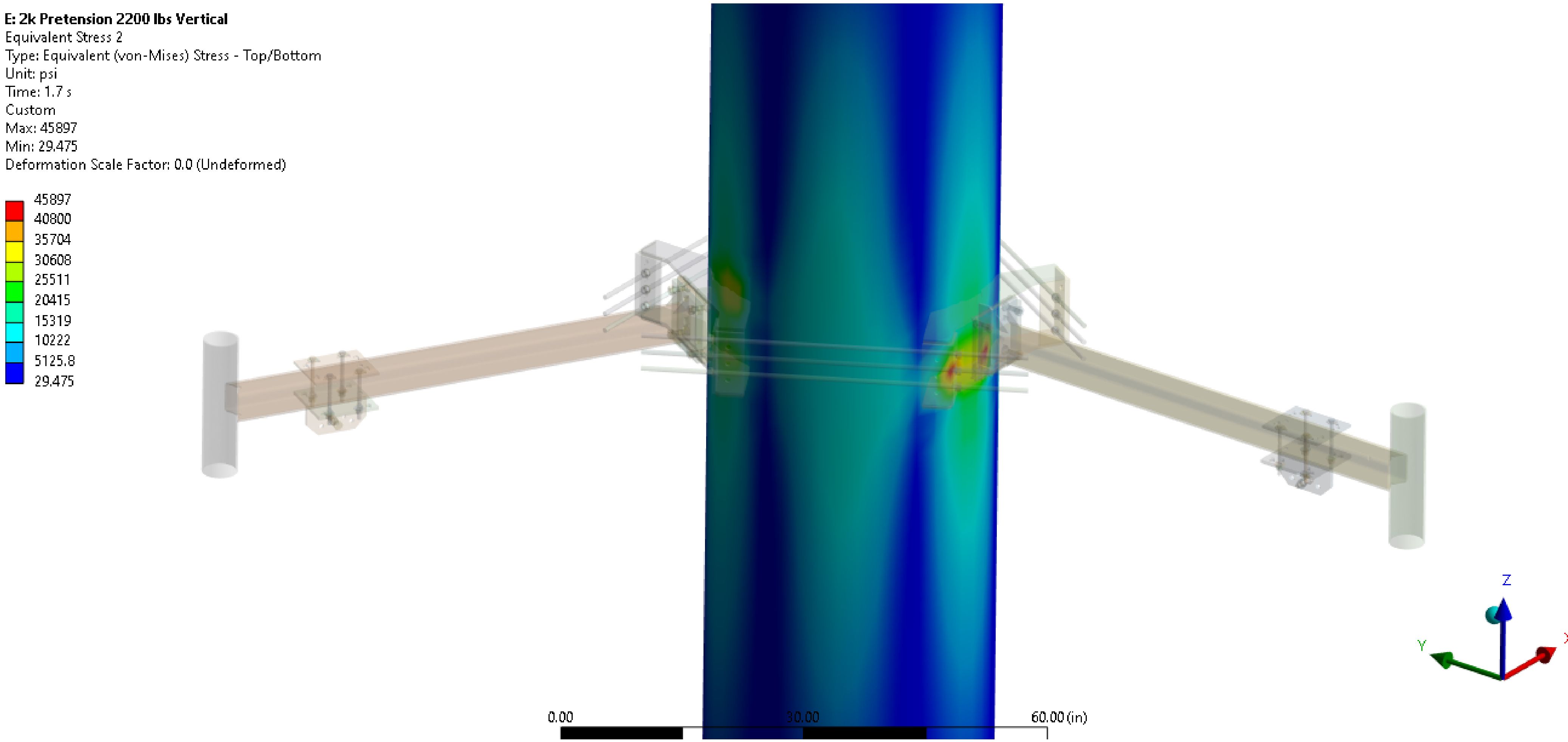


D: 2k Pretension 2200 lbs Vertical
Total Deformation 2
Type: Total Deformation
Unit: in
Time: 2 s
Custom
Max: 0.21217
Min: 0
Deformation Scale Factor: 0.0 (Undeformed)
0.21217
0.19701
0.18186
0.1667
0.15155
0.13639
0.12124
0.10608
0.090929
0.075774
0.060619
0.045464
0.03031
0.015155
0
0.00
35.00
70.00 (in)
17.50
52.50
Z
Y
X


D: 2k Pretension 2200 lbs Vertical
Equivalent Stress 2
Type: Equivalent (von-Mises) Stress - Top/Bottom
Unit: psi
Time: 2 s
Max: 36345
Min: 122.54
Deformation Scale Factor: 0.0 (Undeformed)
36345
32320
28296
24271
20246
16221
12197
8172
4147.3
122.54
0.00
35.00
70.00 (in)
17.50
52.50
Z
Y
X

2000 pretension. 2200 lbs vertical. Single Collar




E: 2k Pretension 2200 lbs Vertical
Equivalent Stress 2
Type: Equivalent (von-Mises) Stress - Top/Bottom
Unit: psi
Time: 1.7 s
Custom
Max: 45897
Min: 29.475
Deformation Scale Factor: 0.0 (Undeformed)
45897
40800
35704
30608
25511
20415
15319
10222
5125.8
29.475
0.00
30.00
60.00 (in)
Z
Y
X