Improved Torque Wrench FEM

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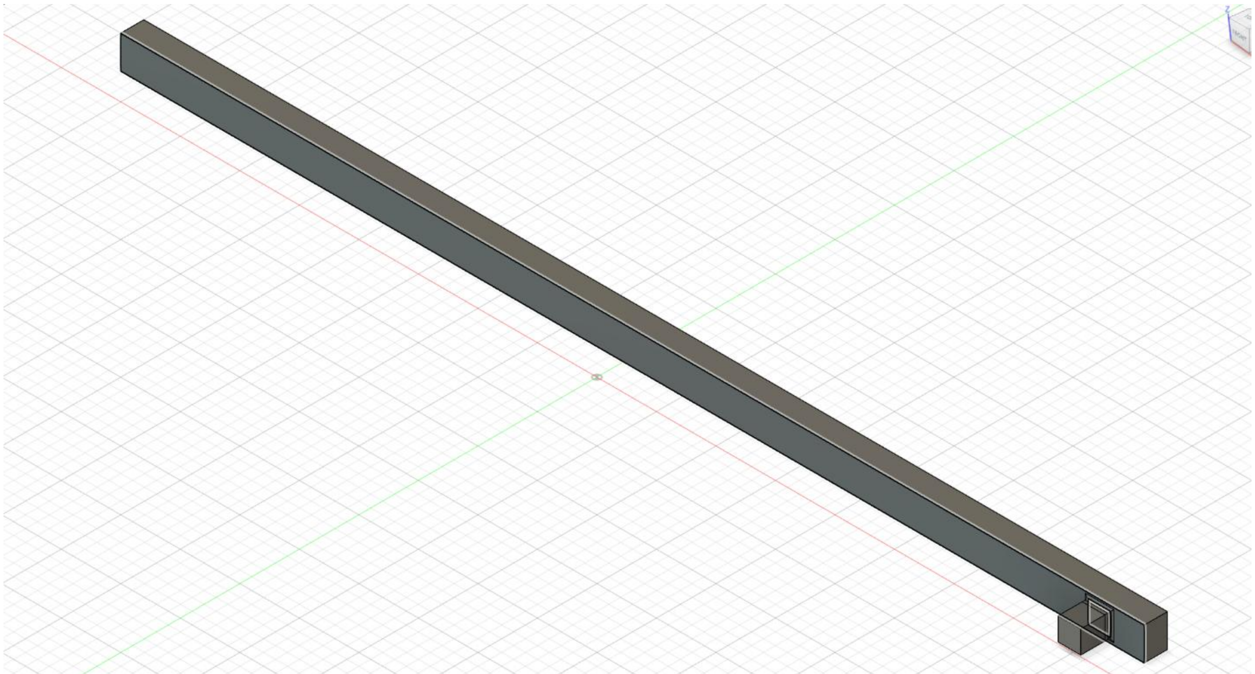
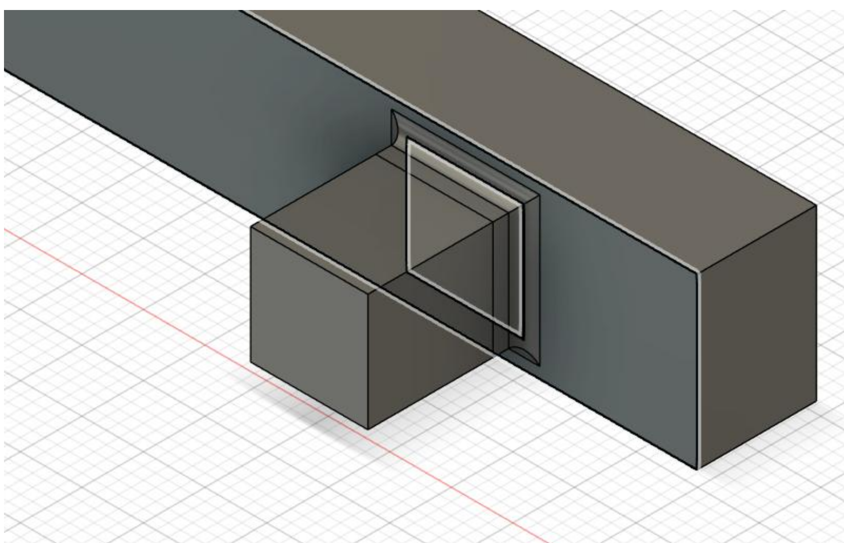
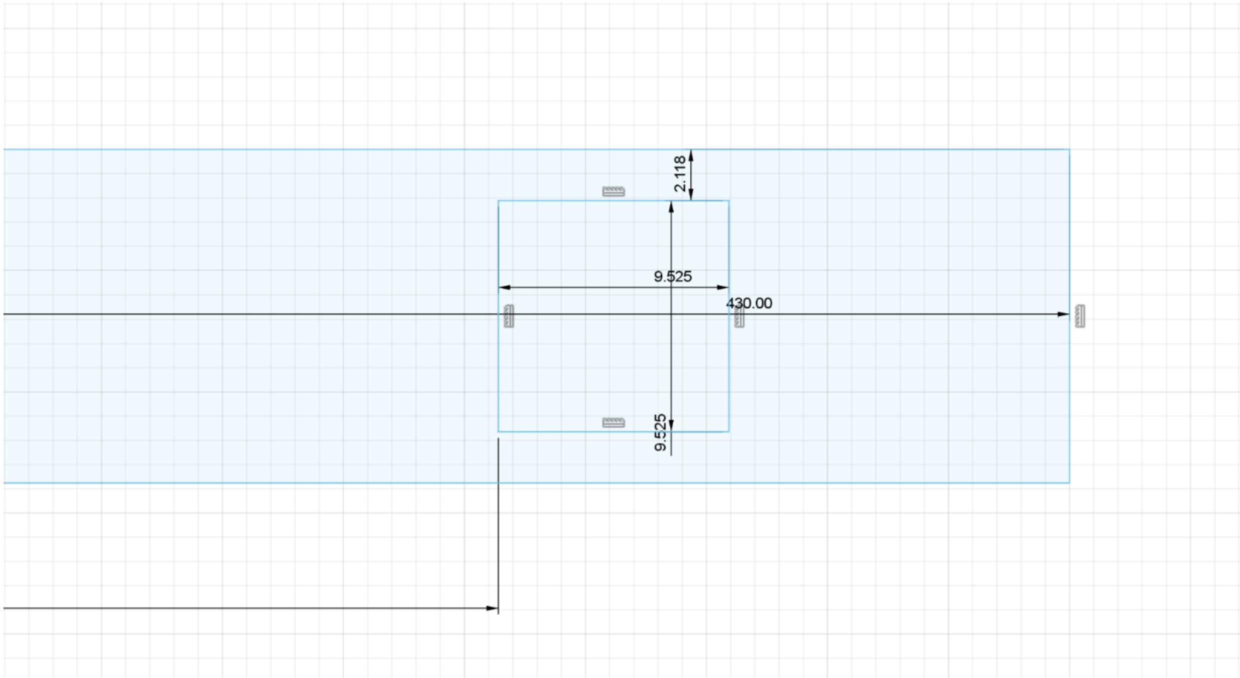
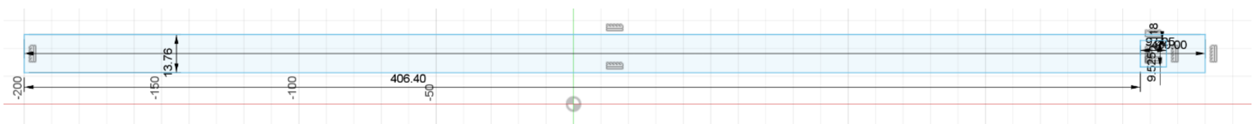
CAD Model









Please note that CAD measurements are in mm.

Material

The material of choice was Ti-6Al-4V, a titanium alloy. This alloy was chosen due to its balance of high strength, good fatigue resistance and high fracture roughness, while having a lower Young's modulus compared to steel. This helps increase strain output for a given geometry.

Young's Modulus	1.1376×10^{11}Pa
Poisson's Ratio	0.34
Ultimate Tensile Strength	8.9632×10^{8} Pa
Fatigue Strength at 10^{8}	4.1369×10^{8}Pa
Fracture Toughness	$6.0436 \times 10^{7}\text{Pa}\sqrt{m}$

Properties above were used directly in hand calculations and FEM-based safety factor checks. E was used in converting stress to strain and determining the strain-gauge sensitivity.

Hand calculation for reference.

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BEST (by output): Ti-6Al-4V | b=0.380 h=0.540 c=0.500 | out=1.91 mV/V | X0=4.00 XK=4.26 XS=1.85
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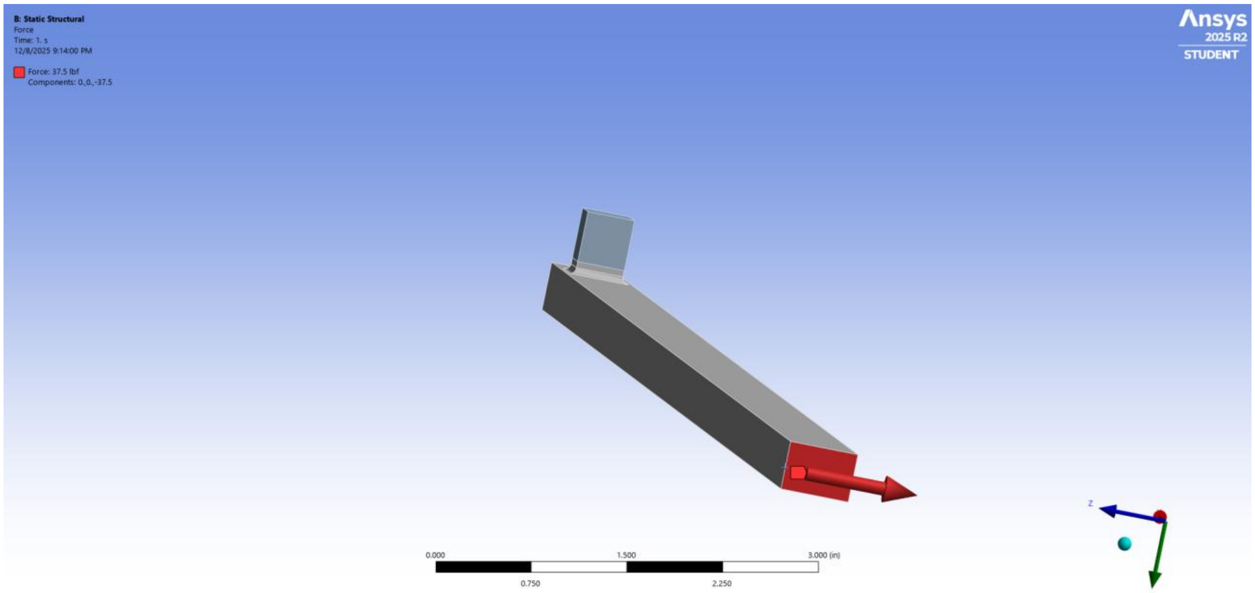
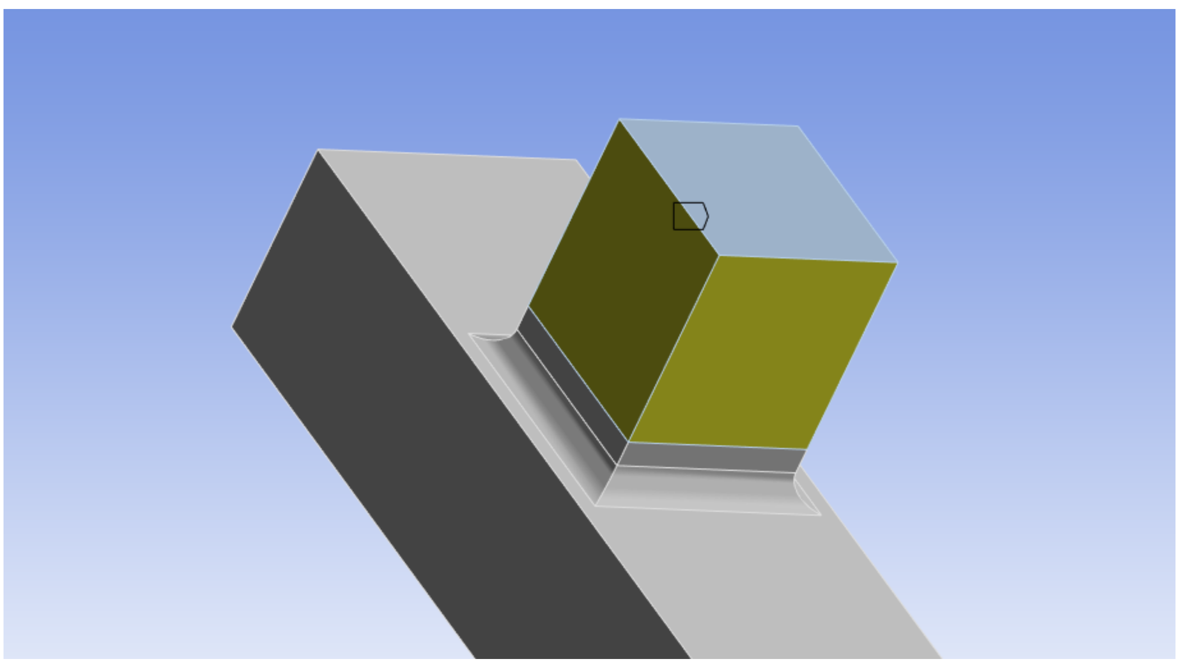
Loads and Boundary Conditions



The load can be seen applied on the bottom surface of the torque wrench. As Torque is 600 in-lbf, the force can be found as $F = \frac{T}{L} = \frac{600}{16} = 37.5$. A force with magnitude of 37.5lb in the -z direction, as my torque wrench was orientated differently.

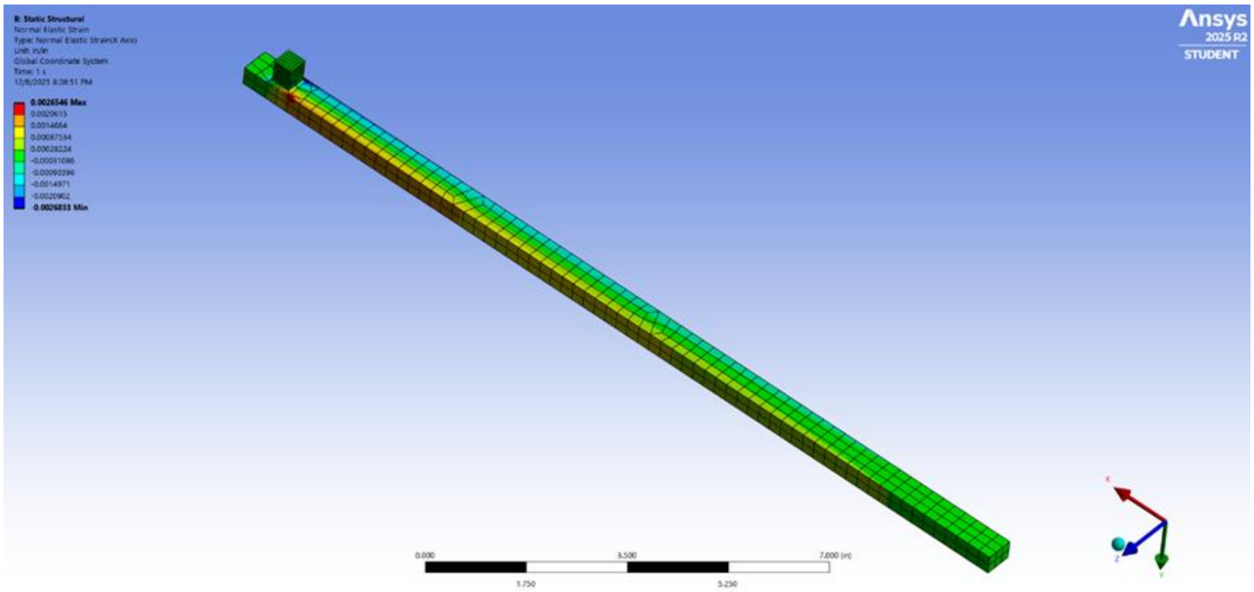


The highlighted surfaces, all four sides of the drive bit were constrained with zero displacement in all three directions $u = (u_x, u_y, u_z) = (0,0,0)$. All other faces were traction free, reproducing a cantilever condition for static bending. The model restricts local rotation at the support, which is consistent with the Euler-Bernoulli cantilever assumptions.

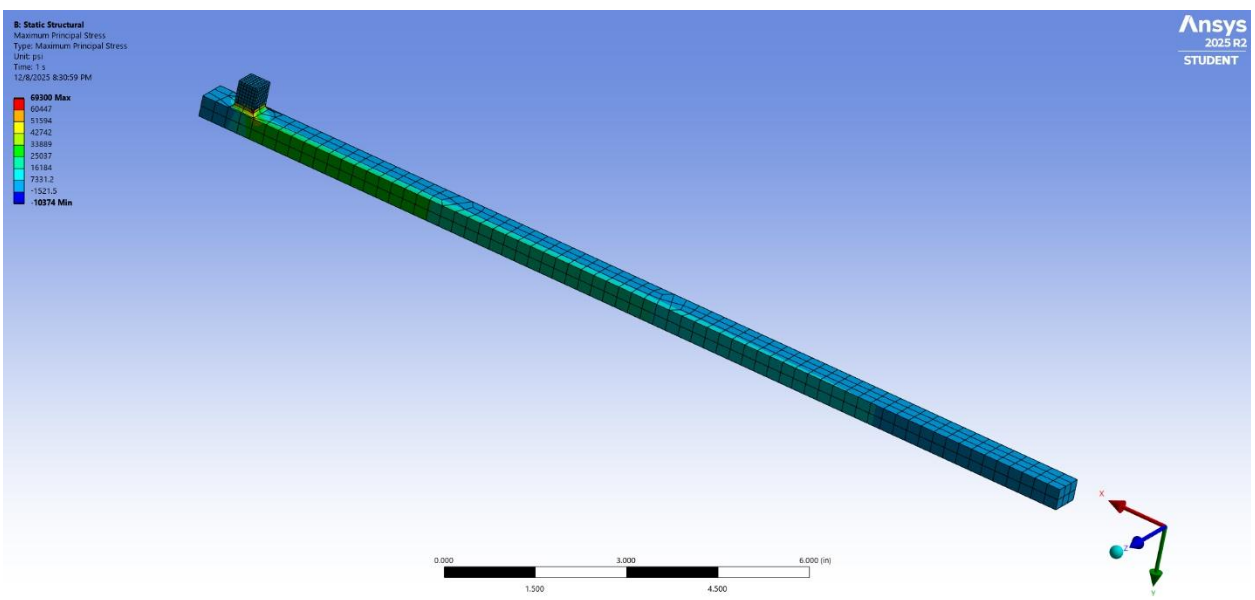
Before Mesh Refinement

With element sizing on the bar at 0.25 in and 0.06 on the drive bit, there were 4865 total nodes.

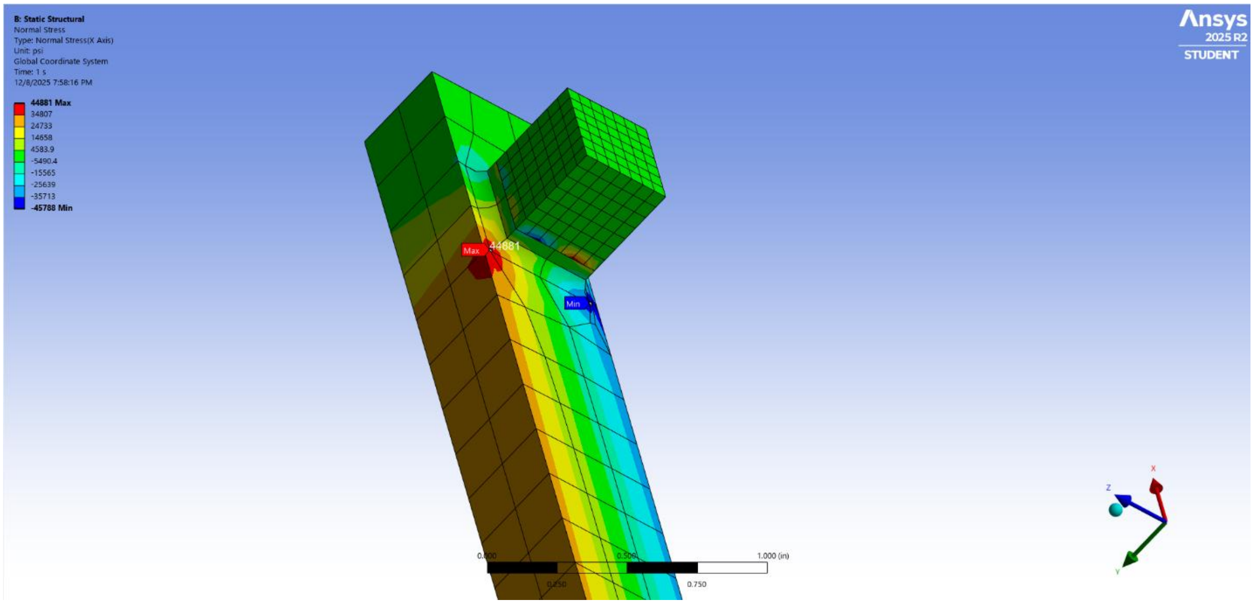
Normal Elastic Strain Contours



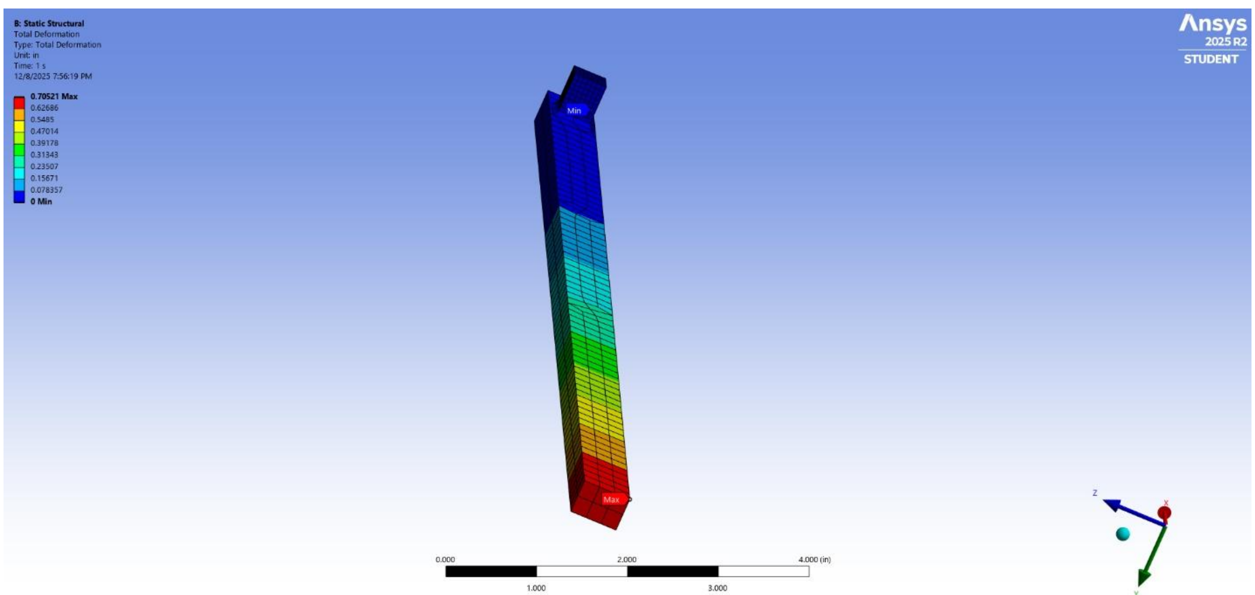
Maximum Principal Stress contours



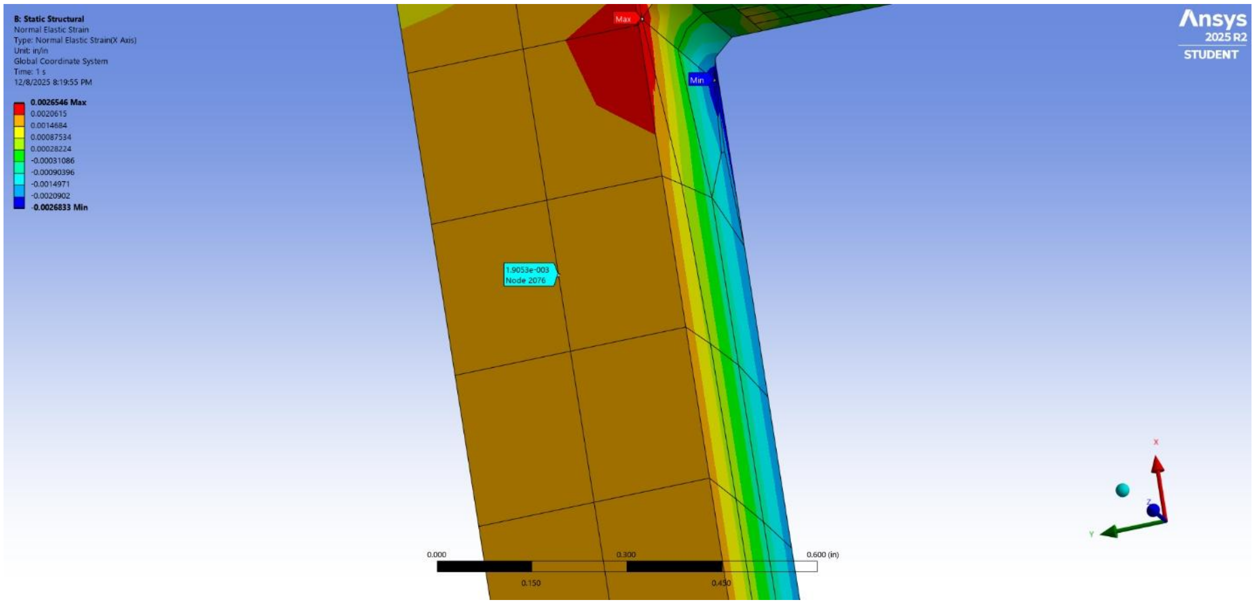
Maximum Normal Stress



Total Deformation



Normal Elastic Strain at the gauge



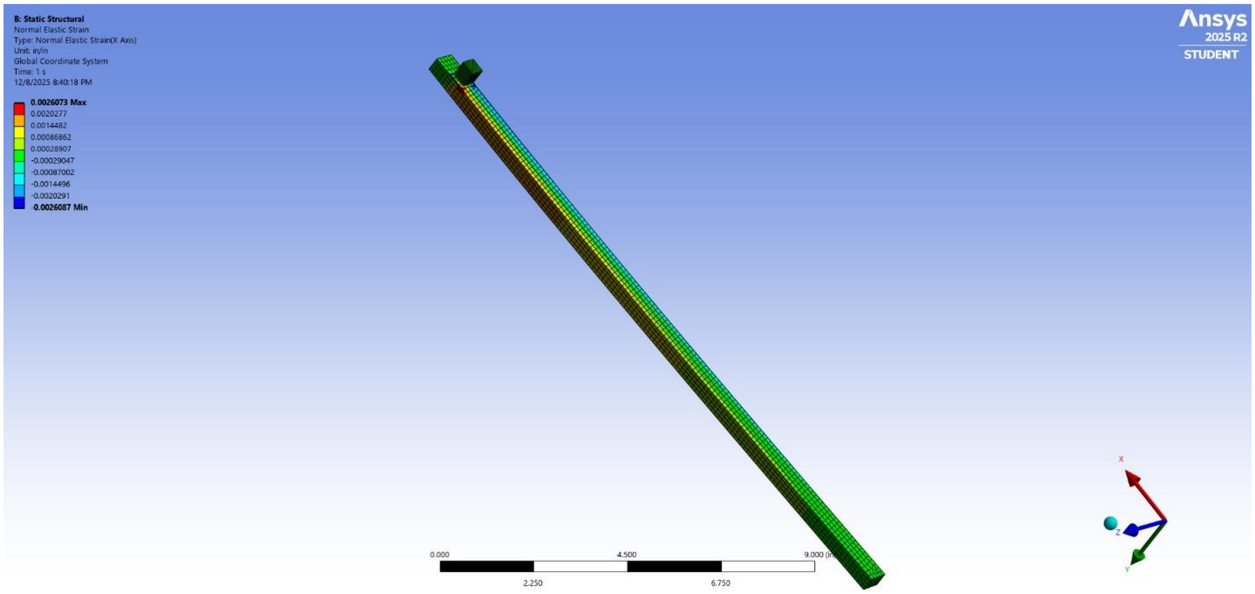
Maximum Normal stress	44841Psi
Maximum Deflection	0.70521
Normal Elastic Strain at strain gauge	1905 με

The strain gauge is placed where c = 0.5in, shown in the picture above. Using a half-bridge assumption, Output = 1.905 mV/V.

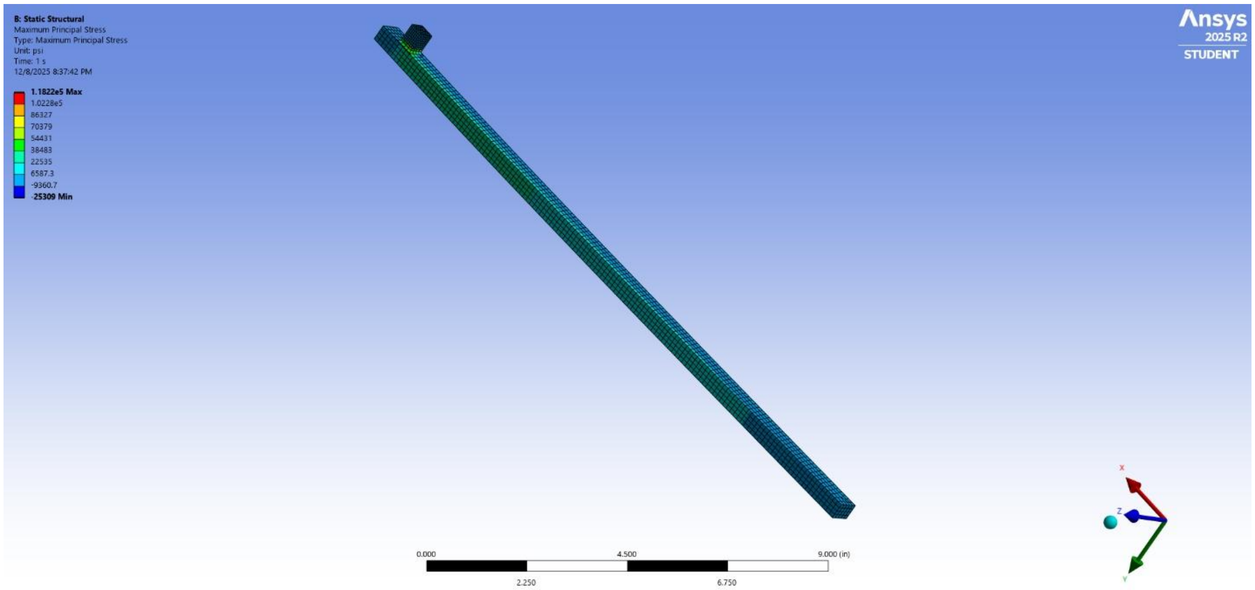
After Mesh Refinement

After the mesh refinement, I halved the element size across the bar to 0.125 in, resulting in an increase to a total of 14773 nodes across the whole structure.

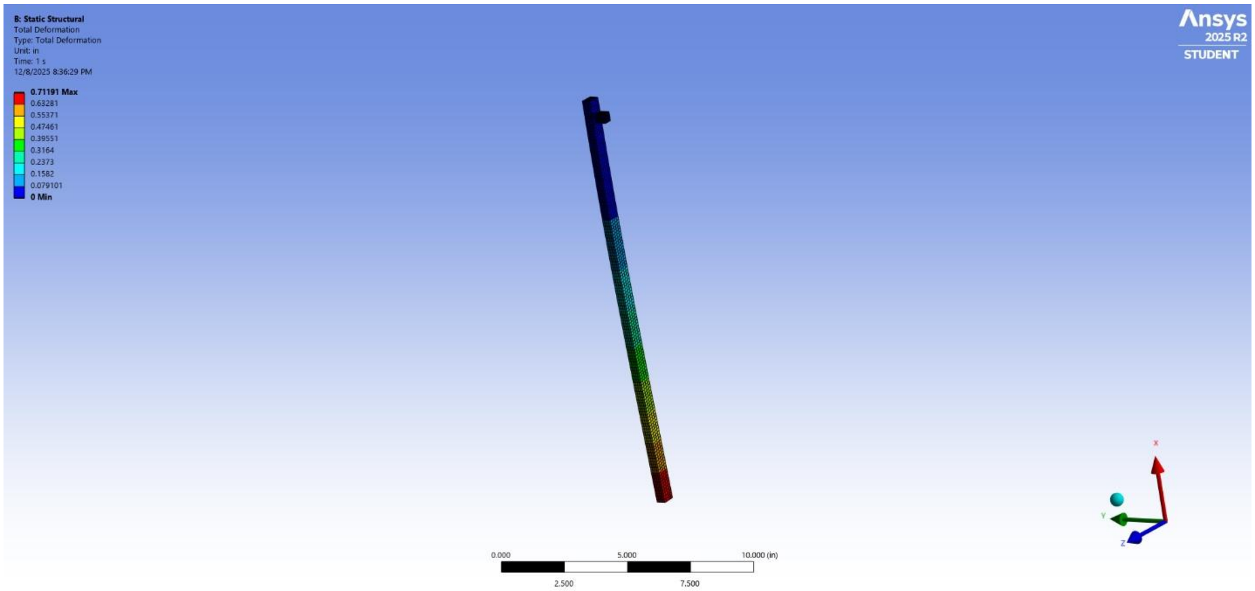
Normal Elastic strain Contour



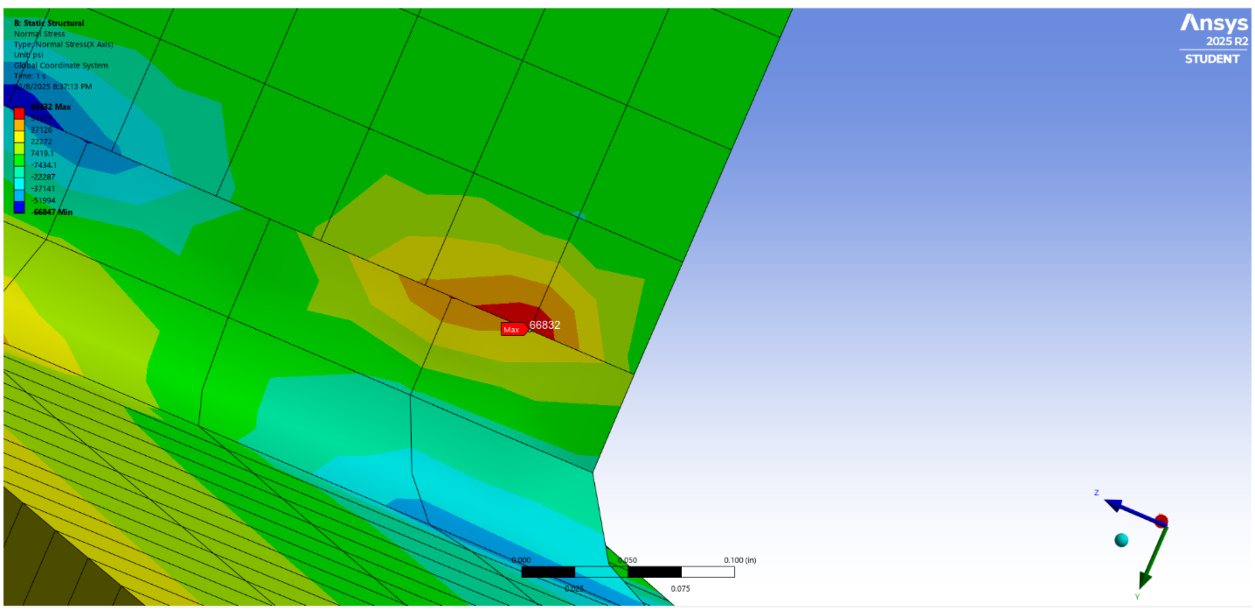
Normal Principal Stress Coujntour



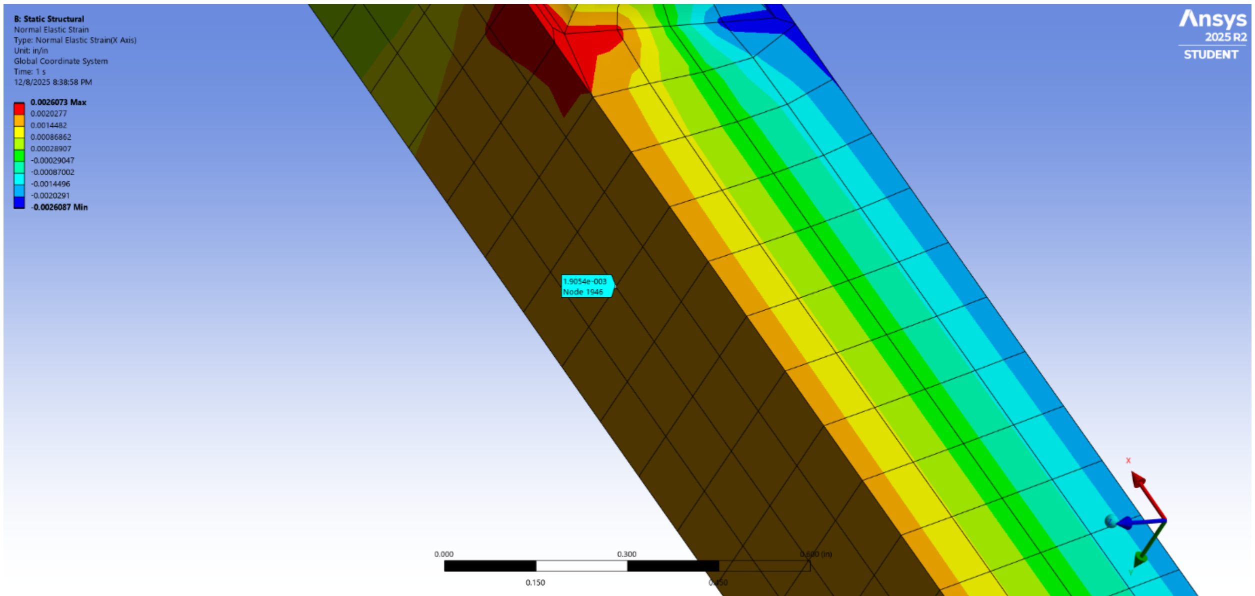
Total deformation



Maximum Normal Stress



Normal Elastic Strain at gauge



Maximum Normal stress	66832psi
Maximum Deflection	0.71191
Normal Elastic Strain at strain gauge	1905 με

A new area of stress concentration has appeared with the new nodes, increasing it from 44841psi to 66832psi. The maximum deflection also increases from 0.70521in to 0.71191in. Using the half bridge assumption, the output stays the same. Output = 1.905 mV/V.

Hand calculation for reference.

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