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MAE 3270 Final Project

## Introduction

For my wrench design, I made two key modifications. First, I reduced the width of the wrench to 0.65 inches from the original 0.75 inches. This served to increase the strain gauge sensitivity, while maintaining a careful balance with the maximum stress in the wrench.

Second, I changed the material to Titanium (Ti-6Al-4V) alloy. The material properties found in Granta are pictured below. This has a much lower modulus of elasticity than the M42 steel. This allows for a higher strain gauge sensitivity, as the wrench will strain roughly twice as much under the same load. This alloy is also much less brittle than the M42 steel which has a fracture toughness over 3 times lower than the titanium. This is important as the higher elasticity will increase stress in the wrench. Finally, it has a fatigue strength, yield strength, and ultimate tensile strength well within the safety margin that we require. Results from the hand calculation script are given here, showing the design meets the requirement based on theory alone.

```
Titanium Ti-6Al-4V (Annealed)
Dims: h=0.65 in, b=0.5 in
Sensitivity:    1.0135 mV/V
Max Stress:     17.0414 ksi
Deflection:     0.27965 in
FOS Strength: 6.6896
FOS Fatigue:  2.7815
FOS Fracture: 11.2918
```

For the strain gauge, I chose to use this strain gauge (CEA-06-125UN-350) manufactured by Micro-Measurements. This will be mounted 1 in from the drive head. It is a universal, linear, general purpose, constantan foil strain gauge. It is 0.275 in x 0.38 in x 0.19 in, meaning it will fit comfortably on the side of the wrench which is 0.5 inches tall.

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CEA-06-125UN-350 strain gauge, which will be mounted 1 in from the drive on the vertical face of the wrench side.

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## Titanium, alpha-beta alloy, Ti-6Al-4V, annealed

Datasheet view: All attributes | Show/Hide | Find Similar

### Price

| | | | | |
|---|---|---|---|---|
| Price | * 10.4 | - | 13.1 | USD/lb |
| Price per unit volume | 2.86e3 | - | 3.65e3 | USD/ft^3 |

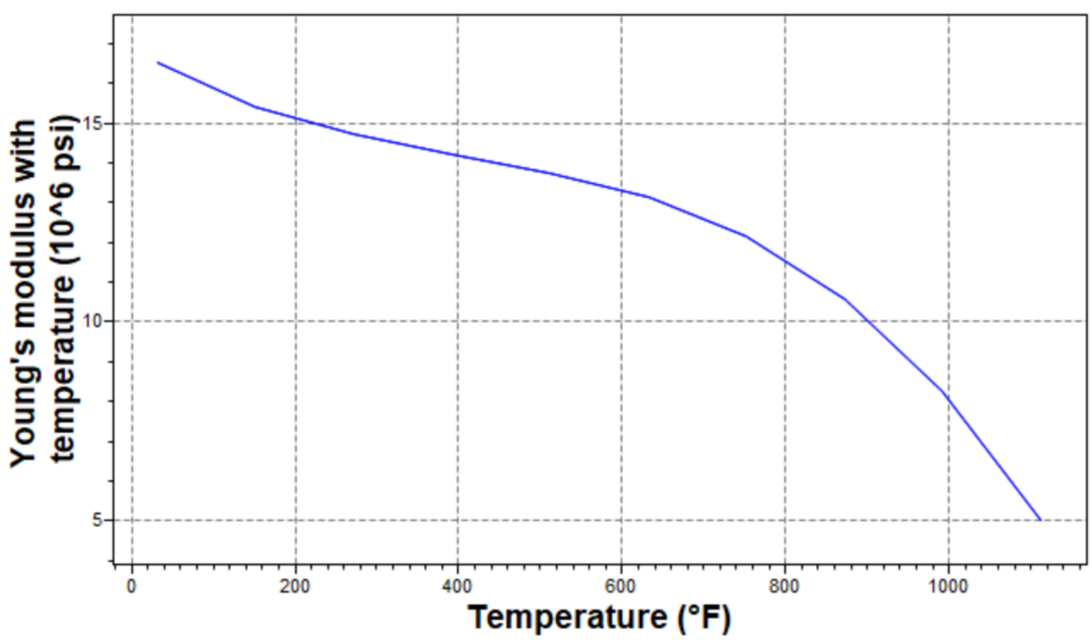
### Physical properties

| | | | | |
|---|---|---|---|---|
| Density | 0.159 | - | 0.161 | lb/in^3 |

### Mechanical properties

| | | | | |
|---|---|---|---|---|
| Young's modulus | 16 | - | 17.3 | 10^6 psi |
| Young's modulus with temperature | 16.1 | - | 16.1 | 10^6 psi |

Parameters: Temperature = 73.4°F




| | | | | |
|---|---|---|---|---|
| Specific stiffness | * 8.3e6 | - | 9e6 | lbf.ft/lb |
| Yield strength (elastic limit) | 114 | - | 132 | ksi |
| Yield strength with temperature | 124 | - | 124 | ksi |

Parameters: Temperature = 73.4°F

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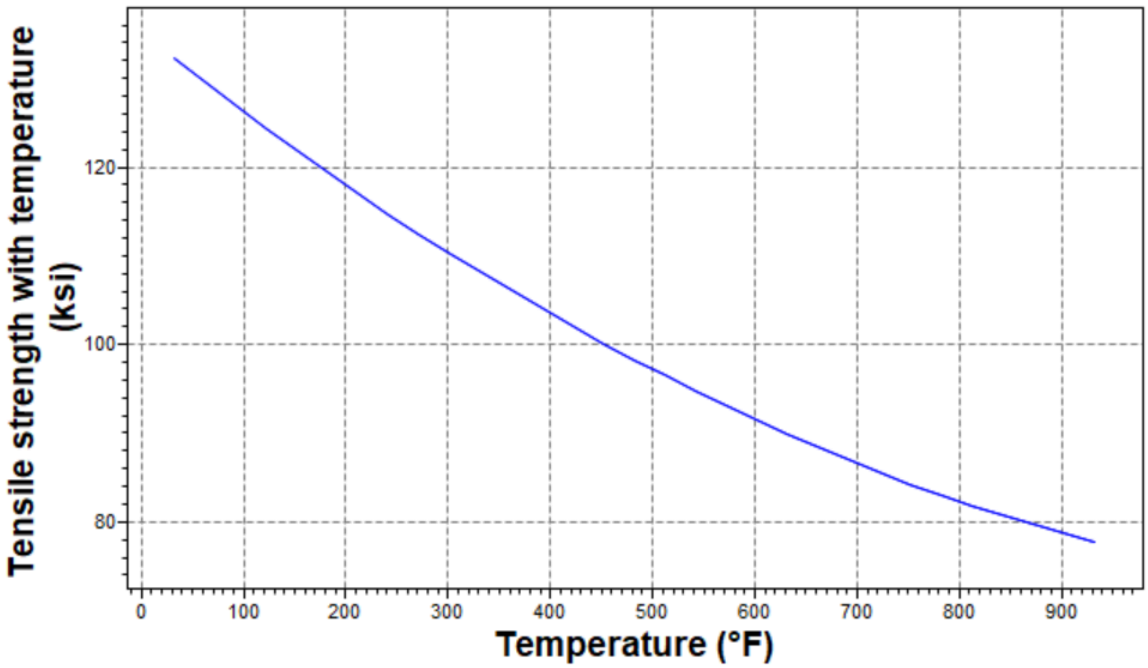
| | | | | | |
|---|---|---|---|---|---|
| Tensile strength | ⓘ | 125 | - | 142 | ksi |
| Tensile strength with temperature | ⓘ | 129 | - | 129 | ksi |

Parameters: Temperature = 73.4°F



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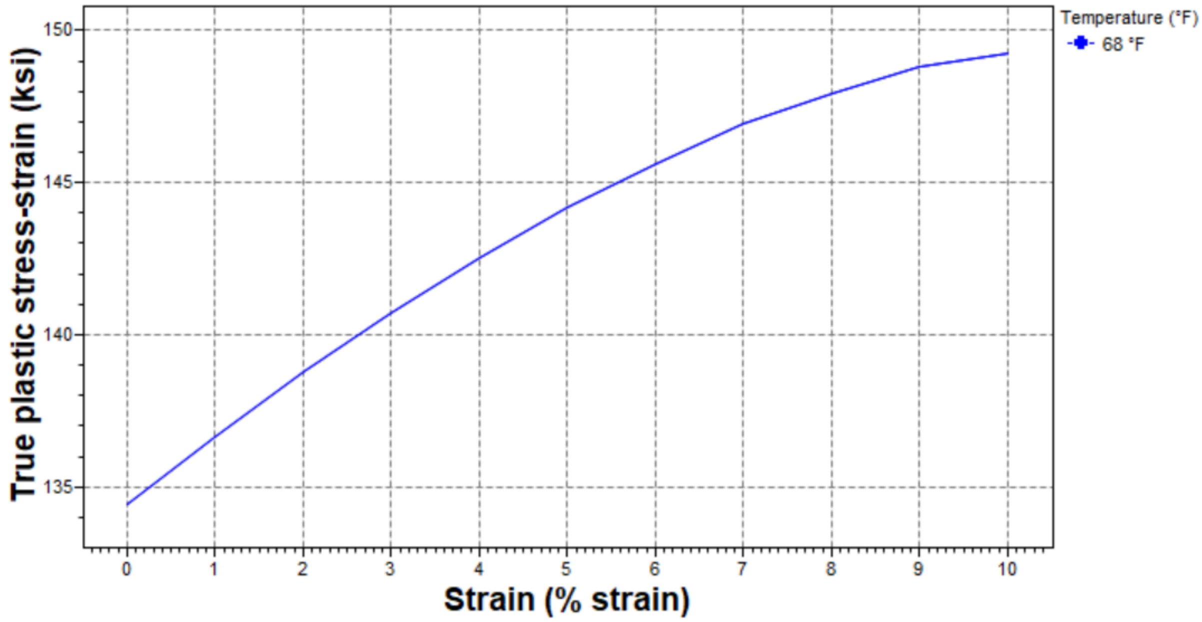


| | | | | | |
|---|---|---|---|---|---|
| Compressive strength | ⓘ | * 123 | - | 157 | ksi |
| Flexural modulus | ⓘ | * 16 | - | 17.3 | 10^6 psi |
| Flexural strength (modulus of rupture) | ⓘ | 114 | - | 157 | ksi |
| Shear modulus | ⓘ | 5.8 | - | 6.53 | 10^6 psi |
| Bulk modulus | ⓘ | 14 | - | 22.2 | 10^6 psi |
| Poisson's ratio | ⓘ | 0.31 | - | 0.37 | |
| Shape factor | ⓘ | 13 | | | |
| Hardness - Vickers | ⓘ | 337 | - | 373 | HV |
| Hardness - Brinell | ⓘ | 323 | - | 357 | HB |
| Elastic stored energy (springs) | ⓘ | * 32.6 | - | 43.8 | ft.lbf/in^3 |
| Fatigue strength at 10^7 cycles | ⓘ | * 47.4 | - | 55.3 | ksi |
| Fatigue strength model (stress amplitude) | ⓘ | * 44.2 | - | 59.3 | ksi |

Parameters: Stress Ratio = -1, Number of Cycles = 1e7cycles

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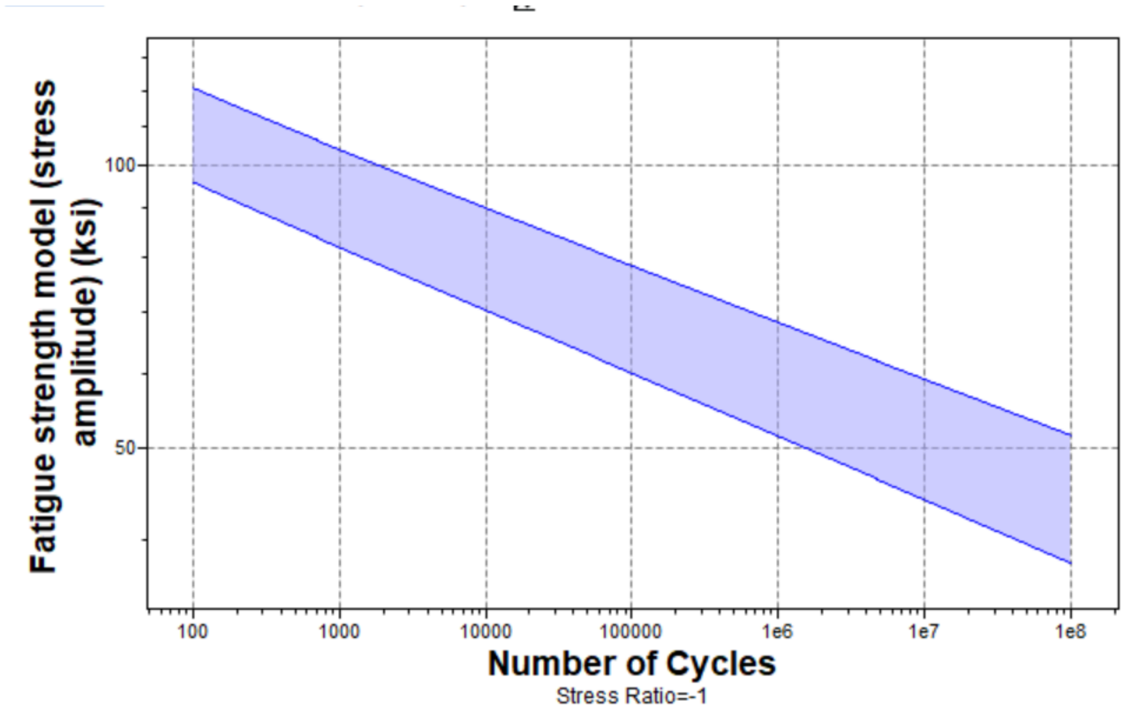


## Impact & fracture properties

| | | | | |
|---|---|---|---|---|
| Fracture toughness | 76.4 | - | 97.4 | ksi.in^0.5 |
| Toughness (G) | * 29.6 | - | 47.1 | ft.lbf/in^2 |

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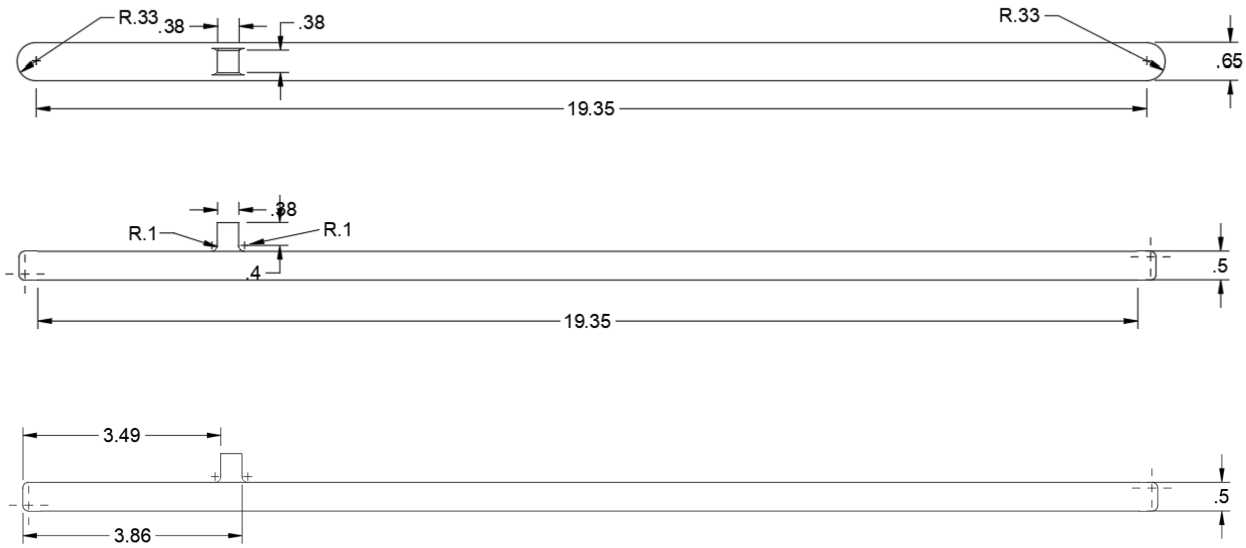
**CAD Model**




CAD drawings of the model I came up with. The edges of the drive and wrench handle are filleted in order to minimize the stress concentrations that were present in the edges of the base design.

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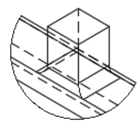
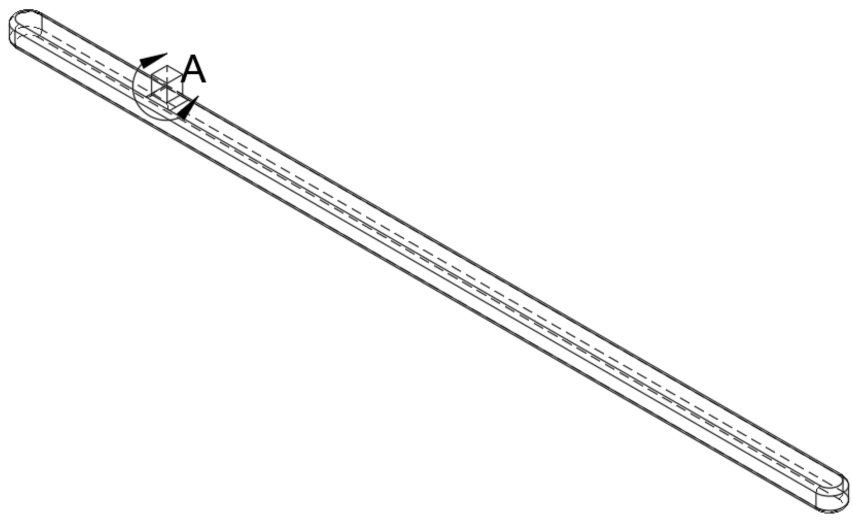
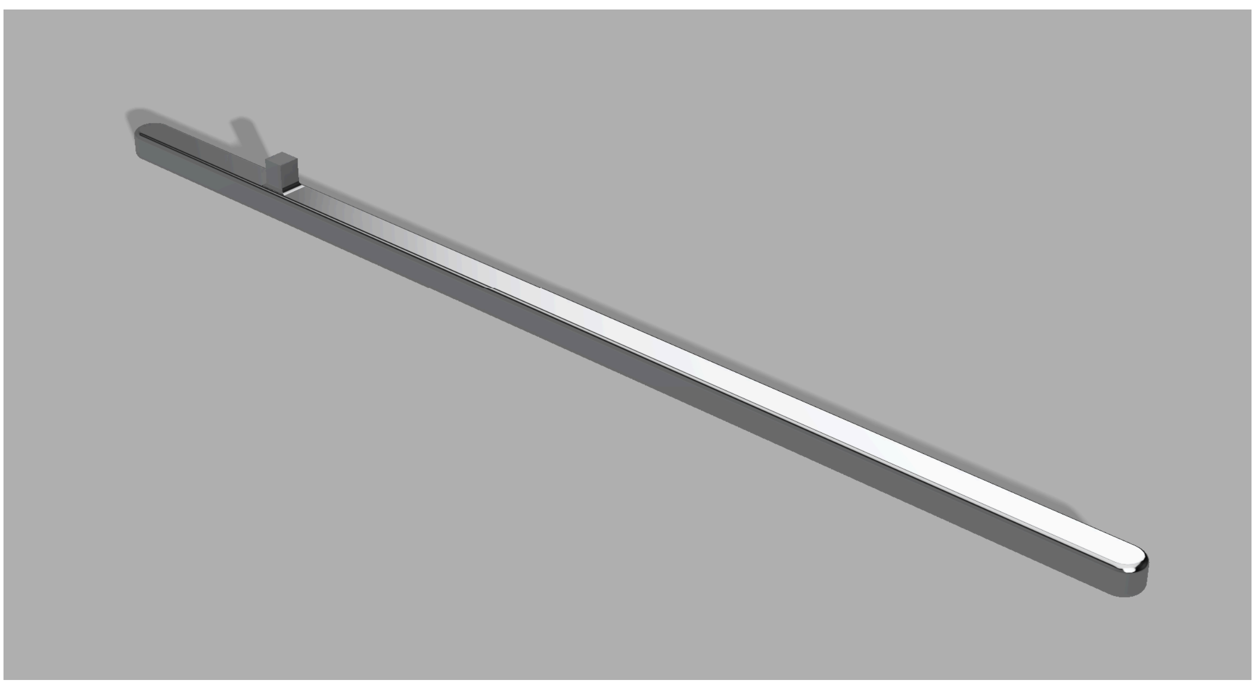


DETAIL A
SCALE 1:1



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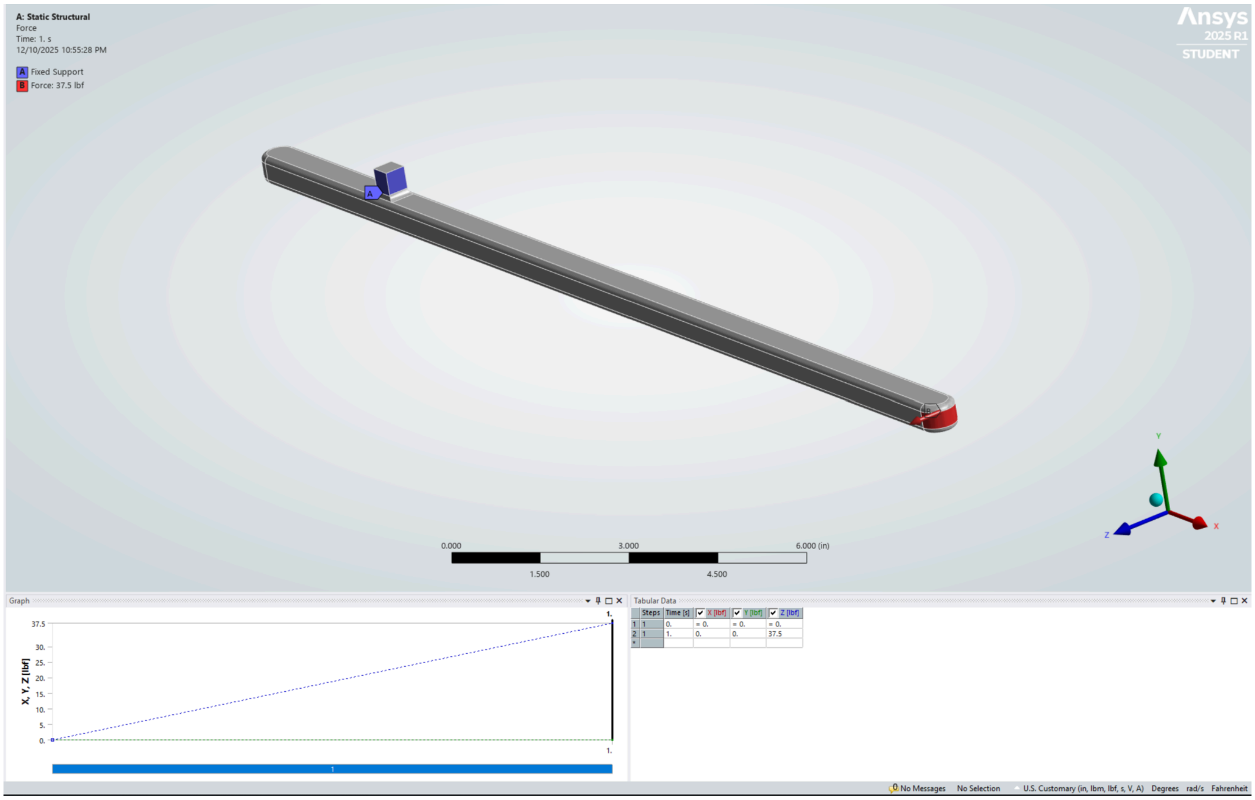
## FEM Analysis and Results




FEM loads and boundary conditions. The drive head is fixed in place, and the load of 37.5 lbf (600 lbf-in / 16 in) is applied to the end of the wrench.

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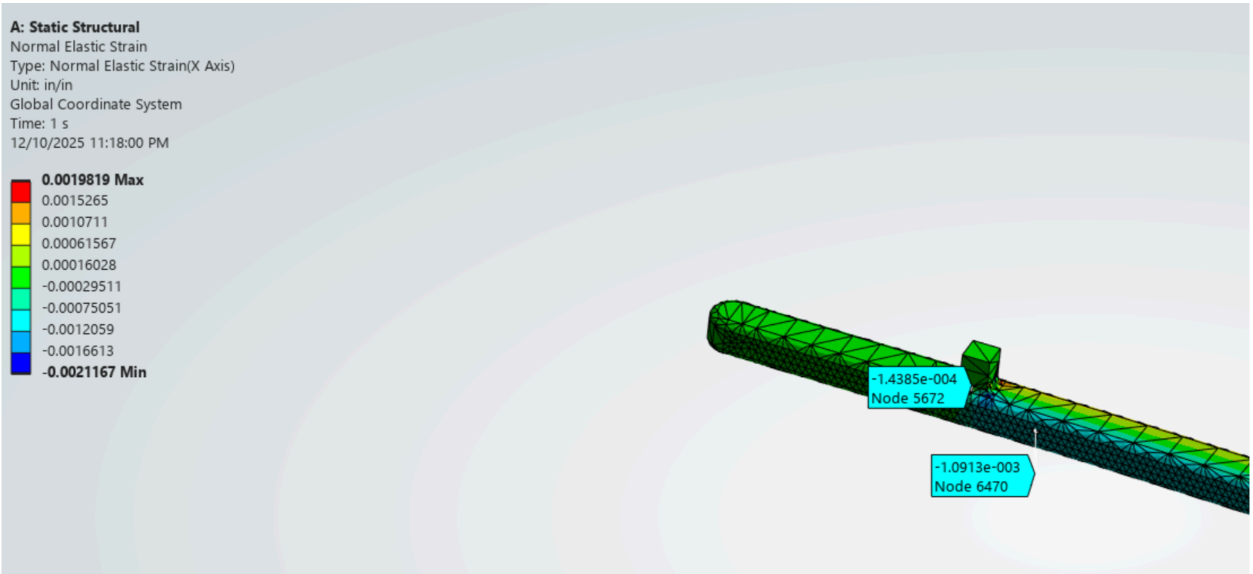
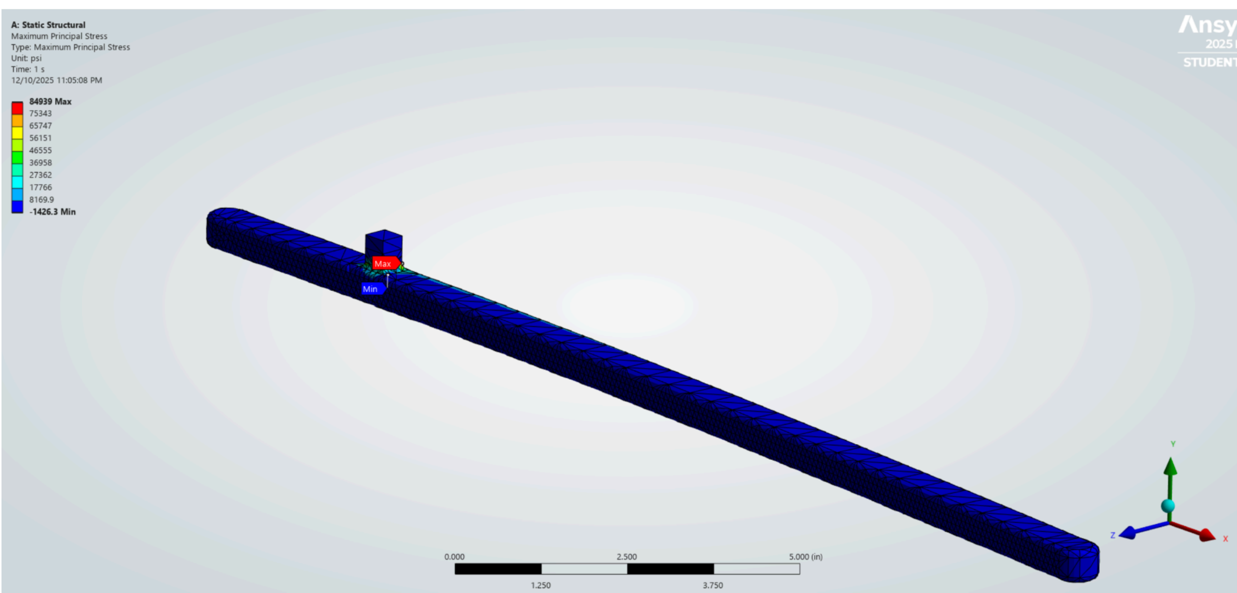
## FEM Results - Study 1 (0.1 in Mesh)




First FEM analysis. Mesh size: 0.1 in.
Maximum strain: 0.0019819
Gauge Strain: -0.0010913




First FEM analysis. Mesh size: 0.1 in.
Maximum stress: 84.939 ksi.

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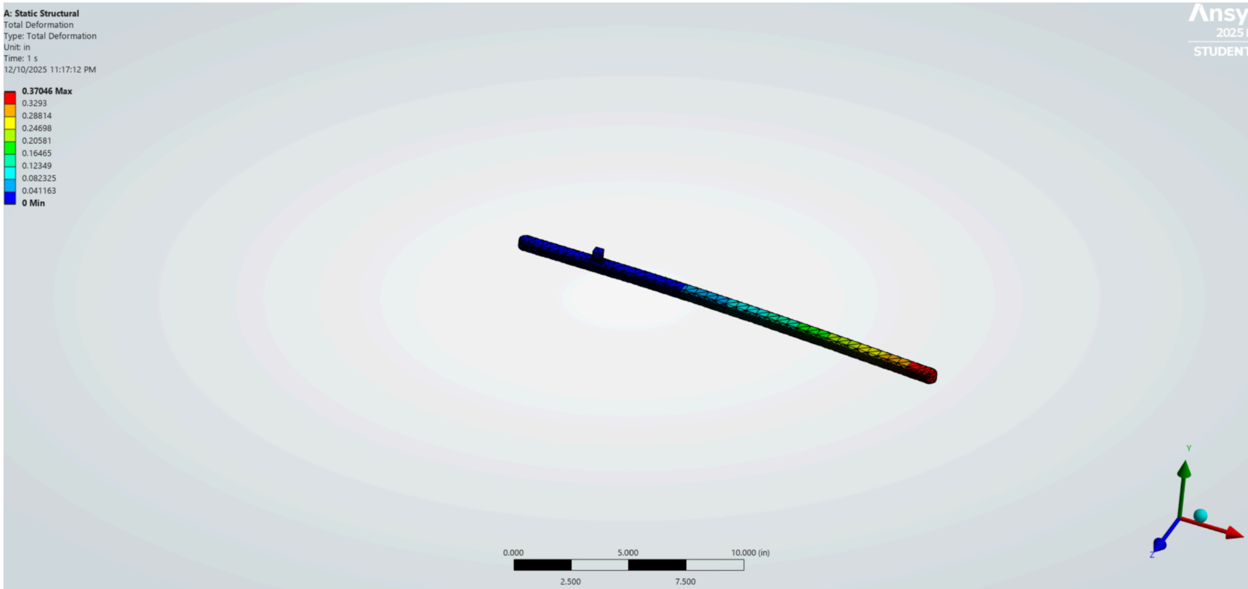


First FEM analysis. Mesh size: 0.1 in.
Maximum deformation: 0.37046 in

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FEM Results - Study 1 (0.1 in Mesh)

| | | |
|---|---|---|
| Max Normal Stress | 84,939 psi | Corner of fillet connecting drive head to wrench |
| Load Point Deflection | 0.37046 | Handle tip |
| Gauge Strain | -.0010913 | Gauge location, 1 in from drive |
| Strain Gauge Sensitivity | 1.108 | |

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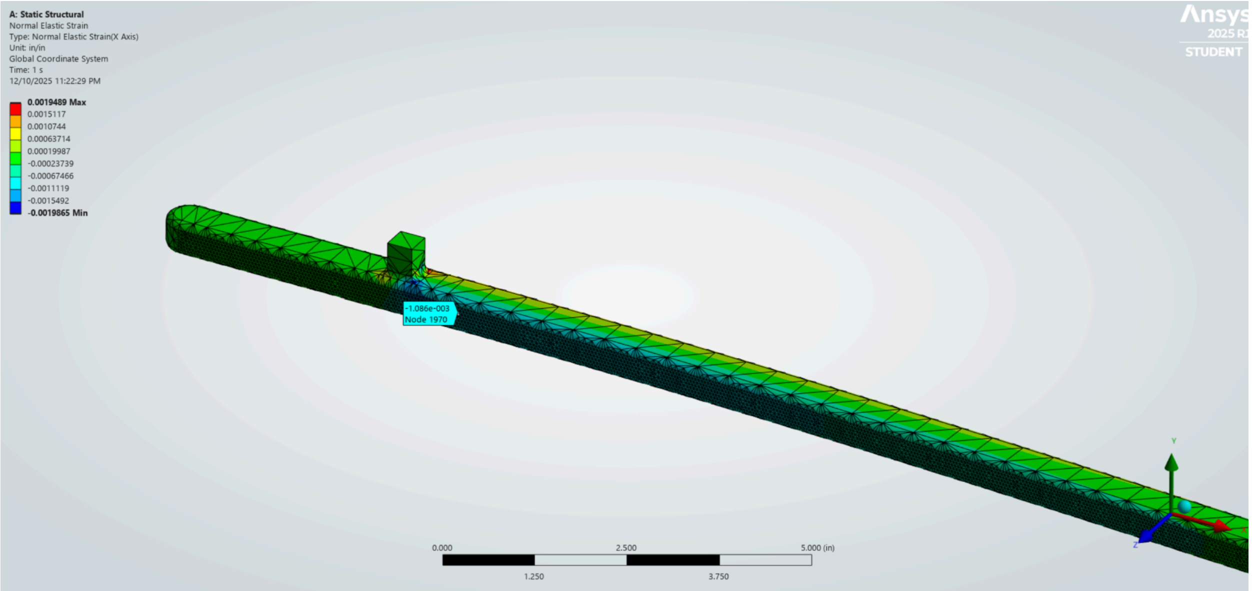
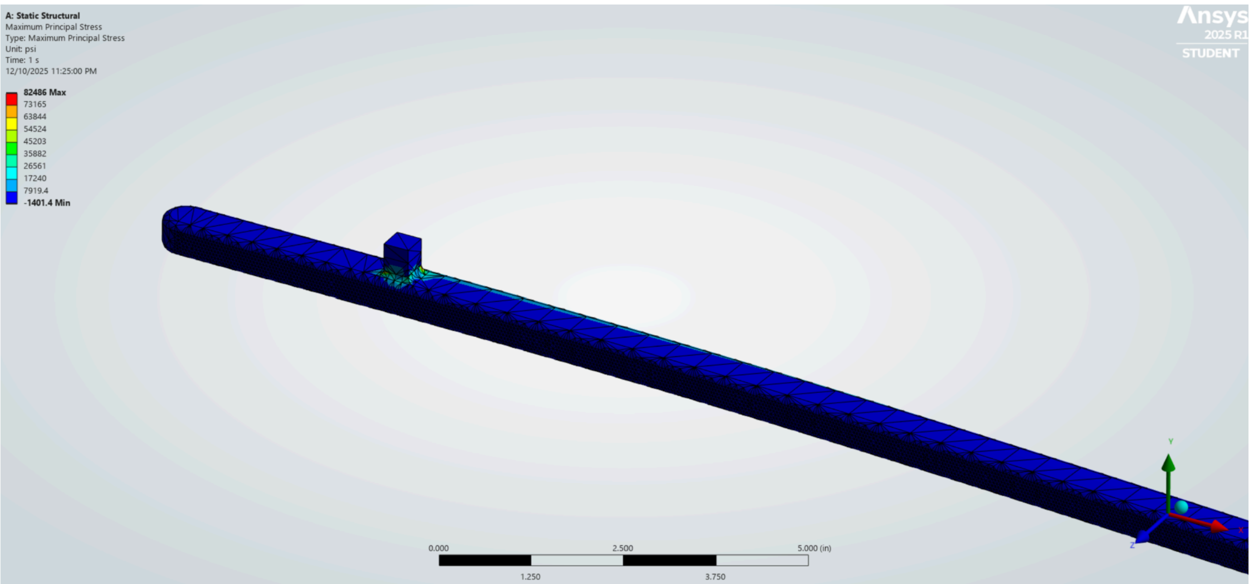
FEM Results - Study 2 (0.05 in Mesh)




Second FEM analysis. Mesh size: 0.05 in.
Gauge Strain: -0.001086




Second FEM analysis. Mesh size: 0.05 in.
Maximum stress: 82,486 psi

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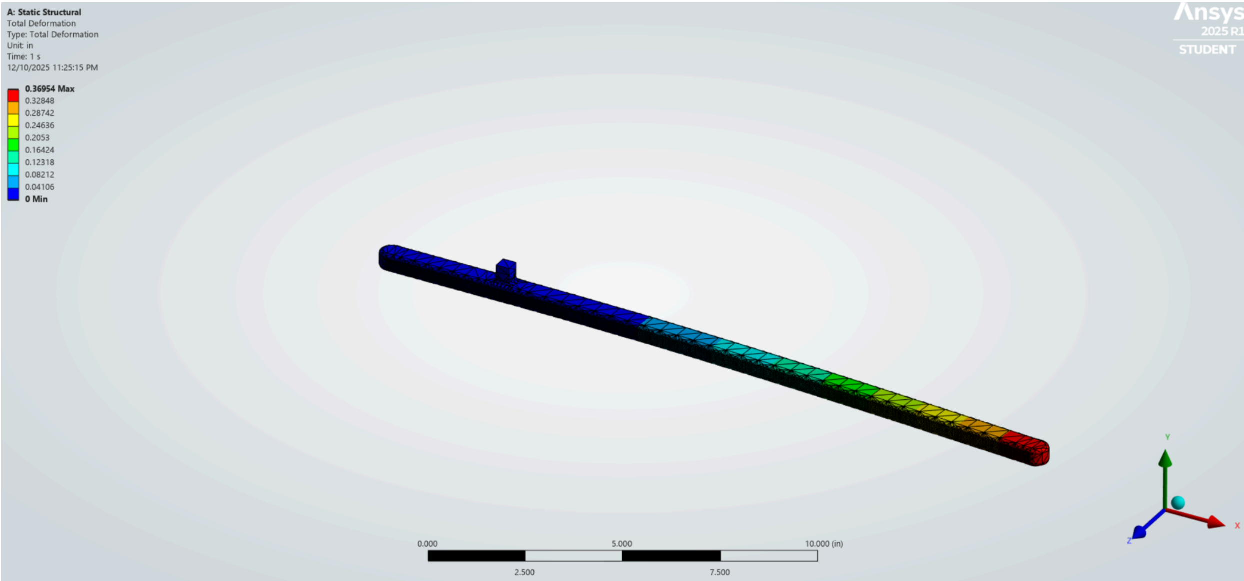


Second FEM analysis. Mesh size: 0.05 in.
Maximum deformation: 0.36954 in

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FEM Results - Study 2 (0.05 in Mesh)

| | | |
|---|---|---|
| Max Normal Stress | 82,486 psi | Corner of fillet connecting drive head to wrench |
| Load Point Deflection | 0.36954 | Handle tip |
| Gauge Strain | -.001086 | Gauge location, 1 in from drive |
| Strain Gauge Sensitivity | 1.102 | |