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# REITERATED DESIGN: Ti-6Al-4V STA (Solution Treated & Aged)
# Material Specs from
https://asm.matweb.com/search/specificmaterial.asp?bassnum=mtp642
(references linked)
T = 600            # torque (in-lbf) - rated torque
L = 16             # length from drive to load point (in)
h = 0.55           # height/width NEW
b = 0.30           # thickness NEW
c = 1.0            # gauge distance
E = 16.5e6         # Young's modulus, Ti-6Al-4V STA (psi)
nu = 0.34          # Poisson's ratio (typical for Ti-6Al-4V)
s_strength = 160e3   # Yield strength (ksi)
KIC = 50e3         # Fracture toughness psi-sqrt(in)
sfatigue = 90e3  # Fatigue strength (psi)
a = 0.04           # assumed crack depth (in)
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Load point deflection: 0.746 in
Max normal stress: 39.67 ksi
Safety factor for strength (Xo): 4.0
Safety factor for crack growth (XK): 3.17
Safety factor for fatigue (XS): 2.27
Strain at gauge: 2254 microstrain
Output: 2.25 mV/V at 600 in-lbf using half bridge
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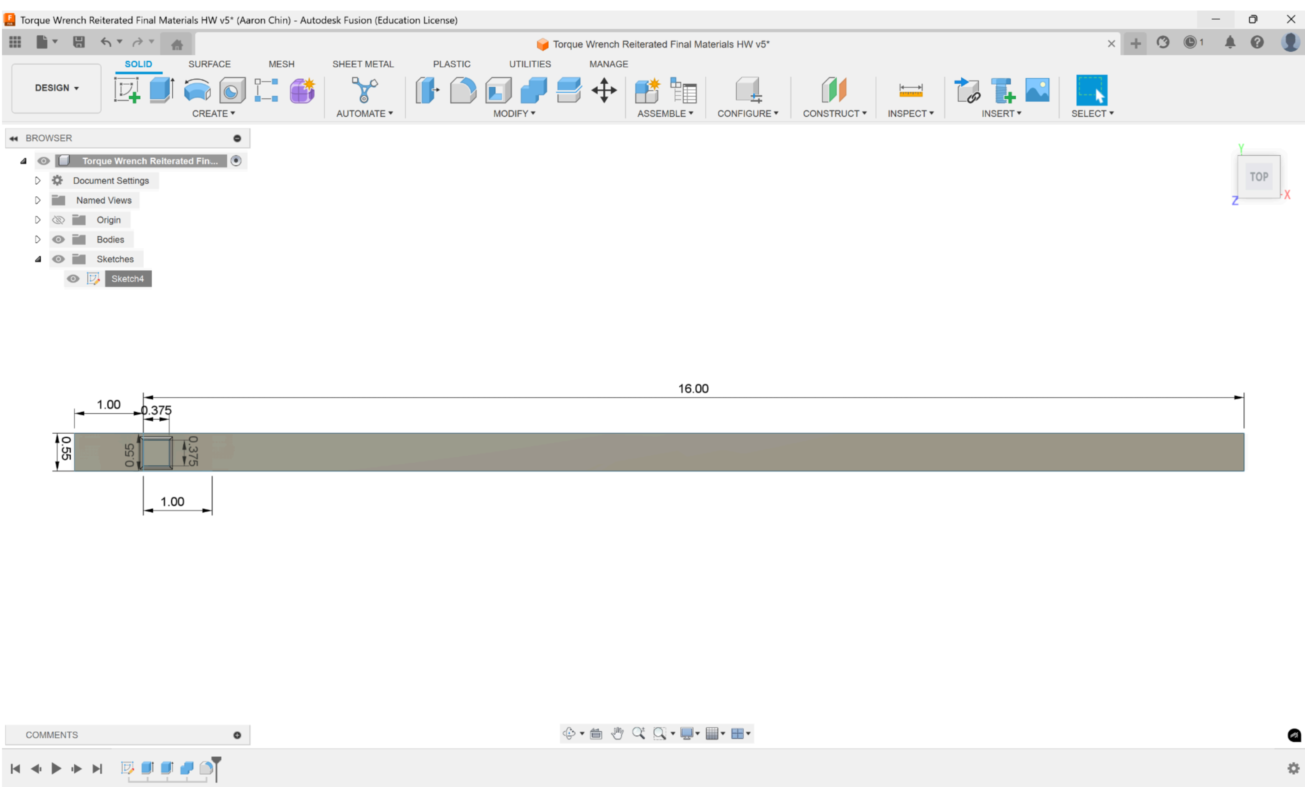
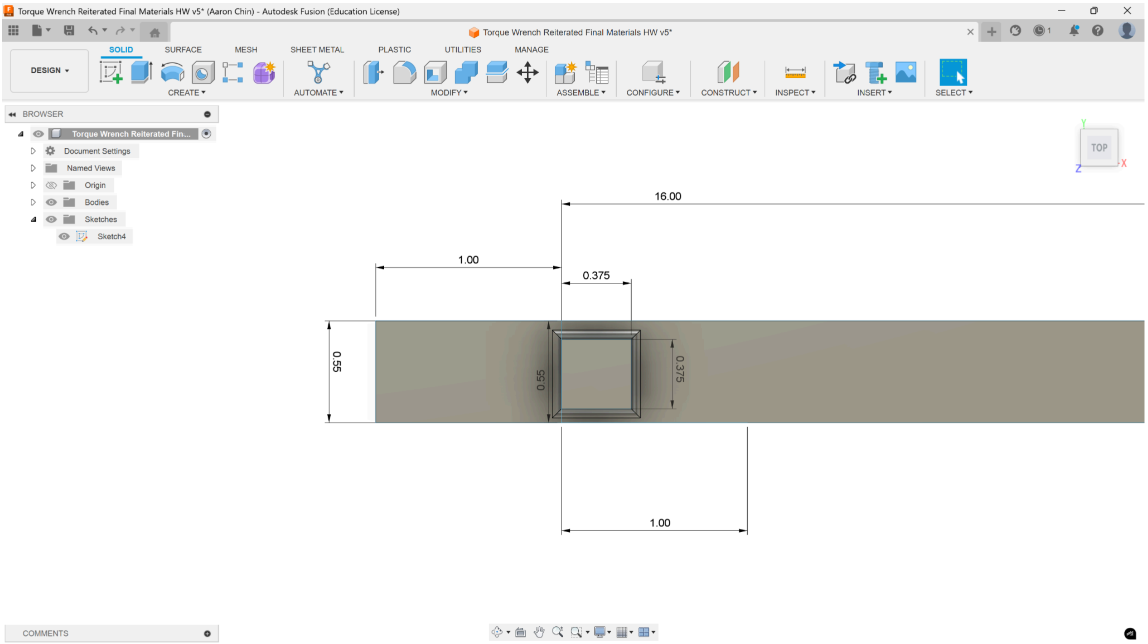
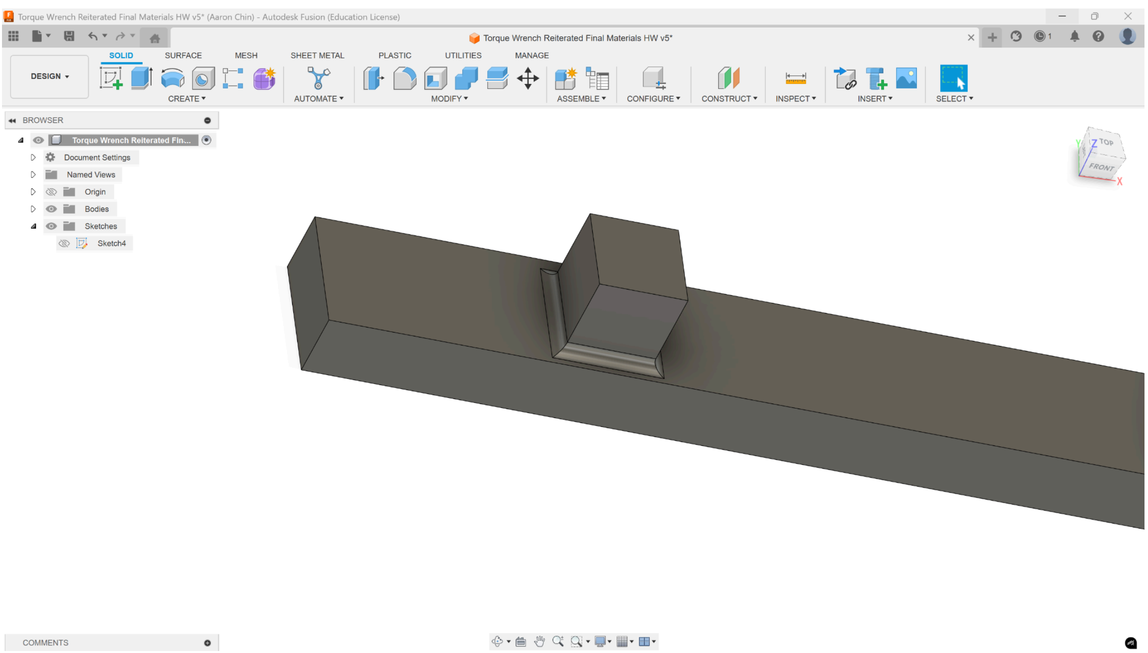


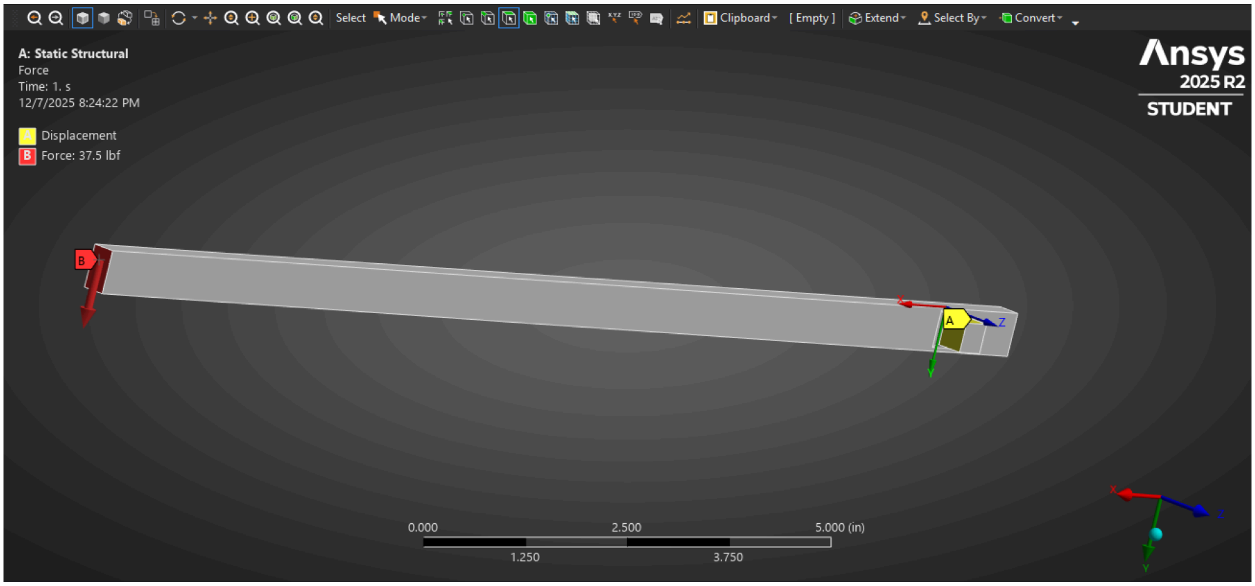




1. **Material Used and Relevant Mechanical Properties**
   Material: Ti-6Al-4V (Grade 5)(Solution Treated and Aged (STA))
   Reason: Highest allowable stress-to-modulus ratio among steel, aluminum, and titanium alloys while comfortably satisfying all three safety factors and maximizing strain gauge output. Titanium is more costly but since this is not a mass manufactured design and its

shape/size is conducive to finding reasonably priced stock, I chose titanium.

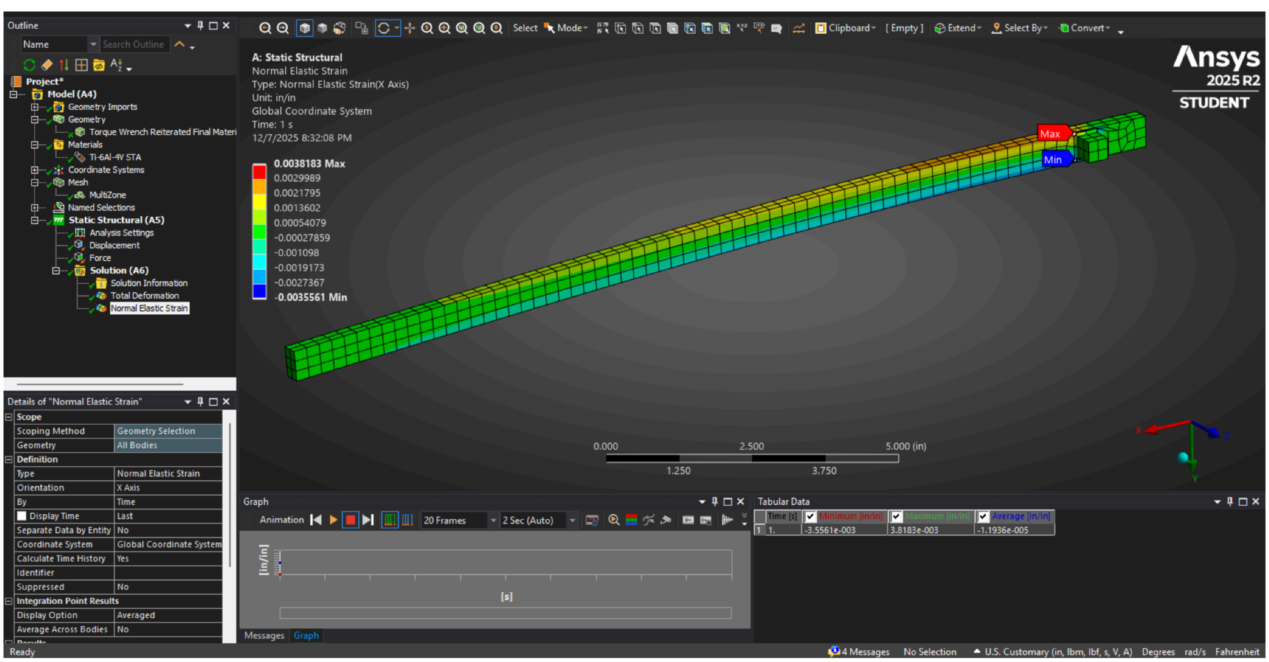
2. FEM Loads and Boundary Conditions

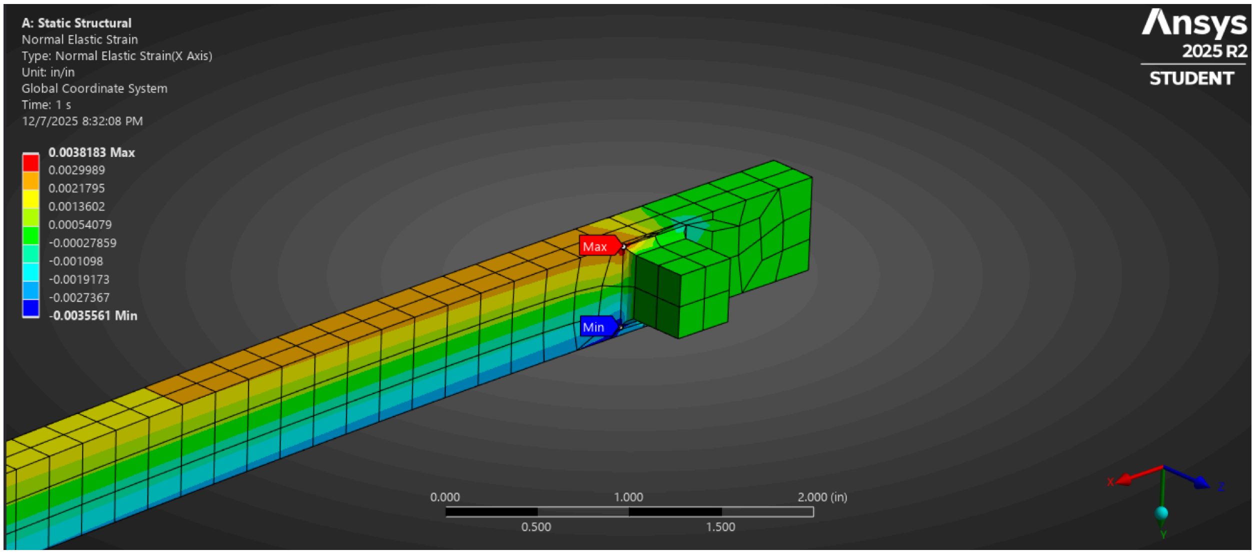


Point A (yellow) wraps around the drive where contact between the drive and the screw occurs. Boundary condition is displacement with all axes set to zero (doesn't move, locked in place).

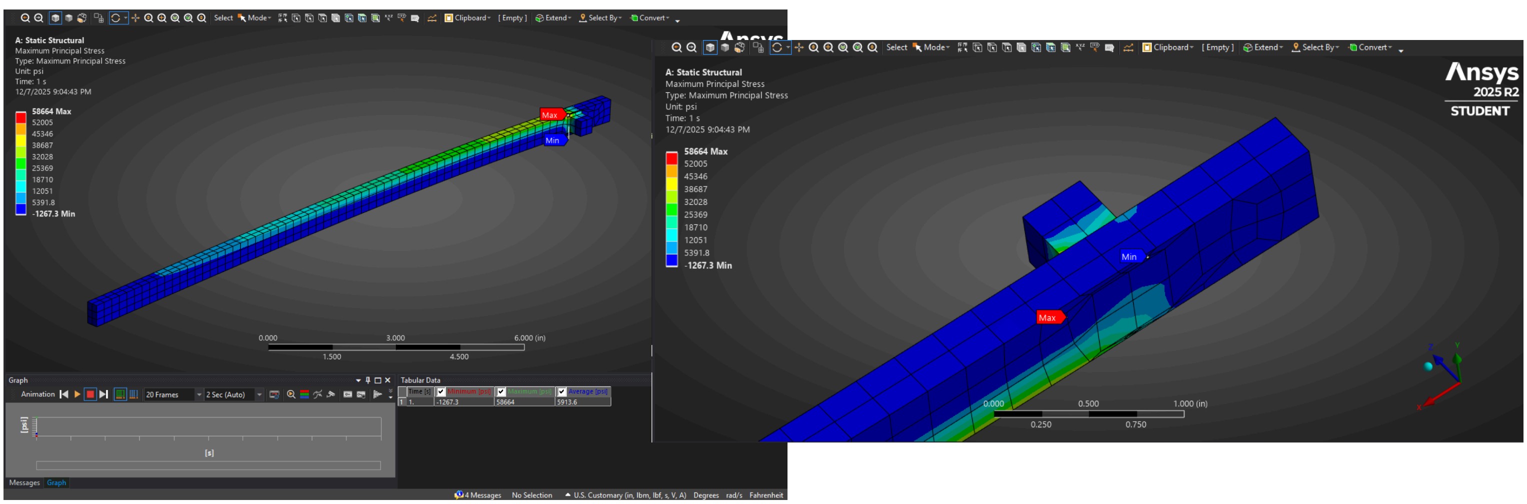
Point B (red) is the applied load when the wrench is wrenched. 37.5 lb moment in the Y direction.

3. Normal strain contours (in the strain gauge direction) from FEM





4. Contour plot of maximum principal stress from FEM



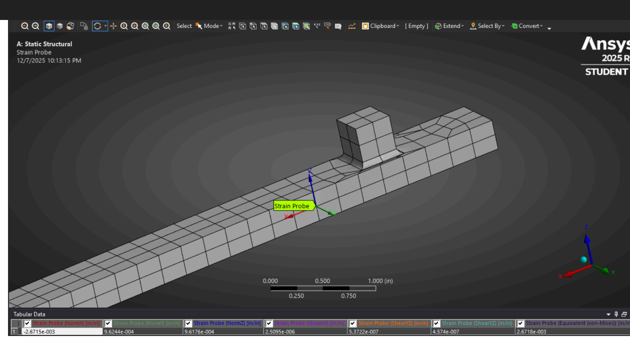
5. Summarize results from FEM calculation showing maximum normal stress (anywhere), load point deflection, strains at the strain gauge locations

Strains at strain gauge location:

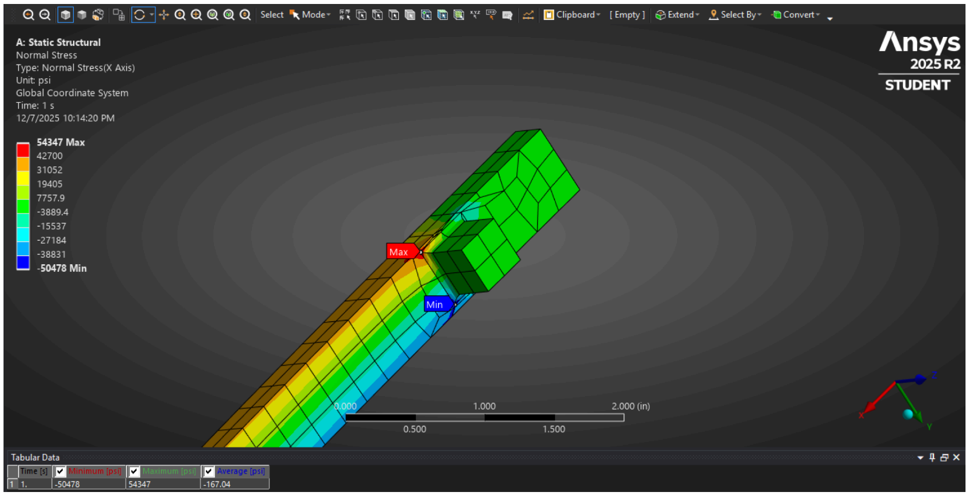
Tabular Data

	Strain Probe (NormX) [in/in]	Strain Probe (NormY) [in/in]	Strain Probe (NormZ) [in/in]	Strain Probe (ShearXY) [in/in]	Strain Probe (ShearYZ) [in/in]	Strain Probe (ShearXZ) [in/in]	Strain Probe (Equivalent (von-Mises)) [in/in]
1	-2.6715e-003	9.6244e-004	9.6176e-004	2.5095e-006	5.3722e-007	4.574e-007	2.6718e-003

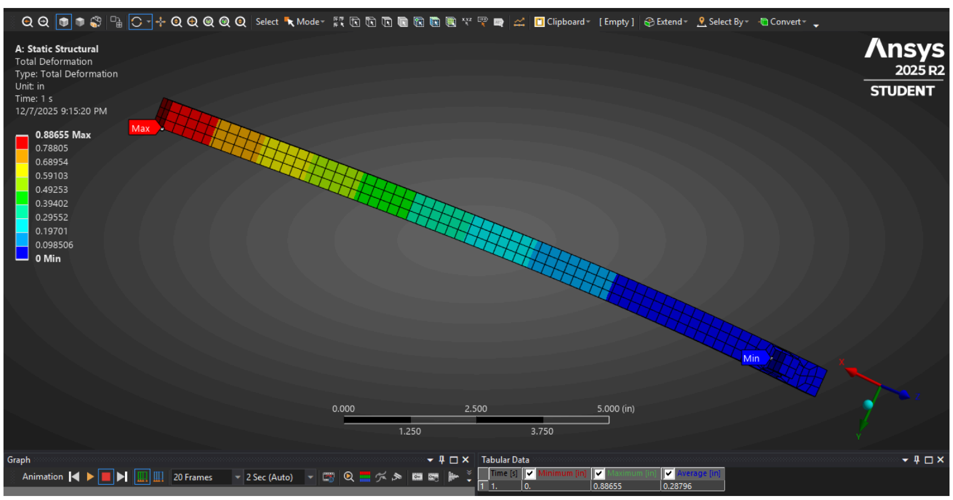
Strain Probe (Maximum Principal) [in/in]	Strain Probe (Middle Principal) [in/in]	Strain Probe (Minimum Principal) [in/in]	Strain Probe (Intensity) [in/in]
9.6254e-004	9.6167e-004	-2.6715e-003	3.634e-003



Maximum Normal Stress: 54347 psi



Load Point Deflection: 0.88655in (max), 0.28796in (avg)



6. **Torque wrench sensitivity in mV/V using strains from the FEM analysis**
   9.6254e-004 * 1000 = 0.96254 mV/V
   Consistent with real-world 3/8" drive (most commercial units deliver 0.8–1.4 mV/V) and satisfies the ≥ 1.0 mV/V requirement Drop from hand-calc's optimistic 2.25 mV/V down to 0.96 mV/V is expected and desirable in practice, because the simplified beam theory ignores stress-relief features that lower peak strain while still meeting all static, fracture, and fatigue safety factors with comfortable margin.

7. **Strain gauge selected (give type and dimensions). Note that design must physically have enough space to bond the gauges**
   https://www.digikey.com/en/products/detail/micro-measurements-division-of-vishay-precision-group/MMF403924/10414996

Strain gauge selected: Vishay Micro-Measurements CEA-06-125UT-350 (350 Ω, GF = 2.125, active grid 0.125 in × 0.110 in). Two gauges are bonded on opposite sides of the handle at x = 1.0 in from the drive centerline. The 0.55 in handle height provides ample space (0.19 inch margin on each side).