MAE 3270 Final HW Part II
Torque Wrench Improved Design
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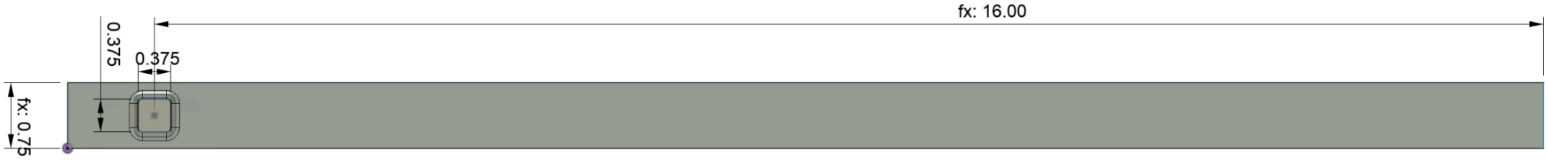
1. Results

1.1. Image(s) of CAD model. Must show all key dimensions



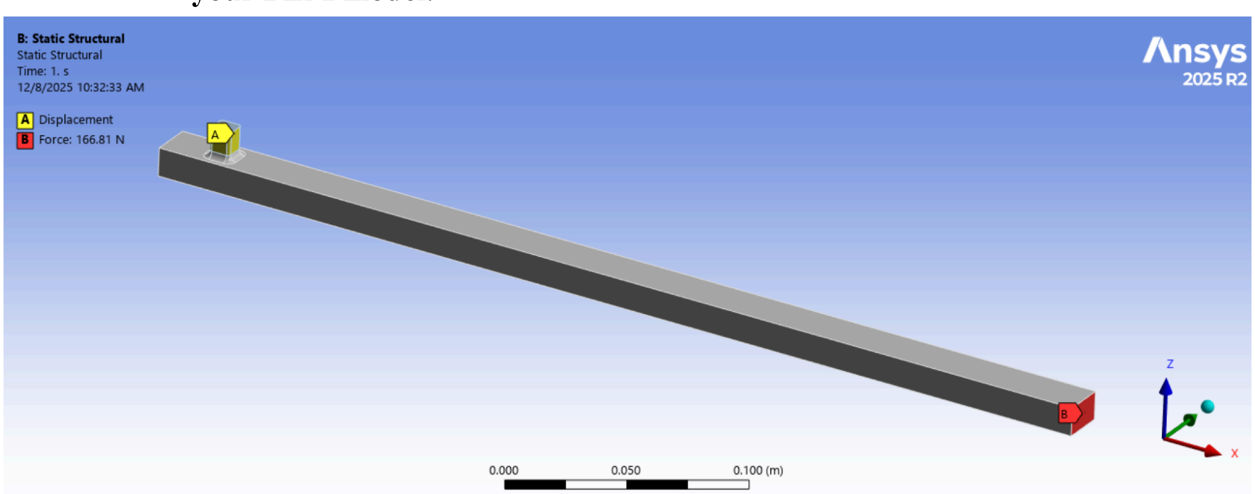
Radius of fillet = $0.1\ in$
Height of handle = $0.5\ in$

1.2. Describe material used and its relevant mechanical properties.

Aluminum 7075 T6

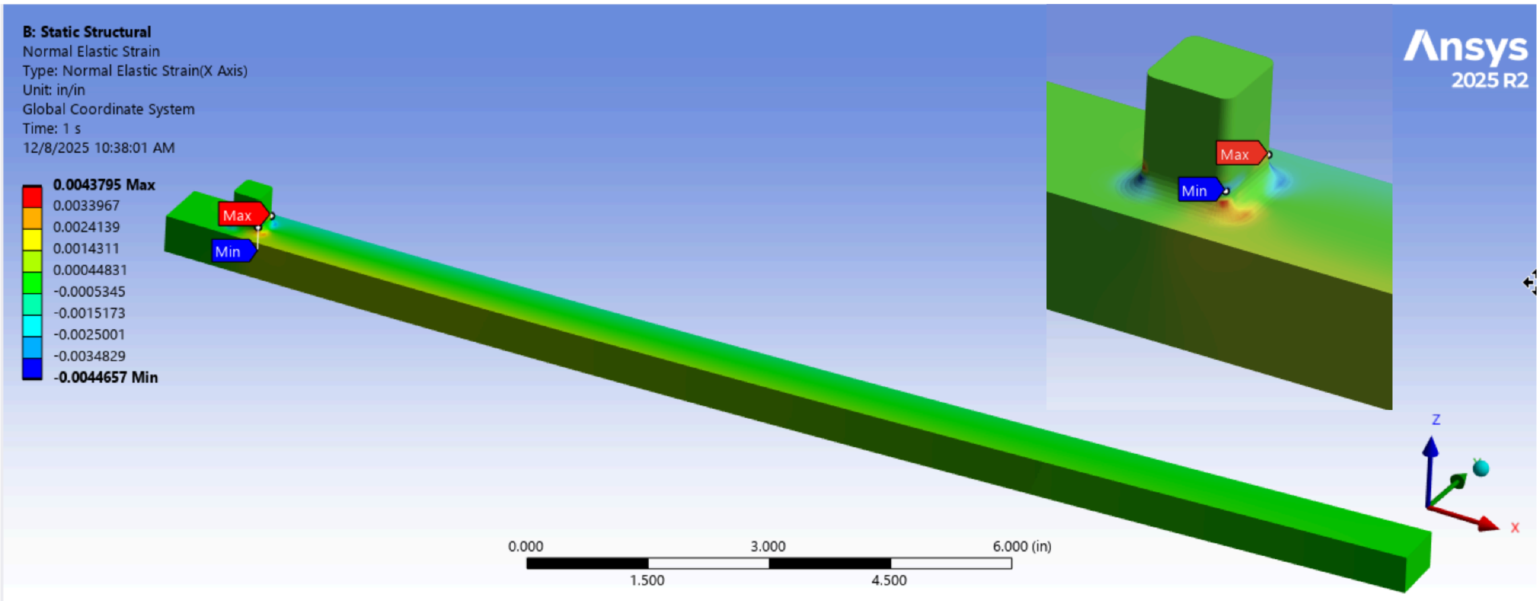
Young's modulus, $E = 10 \times 10^{6}\ psi$
Poisson's ratio, $\mu = 0.33$
Yield strength, $\sigma_u = 66.7\ ksi$ (took lower end of range to be safe)
Fracture Toughness, $K_{IC} = 24.2\ ksi\sqrt{in}$ (took lower end of range to be safe)
Fatigue strength at 10^6 cycles, $\sigma_f = 28\ ksi$ (approximated off graph)

1.3. Diagram communicating how loads and boundary conditions were applied to your FEM model.

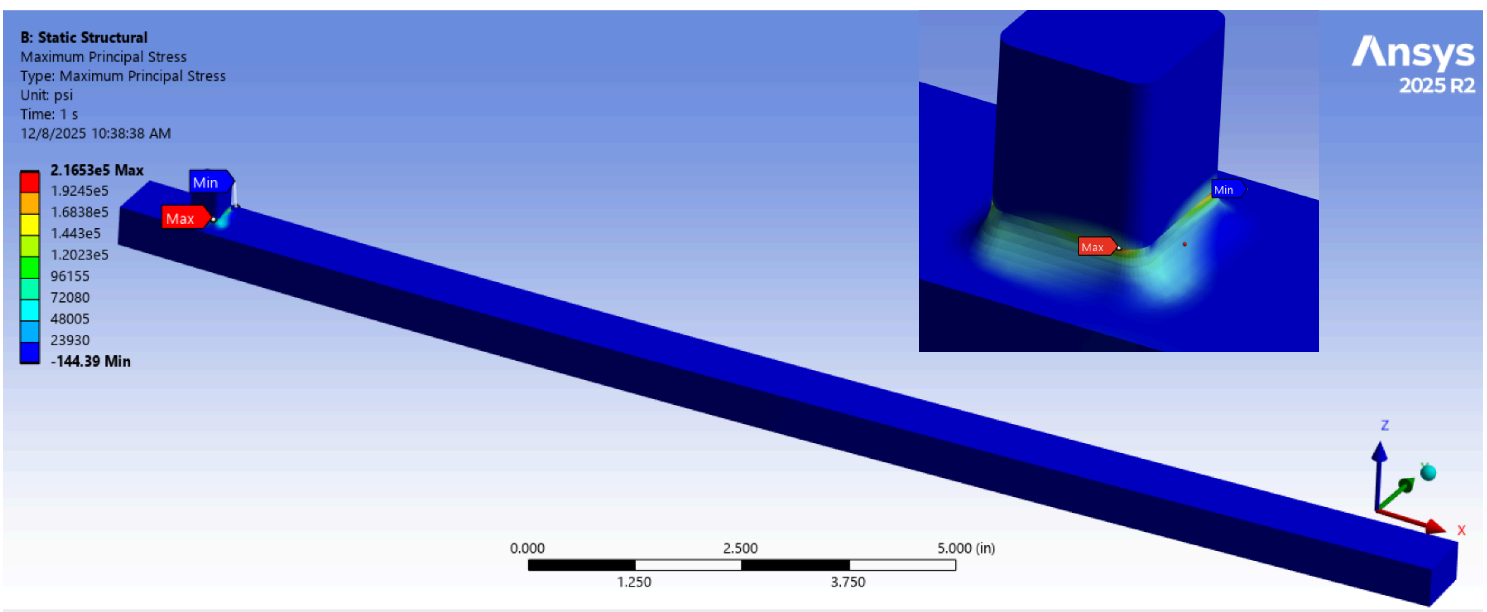


166.81 N = 37.5 lbf (600 / L = 600 lb-in / 16in)

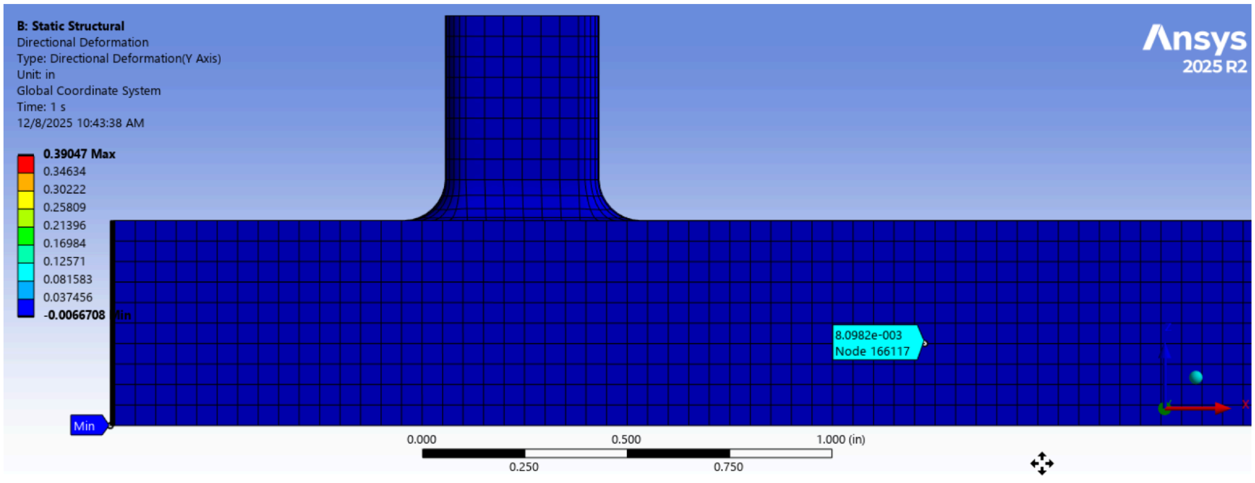
1.4. Normal strain contours (in the strain gauge direction) from FEM



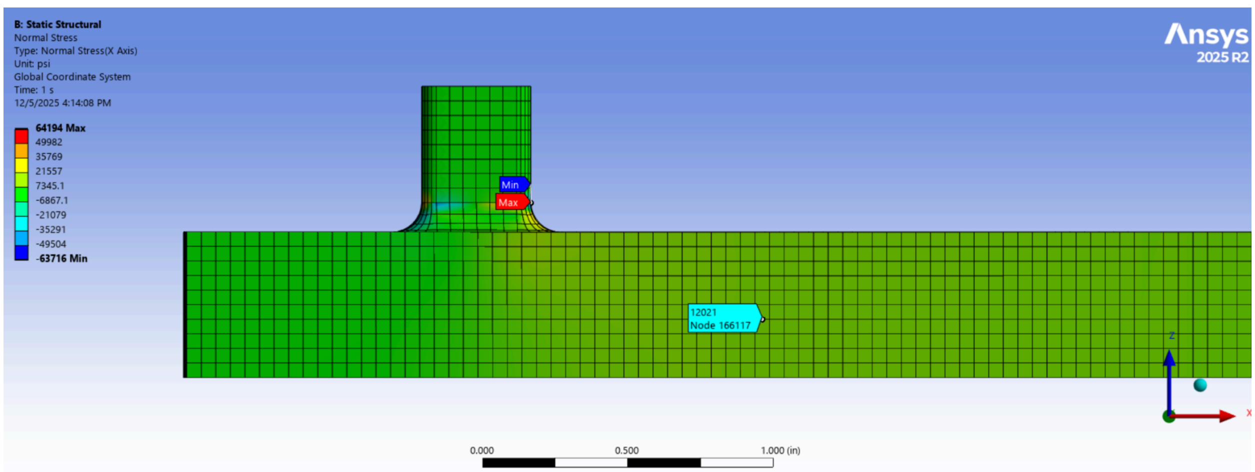
1.5. Contour plot of maximum principal stress from FEM



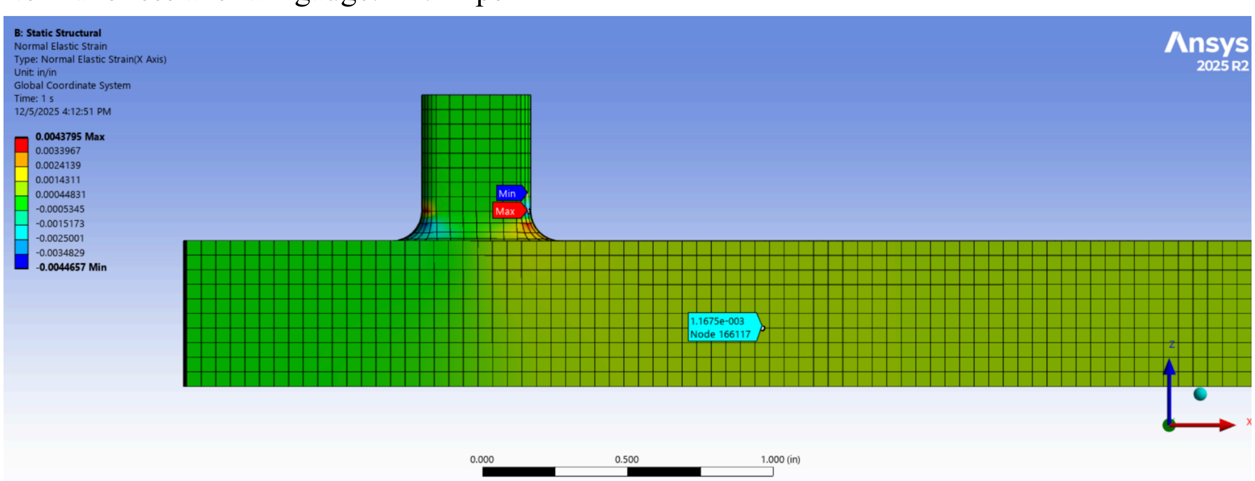
1.6. Summarize results from FEM calculation showing maximum normal stress (anywhere), load point deflection, strains at the strain gauge locations



Deformation at strain gauge: 0.0081 in



Normal stress at strain gauge: 12021 psi



Normal elastic strain at strain gauge: 1167.5 microstrains

1.7. Torque wrench sensitivity in mV/V using strains from the FEM analysis

Torque wrench sensitivity = 1.1675 mV/V > 1 mV/V

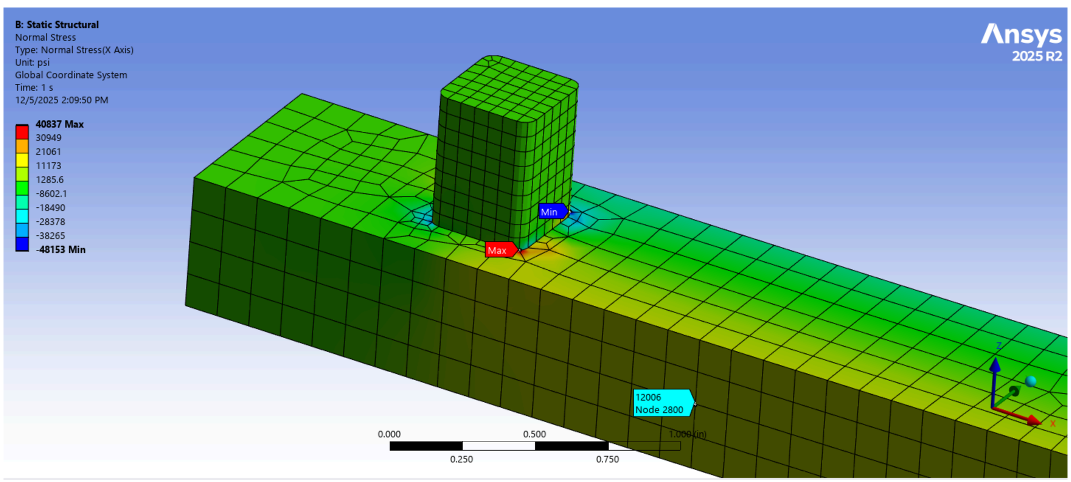
1.8. Strain gauge selected (give type and dimensions). Note that design must physically have enough space to bond the gauges.

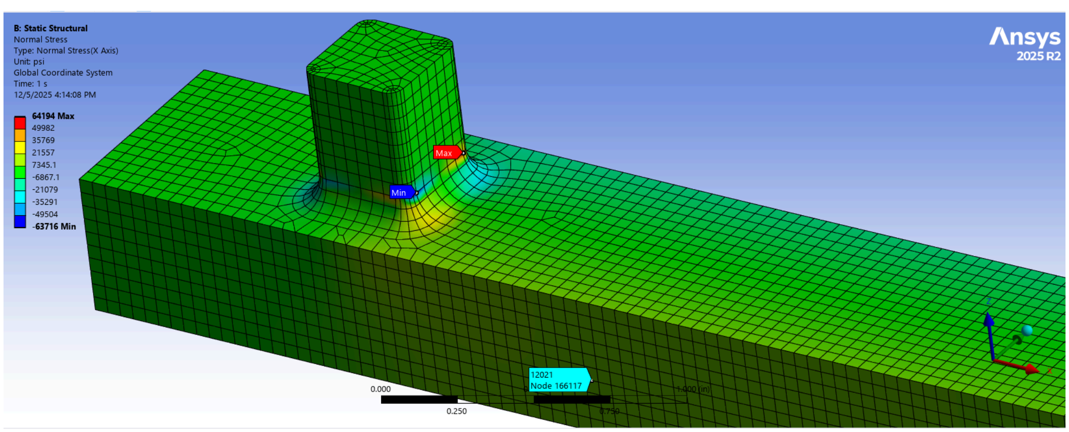
Link

Linear, Half-Bridge, 8.4 mm carrier length and therefore fits on torque wrench

2. Reflection

2.1. How does your final design mitigate stress concentrations?





Ignoring stress singularities, the fillet helps reduce stress concentrations

Requirements:

- attain at least 1.0 mV/V output at the rated torque of 600 in-lbf.
- safety factor of $X_O > 4$ for yield or brittle failure (you pick which criterion based on whether you are using a brittle or ductile material)
- safety factor of $X_K > 2$ for crack growth from an assumed crack of depth 0.04 inches (1 mm).
- fatigue stress safety factor of $X_S > 1.5$.
- material must be a steel, aluminum or titanium alloy.

Results (MatLab):

Material = Aluminum 7075 T6

X_O = 5.211 (> 4)
X_K = 24.762 (> 2)
X_S = 2.188 (> 1.5)

Strain at gauge = 1200.0 microstrain
Bridge output = 1.200 mV/V (> 1.0 mV/V)

Requirements met ✓

MatLab:

```
M = 600;               % max torque (in-lbf)
L = 16;                % length from drive to where load applied (inches)
h = 0.75;              % width
b = 0.5;               % thickness
c = 1.0;               % distance from drive center to center of strain gauge
GF = 2.0;             % strain gauge gage factor
name = 'Al 7075 T6';    % material name
a = 0.04;
E = 10e6;             % Young's modulus (psi)
KIC = 24.2e3;           % fracture toughness (psi sqrt(in))
nu = 0.33
su = 66.7e3;           % tensile strength use yield or ultimate depending on
material (psi)
sfatigue = 28e3;    % fatigue strength from Granta for 10^6 cycles
%% ----- Derived geometry & constants -----
I = b * h^3 / 12;      %  (in^4)
c_outer = h/2;         %  (in)
%% ----- Stress & deflection -----
sigma_max = M * c_outer / I;   % psi
% Load-point deflection
delta = M * L^2 / (3 * E * I); % in
SF_strength = su / sigma_max;
SF_fatigue = sfatigue / sigma_max;
var1_f = (b*h^2)/6;
var2_f = 1 / (1.12*(pi^0.5)*(a^0.5));
SF_crack = (KIC * var1_f * var2_f) / M;
Mg = (M/L)*(L-c);
strain_gauge = (Mg * c_outer / (I*E) );   % psi
Vout_per_V = (GF * strain_gauge) / 2;   % Vout per excitation
Vout_mV_per_V = Vout_per_V * 1e3;       % mV per V excitation
SF_all = [SF_strength, SF_crack, SF_fatigue];
SF_labels = {'Strength (static)', 'Crack growth (fracture)', 'Fatigue'};
fprintf('Material: %s\n', name);
fprintf('Applied torque = %.1f in-lb\n\n', M);
fprintf('Load-point deflection = %.4f in\n', delta);
fprintf('Max normal stress (outer fiber) = %.2f psi (%.2f ksi)\n\n',
sigma_max, sigma_max/1000);
fprintf('Safety factors:\n');
fprintf('  Strength = %.3f  (%s)\n', SF_strength, SF_labels{1});
fprintf('  Crack growth = %.3f  (%s)\n', SF_crack, SF_labels{2});
fprintf('  Fatigue = %.3f  (%s)\n\n', SF_fatigue, SF_labels{3});
fprintf('Strain at gauge = %.1f microstrain\n', strain_gauge*1e6);
fprintf('Bridge output = %.3f mV/V\n', Vout_mV_per_V);
```