MAE 3270 Final HW Part II
Torque Wrench Own Design

Requirements:

$X_0 \geq 4$ (yield failure)
$X_K \geq 2$ (crack growth)
$X_S \geq 1.5$ (fatigue)
Strain gauge output ≥ 1.0 mV/V

Output of Code: (full code in appendix)

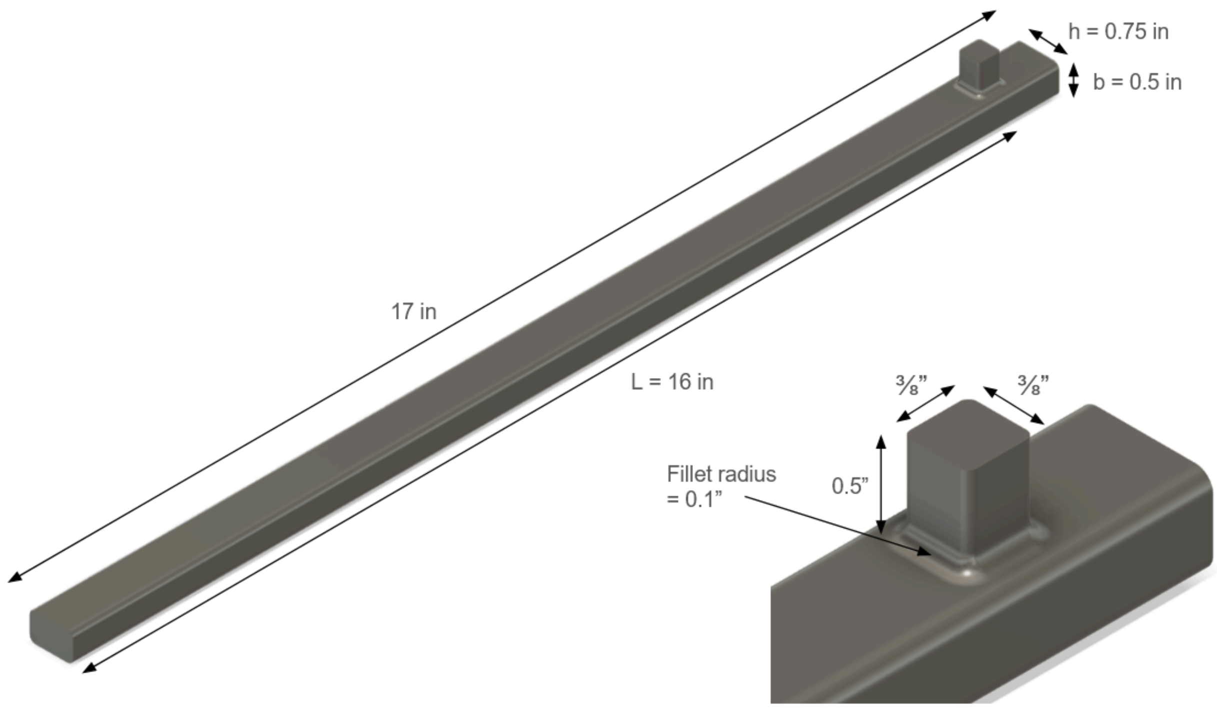
```
--- Stress and Deflection Analysis ---
Deflection, δ = 0.291 in
Max normal stress = 12.80 ksi

--- Safety Factor Results ---
Safety factor (yield failure) = 5.21
Safety factor (fracture) = 4.76
Safety factor (fatigue) = 2.19

--- Strain Gauge Results ---
Strain at gauge = 1200 microstrain
Output at gauge = 1.20 mV/V
```

Design meets all requirements ✓

Deliverables:

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

The design change that I have implemented in the geometry is a fillet of radius 0.1 at the base of the drive to mitigate stress concentrations. For aesthetic and ergonomic purposes I also added this same fillet on the outer edges of the handle.



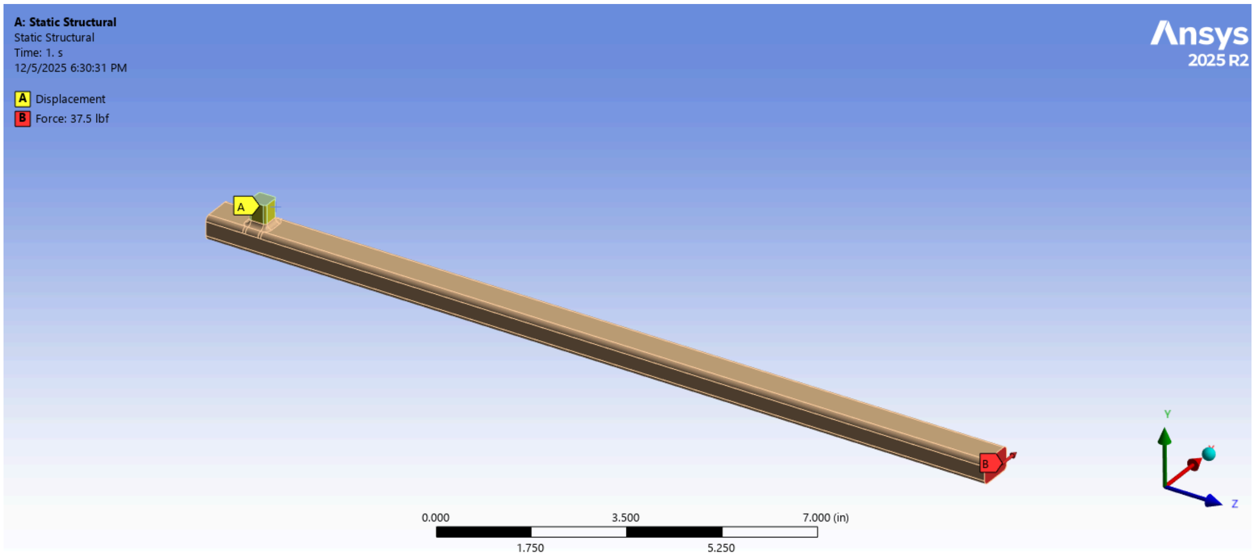
2. Describe material used and its relevant mechanical properties.

Aluminium 7075 T6

- One of the most commonly used aluminum alloys, high strength material used for highly stressed structural components
- Applications: aerospace components and fittings, automotive, gears, shafts, valve parts, bolts, electronics → would be appropriate for a torque wrench

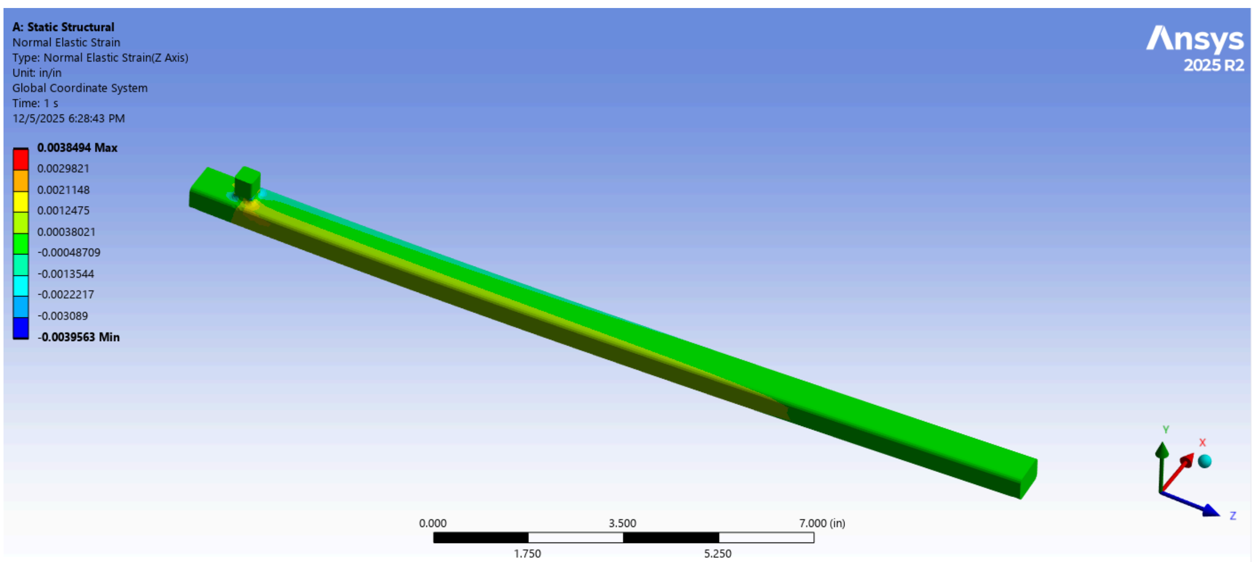
Young's modulus, $E = 10 * 10^6$ psi
Poisson's ratio, $\mu = 0.33$
Yield strength, $\sigma_u = 66.7$ ksi (took lower end of range to be safe)
Fracture Toughness, $K_{Ic} = 24.2$ ksi$\sqrt{in}$ (took lower end of range to be safe)
Fatigue strength at 10^6 cycles = $\sigma_f = 28$ ksi (approximated off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

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

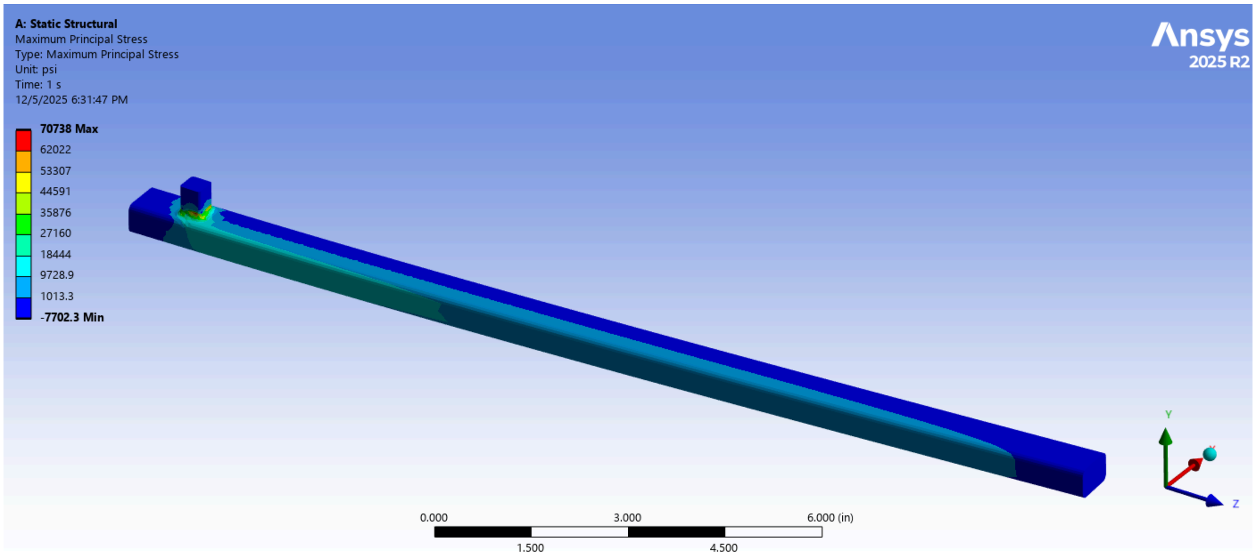


A: Boundary condition: 8 faces of drive fixed (displacement set to 0)
B: Load: 37.5 lbf applied on end face in positive x direction

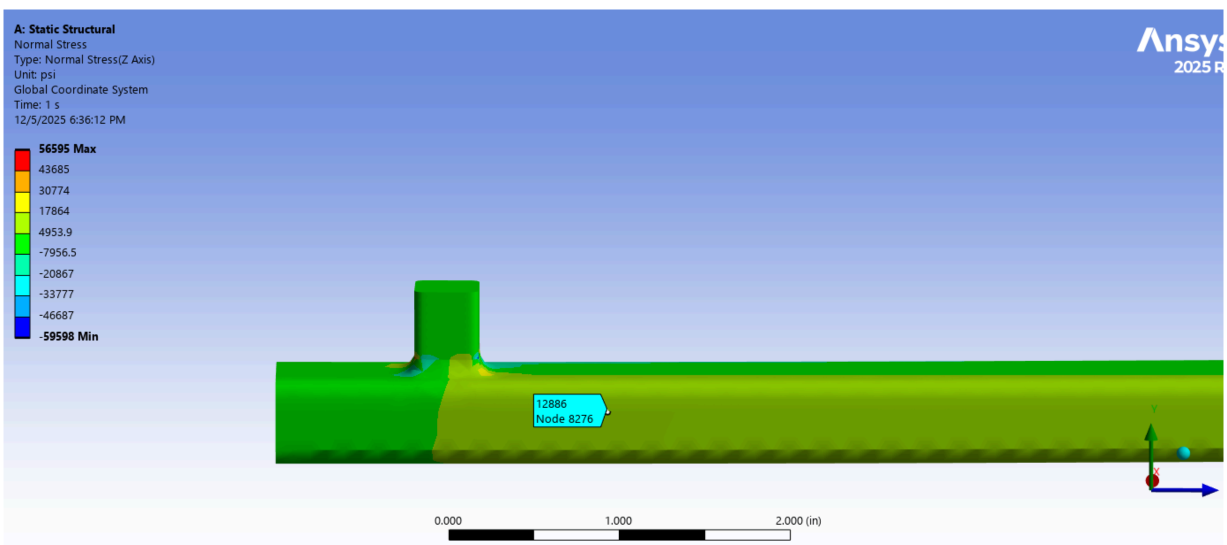
4. Normal strain contours (in the strain gauge direction) from FEM

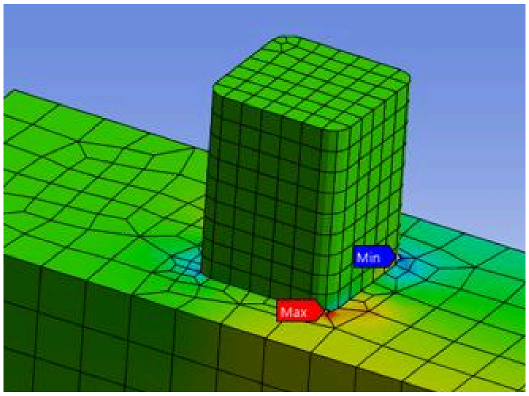


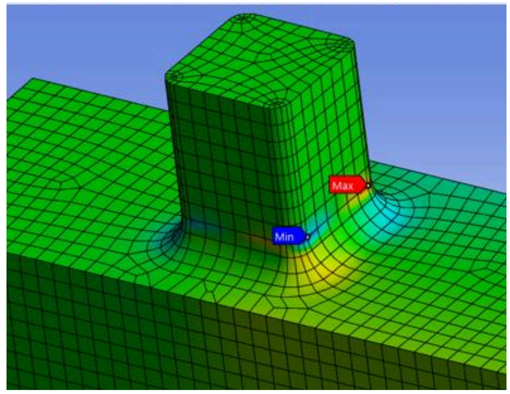
5. Contour plot of maximum principal stress from FEM



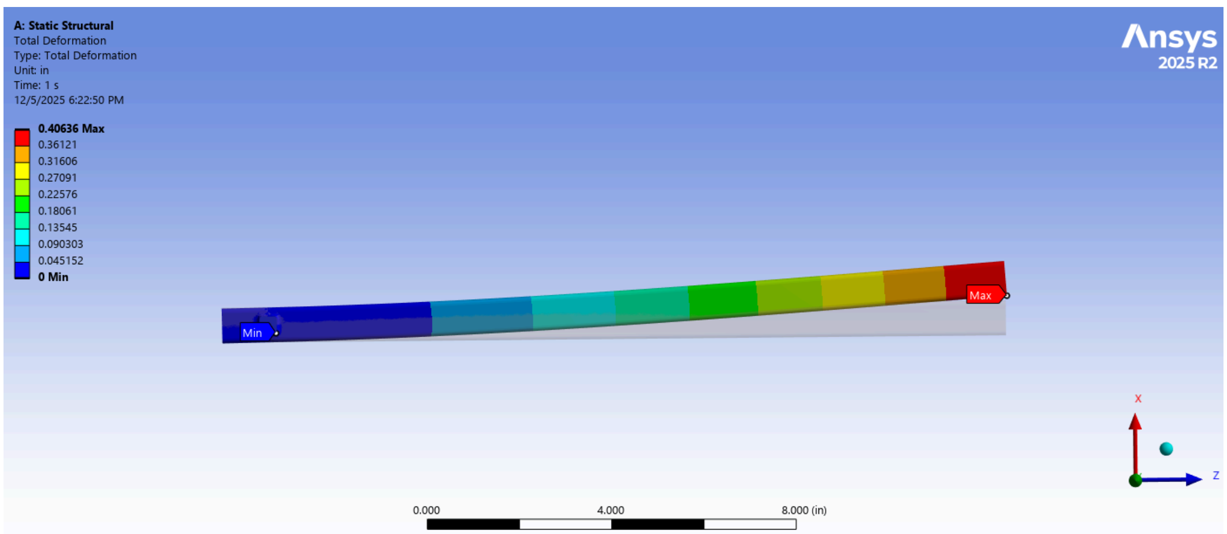
6. Summarize results from FEM calculation showing maximum normal stress (anywhere), load point deflection, strains at the strain gauge locations

Global maximum normal stress: 56595 psi, but this is the stress singularity at an interface of planes due to how the CAD model was imported into ANSYS Max normal stress at filleted corner = 30012 psi Normal stress as gauge location = 12886 psi

Stress concentrations mitigated by fillet Stress at corner goes from 40837 psi to 30012 psi (used probe)

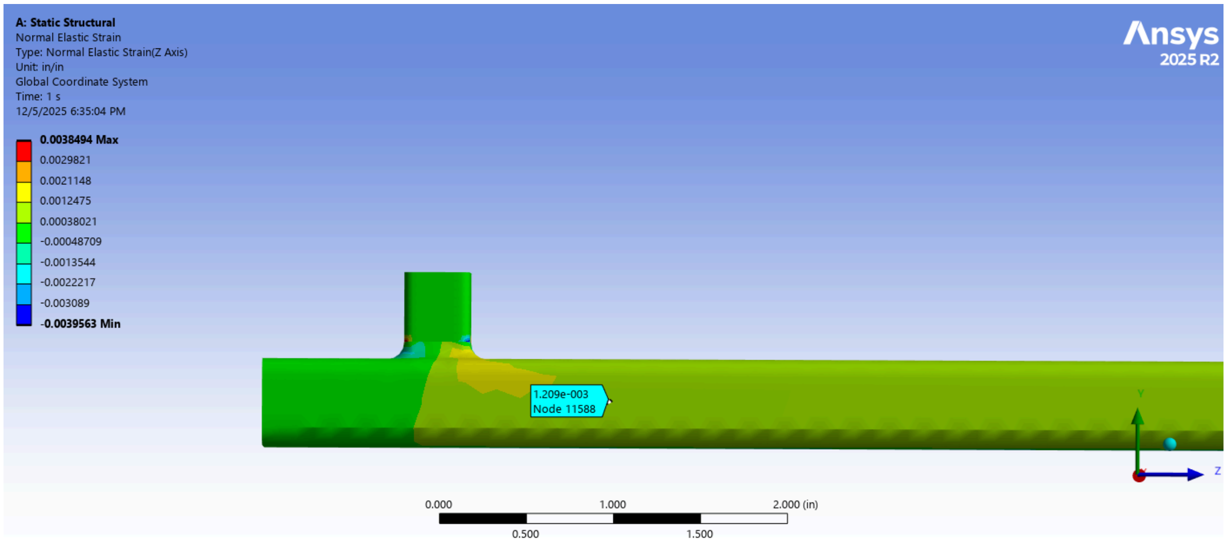




Load point deflection: 0.406 in



Strain at gauge location (confirmed with strain probe coordinate system as well):
1209 microstrain



All the FEM results are close to the results calculated by the MATLAB script
Mesh refinement study: reducing the mesh resulted in values closer to the expected values

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

Gauge Factor = 2
Output at gauge = (gauge factor)*(strain at gauge)/2
= $2*1209*10^{-6}/2$ = 0.001209 V/V = 1.209 mV/V

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

Limiting dimension of torque wrench = 0.5 in = 12.7 mm

Selected strain gauge:
https://www.dwyeromega.com/en-us/half-or-full-bridge-strain-gauges-with-transducer-quality/SGT-Linear-Diaphragm/p/SGT-8-350-LD43

Name: SGT-8/350-LD43
Brand: DwyerOmega
Dimensions: 8.4mm x 5.5mm → fits on torque wrench handle
Type: Half Bridge Linear Diaphragm Pattern
Nominal Resistance: 350 Ω
Voltage, Max: 10 Vrms

Appendix:

MATLAB Code:

```
%% Torque Wrench
%modified design
% Geometry
L = 16;          % in
b = 0.5;         % in
h = 0.75;         % in
a = 0.04;        % in, crack length
c = 1.0; % distance from center of drive to center of strain gauge
I = b*h^3/12;              % area moment of inertia (rectangular section)
c_o = h/2;                 % distance from neutral axis to outer fiber
GF = 2;  %strain gauge gage factor
%  Material properties
name = 'Al 7075 T6'   %material name
E = 10e6;         % psi
nu = 0.33         % Poisson's Ratio
sigma_u = 66.7e3; % psi
KIc = 24.2e3;     % psi√ in
sigma_f = 28e3;   % psi, for 10^6 cycles
% Allowable torque
T_allow_b = sigma_u*I/c_o;    % in-lb
T_allow_K = KIc*b*h^2/(6*1.12*sqrt(pi)*sqrt(a));
T_allow_f = b*h^2*sigma_f/6;
M = 600;        %in-lbf
% Corresponding force
F = M/L;           % lb
% Deflection
delta = M*L^2/(3*E*I);   % in
X_b = T_allow_b/M;
X_K = T_allow_K/M;
X_f = T_allow_f/M;
Mg = M*(L-c)/L;          % Moment at gauge
s_gauge = Mg*c_o/(E*I)*10^6;
Vout = (GF*s_gauge)/2 * 10^-3;  %Vout per excitation in mV
fprintf('--- Stress and Deflection Analysis ---\n');
%fprintf('Force at handle, F                = %.1f lb\n', F);
fprintf('Deflection, δ                   = %.3f in\n', delta);
fprintf('Max normal stress               = %.2f ksi\n\n', M*c_o/I*1e-3);
fprintf('--- Safety Factor Results ---\n');
fprintf('Safety factor (yield failure)   = %.2f\n', X_b);
fprintf('Safety factor (fracture)        = %.2f\n', X_K);
fprintf('Safety factor (fatigue)         = %.2f\n\n', X_f);
fprintf('--- Strain Gauge Results ---\n');
fprintf('Strain at gauge                 = %.0f microstrain\n', s_gauge);
fprintf('Output at gauge                 = %.2f mV/V\n', Vout);
```