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MAE 3270

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Final HW Part 1

5.1.1 Results

1. **Script used for hand calculations and results**

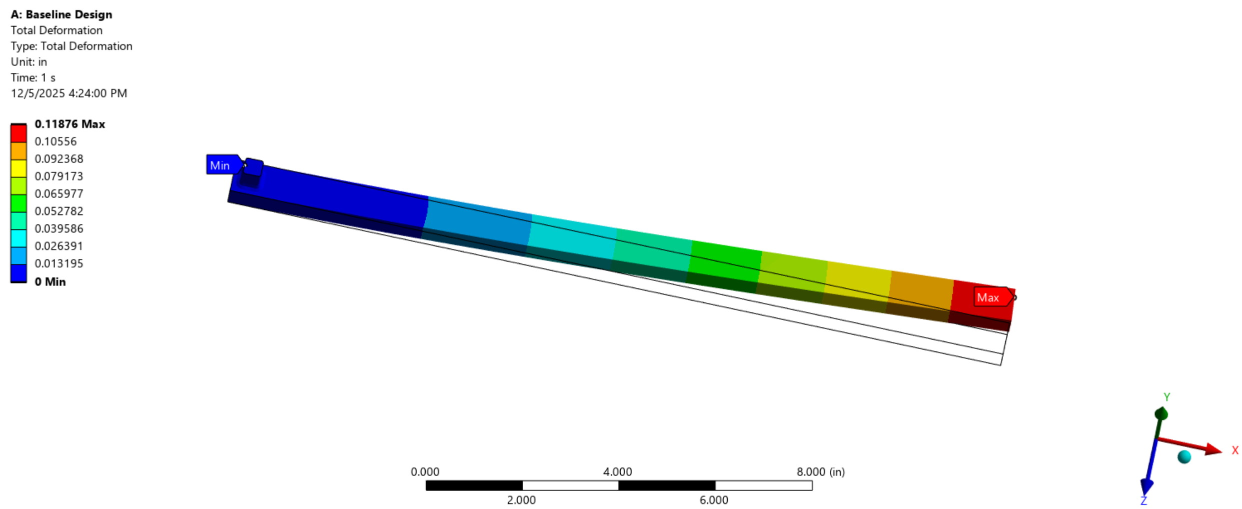
```
% Geometry and Load
M = 600; %Maximum torque [in*lb]
L = 16; %length [in]
h = 0.75 ; %width [in]
b = 0.6125; %thickness [in]
c = 1.0; %distance to strain gauge [in]
a = 0.04; % crack length [in]
P = M/L; % Force from torque [lb]

% M42 Steel
E = 32*10^6; %youngs modulus [psi]
nu = 0.29; %poisson's ratio
sigma_u = 370 * 10^3; %tensile strength [psi]
KIC = 15*10^3; %fracture toughness
sfatigue = 115*10^3; %fatigue strength [psi]
G=E/(2+2*nu); % shear modulus [psi]
I = (b*h^3)/12; % moment of inertia [in^4]

%Yield/Brittle Failure:
y = h/2; % max distance from the neutral axis [in]
sigma_b = (M*y)/I %[psi]

% Fracture Failure
Sg = sigma_b; % [psi]
KI = 1.12*Sg*sqrt(pi*a);  % fracture strength [psi * in^(1/2)]

%Factors of Safety
X0 = sigma_u/sigma_b % FOS for yield/brittle failure, needs to be >= 4
XK = KIC/KI % FOS for fracture, needs to be >= 2
XF = sfatigue/sigma_b % FOS for fatigue failure, needs to be >= 1.5

%strain gauge
gauge_stress = (P*(L-c)*y)/I; % [psi]
gauge_strain = gauge_stress/E * 10^6 % [microstrain]
output_mV_per_V = gauge_strain/1000 %  >1

% deflection
delta = (M*L^2)/(3*E*I) % [in]
```

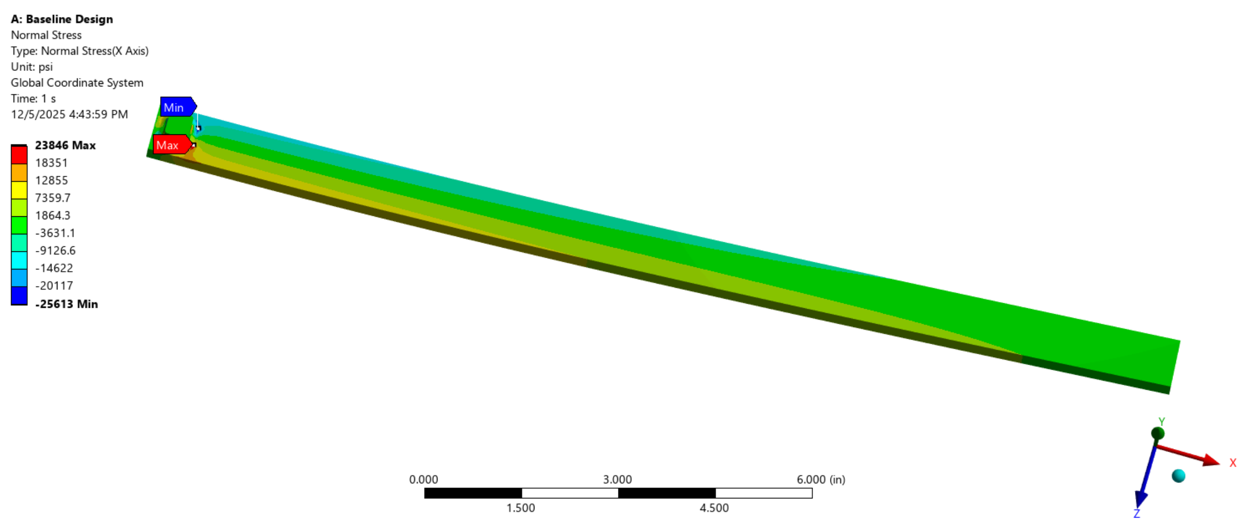
Results

```
sigma_b = 12800
X0 =   28.9062
XK =   2.9516
XF =   8.9844
gauge_strain =  375
output_mV_per_V =   0.3750
delta =   0.0910
```

2. FEM Results

Baseline Design:





FEM Results	
Strain at Gauge Location [microstrain]	365.61
Maximum Stress [psi]	23846
Maximum Deflection [in]	0.11495

5.1.2 Reflections

1. **Beam theory assumes that plane sections remain plane. View the deformed mesh and check if mesh lines that cut across the beam handle remain as straight lines. Do you think that beam theory is reasonably accurate?**

   The mesh lines that cut across the beam handle do remain very close to straight lines. However, the mesh near the drive gets a little wonky due to the fillets. For the beam handle, I do believe that beam theory is quite accurate as the mesh lines do remain close to straight lines.

2. **How do the FEM and hand-calculated maximum normal stresses compare? If they differ significantly, why?**

   The maximum normal stress in the FEM is much higher than the hand-calculated normal stress. This could be for several reasons. Firstly, the hand calculations assume a simplified model of a torque wrench. It uses cantilever beam equations to calculate the maximum normal stress. However, the ANSYS models the connection and boundary conditions of the torque wrench more realistically, since the model has a drive that "connects" to another piece. Another reason why the stress may be higher in ANSYS is because it calculates a stress concentration at the fillet.

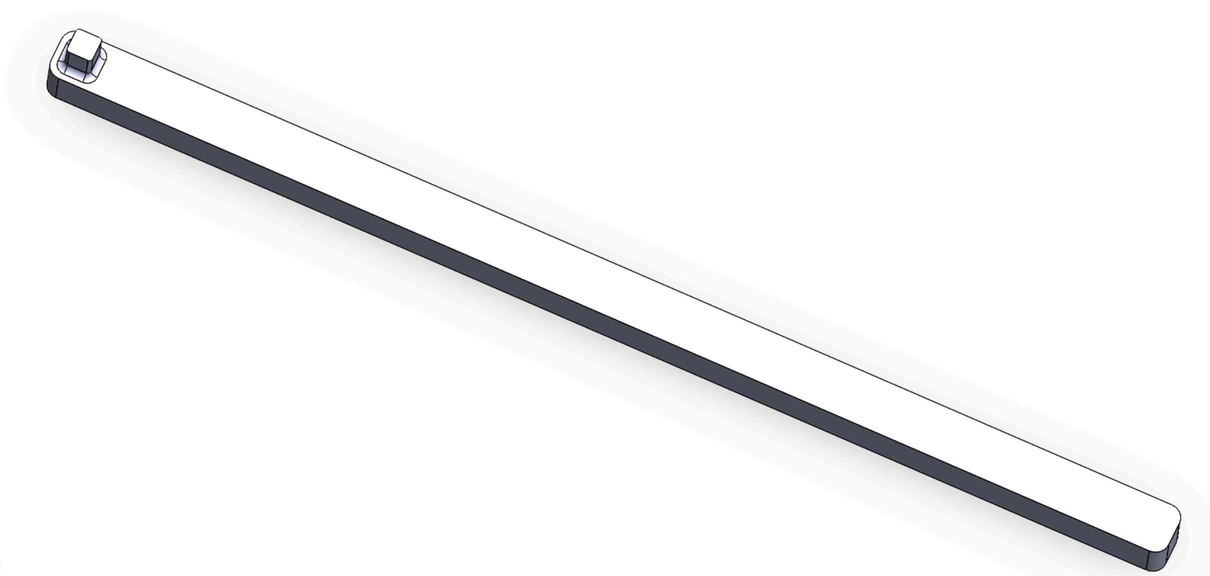
3. **How do the FEM and hand-calculated displacements compare? If they differ, why?**

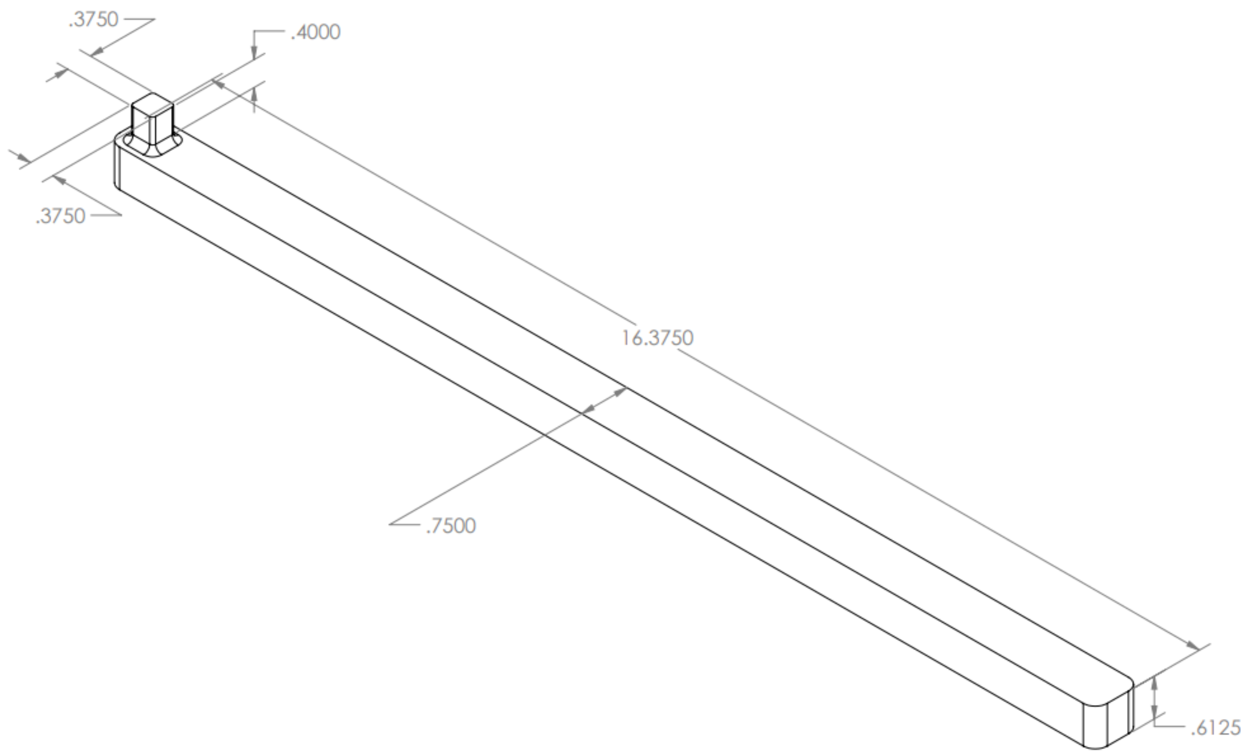
   FEM has a higher displacement than the hand calculated displacement. This is likely due to the boundary conditions in ANSYS being different from pure bending. The clamped area is a smaller area than that of the full beam, resulting in more deflection. Due to the drive being offset from the force application point, the drive is also experiencing torsion. This can also lead to increased total deflection of the end of the handle as it is the combined bending and torsional deflection.

5.2 Your Design

5.1.2 Reflections

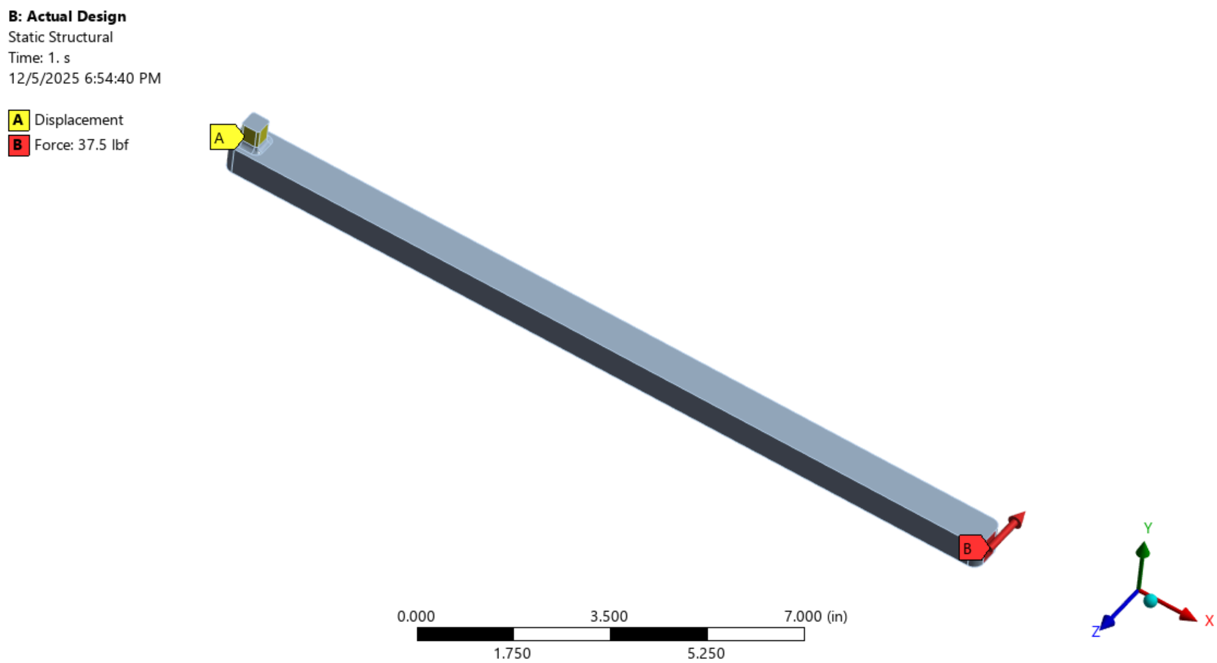
1. **Images of your CAD Model**



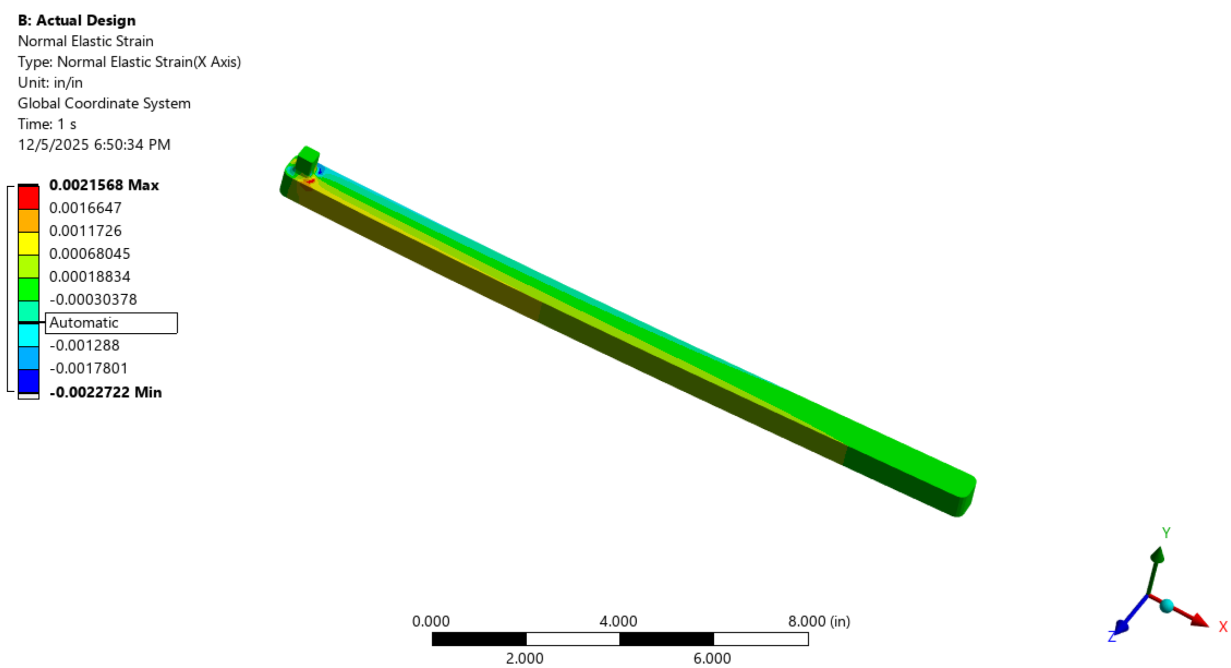


2. **Describe material used and its relative mechanical properties**
   Aluminum 6061 T6 was chosen, a common aluminum alloy with a relatively high modulus and yield strength. This alloy's properties were acquired from Granta – elastic modulus: 9.66 * 10 ^6 psi; poisson's ratio: 0.325; yield strength: 42.1 * 10^3 psi. The rest of the material properties are in the above Matlab script.

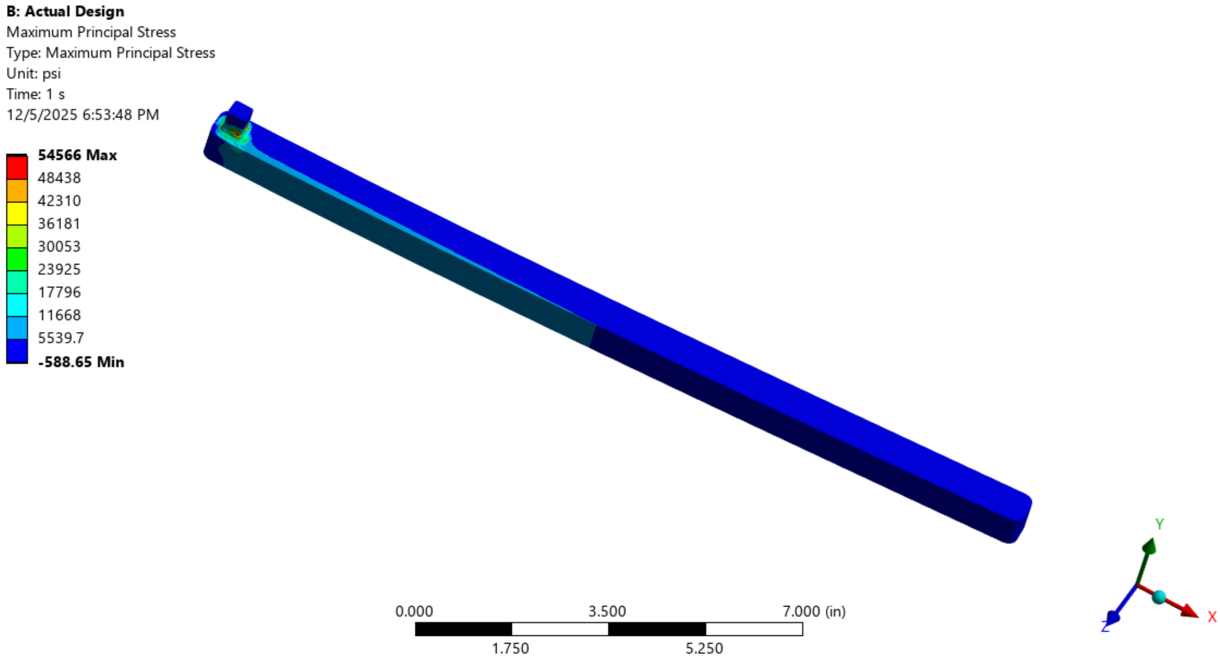
3. **Diagram communicating how loads and boundary conditions were applied to your ANSYS model**



4. Normal strain contours



5. Contour plot of maximum principal stress



6. Summarize results from FEM

FEM Results	
Strain at Gauge Location [microstrain]	988.7
Maximum Normal Stress [psi]	25064
Maximum Deflection [in]	0.3423

7. Torque wrench sensitivity

```
Sensitivity [mV/V] = gauge_strain [microstrain] /1000
                    = 988.7/1000
Sensitivity [mV/V] = 0.9887
```

8. Strain gauge selected

A rosette strain gauge will be used (0°, 45°, 90°) since it will provide accurate reading of the torque wrench in multiple directions. The gage dimensions are 3mm by 1.7mm and the carrier dimensions are 11mm by 11mm (0.433 inches) which will easily fit on the strain gauge and the gauge can be bonded onto the flat surfaces of the shaft. Gauges with these dimensions are sold by DwyerOmega.