Final HW Part 2- Your Design

Wednesday, December 10, 2025   4:45 PM

```
%my design analysis parameters (changed for design iterations):
M = 600; % max torque (in-lbf)
L = 16; % length from drive to where load applied (inches)
h = .795; % width
b = 0.568; % thickness
%YES THESE DECIMALS ARE NESSECARY IT WAS SO CLOSE
%irl you wouldn't be able to hit these tolerances
c = 0; % distance from center of drive to center of strain gauge
E = 10.E6; % Young's modulus (psi)
nu = 0.33; % Poisson's ratio
su = 41.E3; % tensile strength use yield or ultimate depending on material (psi)
KIC = 26.E3; % fracture toughness (psi sqrt(in))
sfatigue = 16.e3; % fatigue strength for 10^6 cycles
name = 'Aluminum 6061'; % material nam
crack_length = .04;

%calculations:

% force applied to create max torque:
F = M/L;
% bending moment at gauge:
M_gauge = F*(L-c);

% moment of inertia of cross section:
I = (b*h^3)/12;
%distance from neutral axis:
y = h/2;
% max normal stress from my/i
stress = M*y/I;
% normal stress at gauge
gauge_stress = M_gauge*y/I;
%strain gauge params
strain = gauge_stress/E;
sens = strain*1000;
%yield safety factor
x0 = su/stress;
%fracture safety factor
%geometry factor =1.12
KI = 1.12*stress*(3.14*crack_length)^0.5;
xk = KIC/KI;
%fatigue safety factor
xf = sfatigue/stress;
%tip deflection (formula for cantilever beam)
delta_tip = F*L^3/(3*E*I);

%print results
disp("stress and deflection analysis")
disp("load point deflection = " + delta_tip+" in")
disp("max normal stress = " + stress/1000 +"ksi")
disp(" ")
disp("safety factor results")
disp("strength safety factor = " + x0)
disp("crack growth safety factor = " + xk)
disp("fatigue safety factor = " + xf)
disp(" ")
disp("strain gauge results")
disp("strain at gauge = " + strain*10^6 +" microstrain")
```

```
disp("output = " + sens+ " mv/V using half bridge")
```

stress and deflection analysis
load point deflection = 0.21528 in
max normal stress = 10.0281ksi

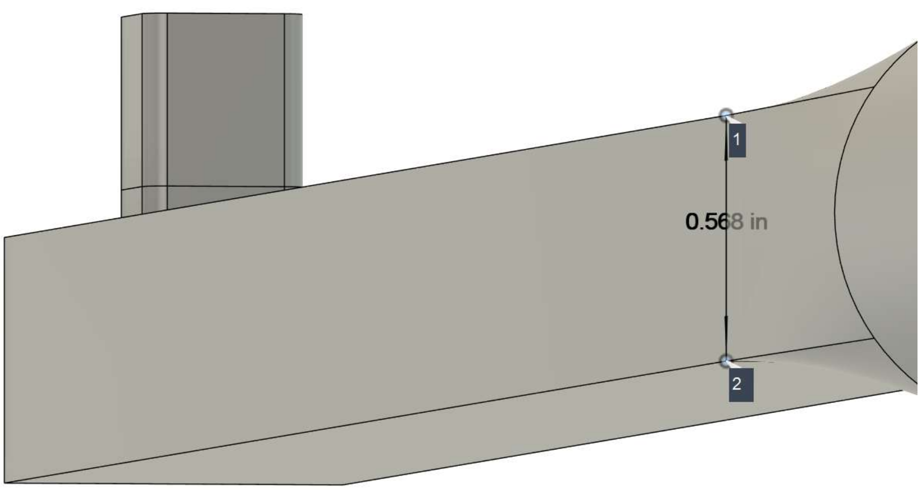
safety factor results
strength safety factor = 4.0885
crack growth safety factor = 6.5319
fatigue safety factor = 1.5955

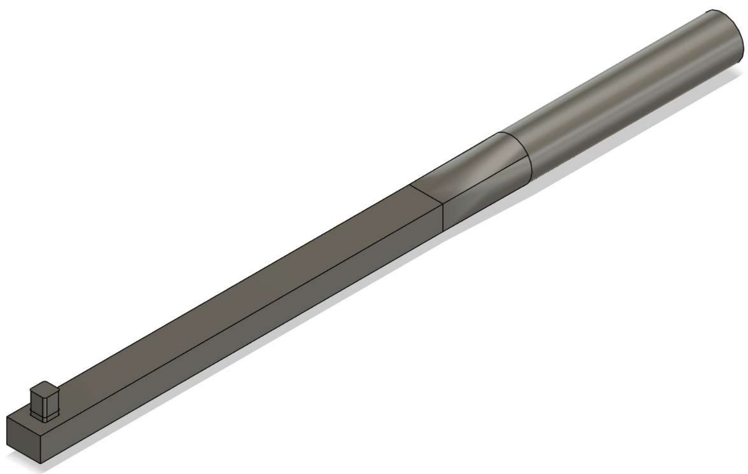
strain gauge results
strain at gauge = 1002.8129 microstrain
output = 1.0028 mv/V using half bridge

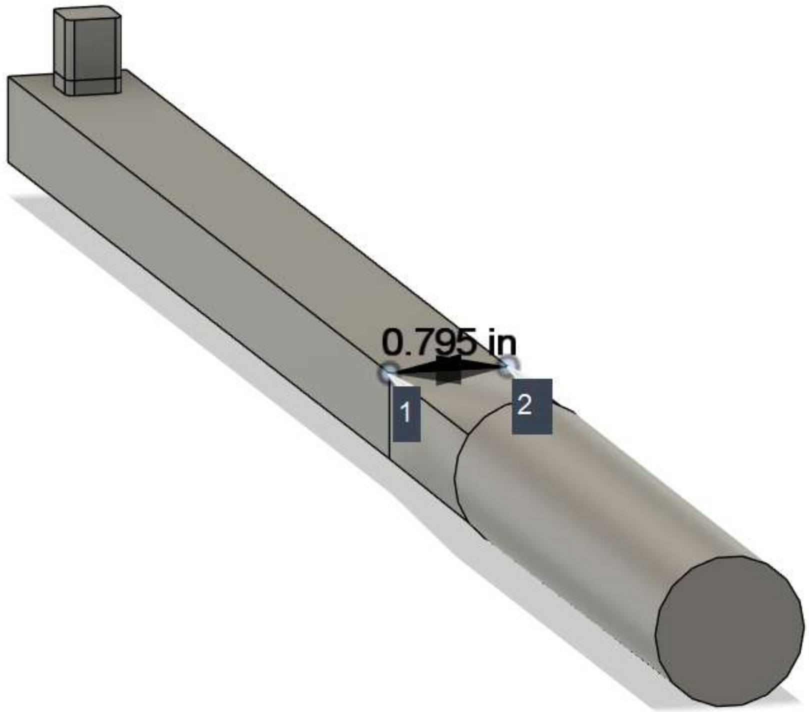
Design meets all specs. Design is similar geometry, different dimensions and Aluminum 6061 instead of M42 Steel

1) Images of CAD

Note: I stuck with a rectangular cross-section to make analysis simple, and optimized dimensions. I added a circular handle but didn't acknowledge this in calcs because there is low stress in that region.

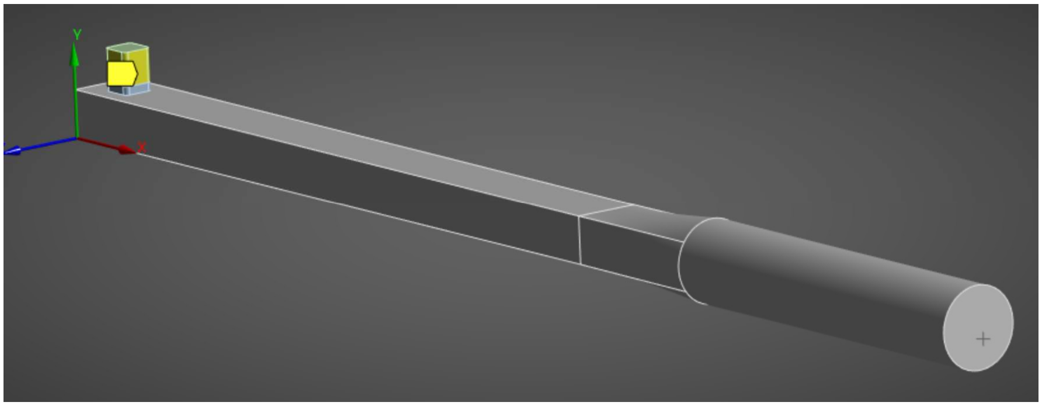


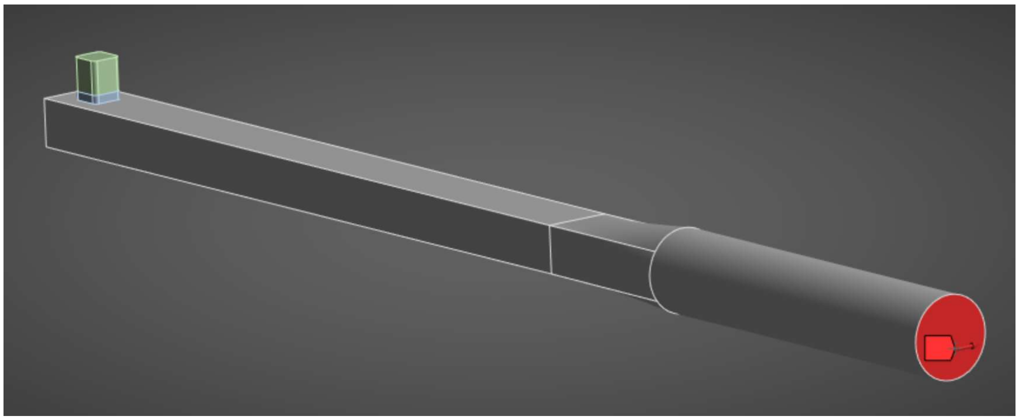




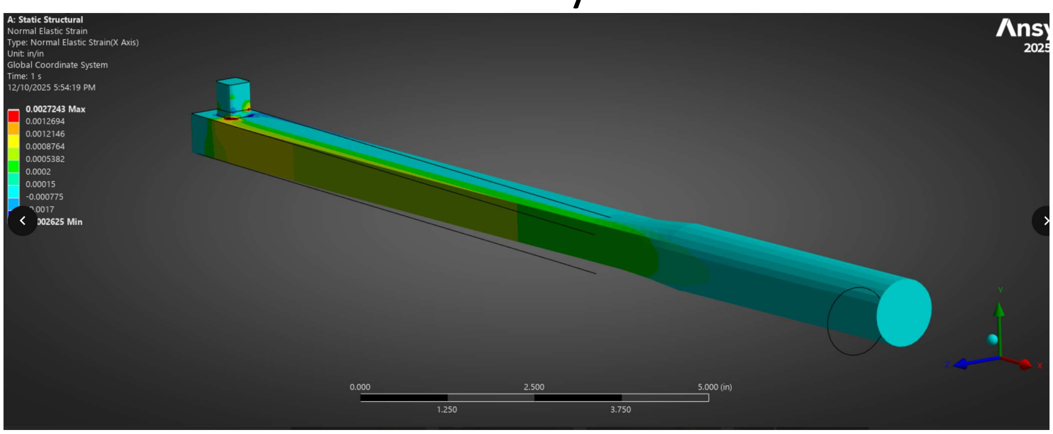
2) I used aluminum 6061 in this analysis. The main reason I used this is it has a lower elastic modulus, which allows a higher sensitivity in the strain gauge. There are some nice properties of aluminum though. It is very cheap and widely available, as well as easy to machine. It is also very ductile and less stiff (lower E) than steel, which reduced fracture likelihood.

3) Clamped condition on drive and force on face:

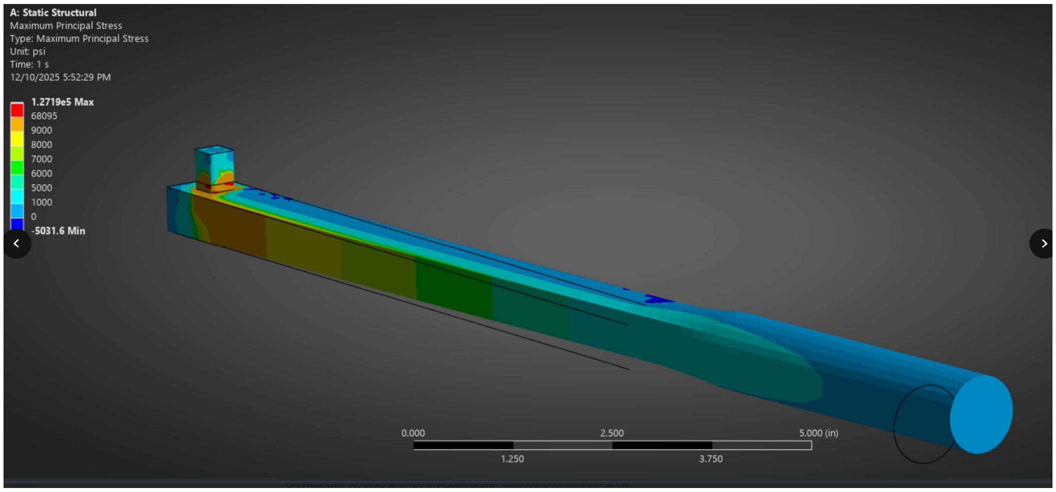




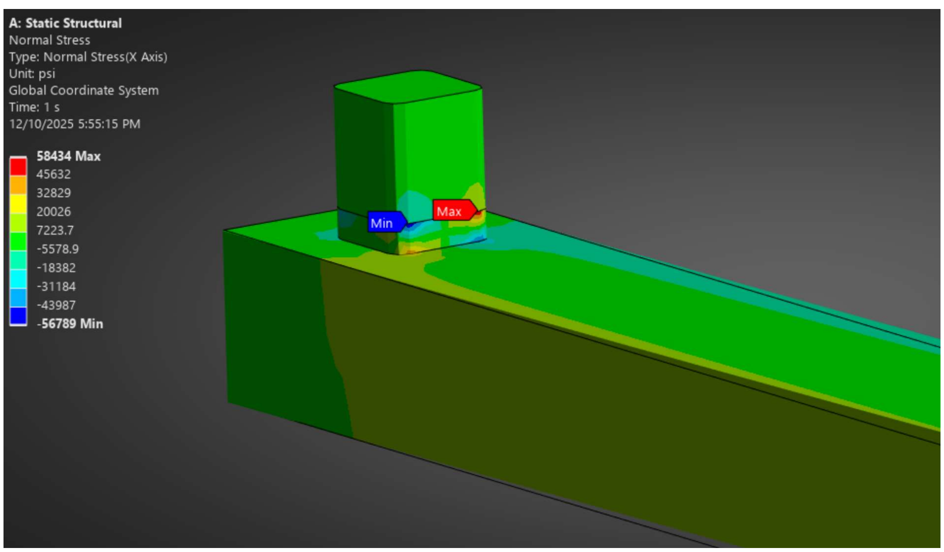
4) Note I changed the isocontour distribution for visibility:

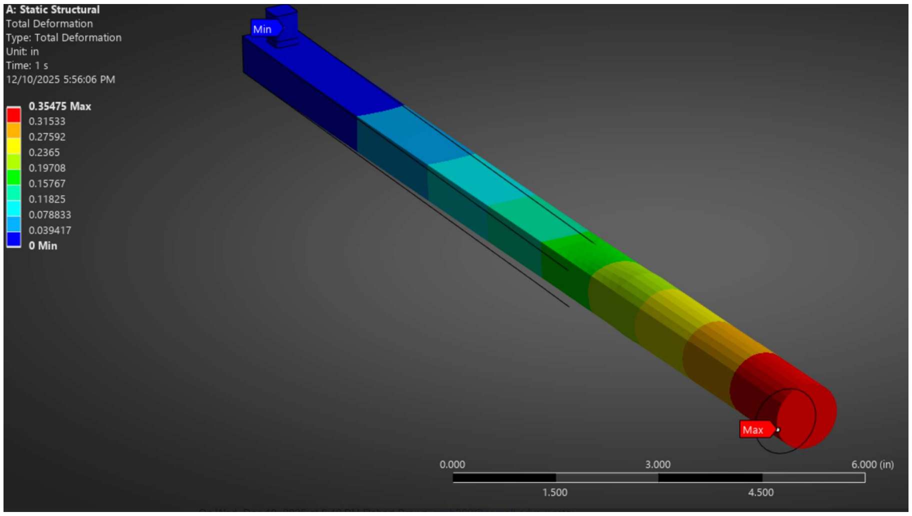


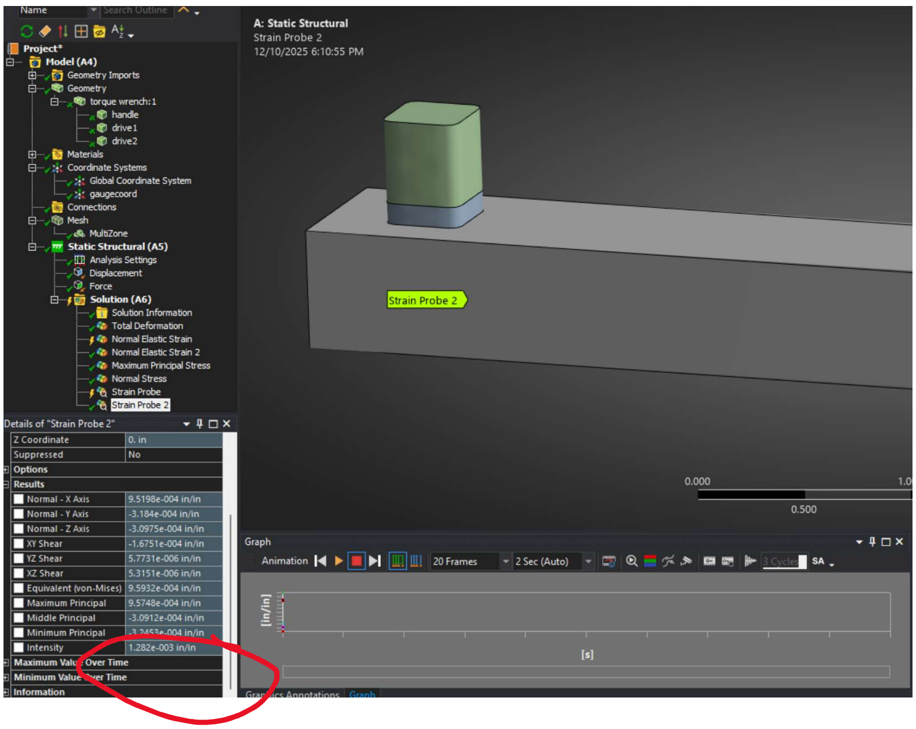
5) Same with this one:



6) Max normal stress, load point deformation, and strain at gauge location. Note that I placed the gauge directly in line with the drive. This was creating some weird singularity so I moved it over a very small amount.







7) Using the previous screenshot, we can see that the sensitivity at the strain gauge is .95 mV/V. This is very close to the desired value and might me due to me slightly moving the strain gauge.
8) I would use bonded foil strain gauges arranged in a full-bridge. From research, the gauge factor must be double the sensitivity. This setup has GF = 2 > 2*.95. I could use a .25"x.25" form factor that would fit in the

space needed.

6) Notes to think about:

I mitigated stress concentration by lofting the square cross-section to the circular cross-section. There was still stress-concentration in the drive though. This could be solve with a fillet but I was worried that this would shorten the clamped area which could cause problems.