Rigging Tensiometer Project

Team 9:
Hope Ashworth, RJ Barton, Dan Brogan,
Nolan Burkholder, Gianni Figueroa

Abstract

Purpose: Create a product that uses strain gages to transduce mechanical energy into electrical energy in a useful and creative way

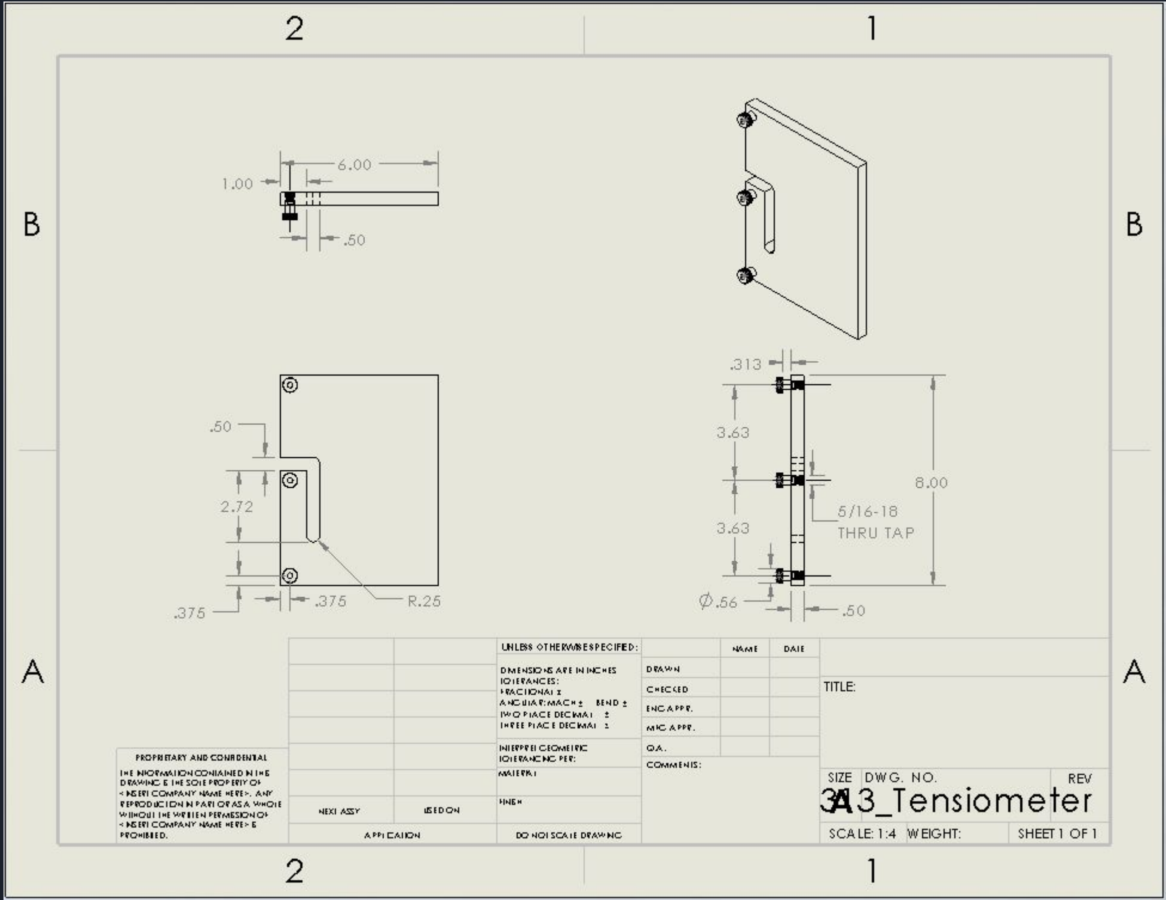
Product: Rigging Tensiometer used to determine the force in mast stay rigging cables

Project Scope:

- Designed Rigging Tensiometer by deriving equations for its design
- Constructed Tensiometer from aluminum block and shoulder screws
- Conducted testing with Instron and P3 Indicator
- Compared observed strain to theoretically predicted strain
- Compared observed strain to Finite Element Analysis

Design Theory

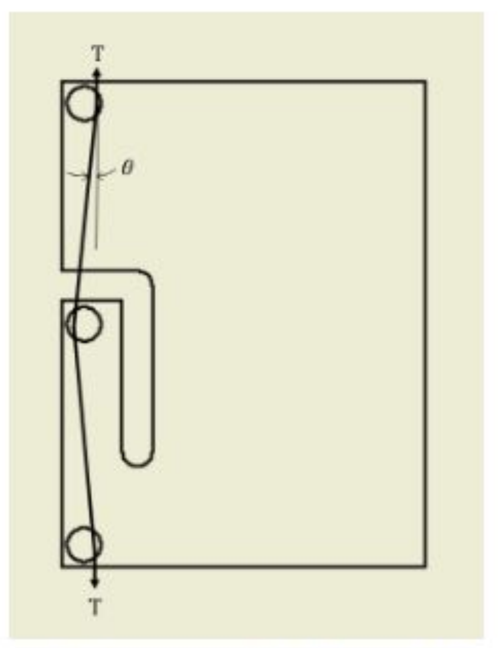
- Used principles from Mechanics of Materials to derive equations for the design of the Tensiometer
- Designed to withstand **2,000lbf** of cable tension with a safety factor of **2.99**

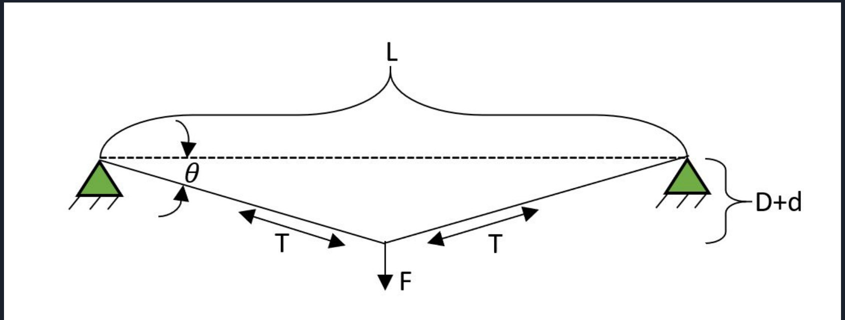


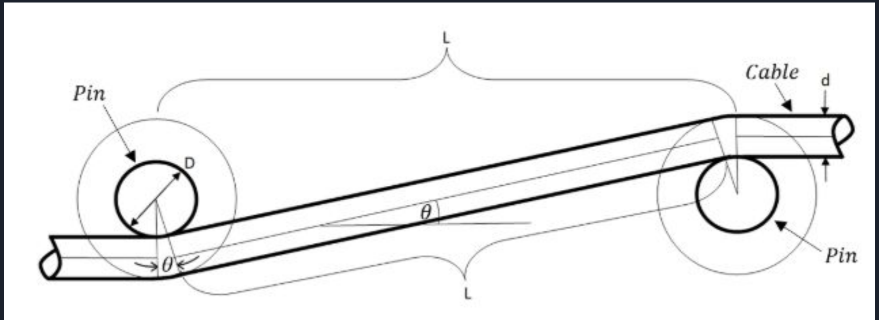
Data Prediction Theory

- The diagrams shown in addition to strain gage theory were used in the derivation of equations to relate an input tension to a strain

$$|\varepsilon| = \frac{6(2T\sin(\theta))(l_c - x)}{Eth^2}$$

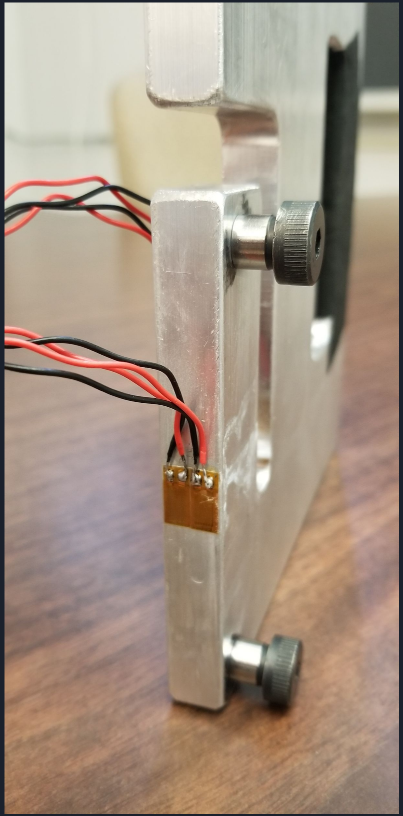


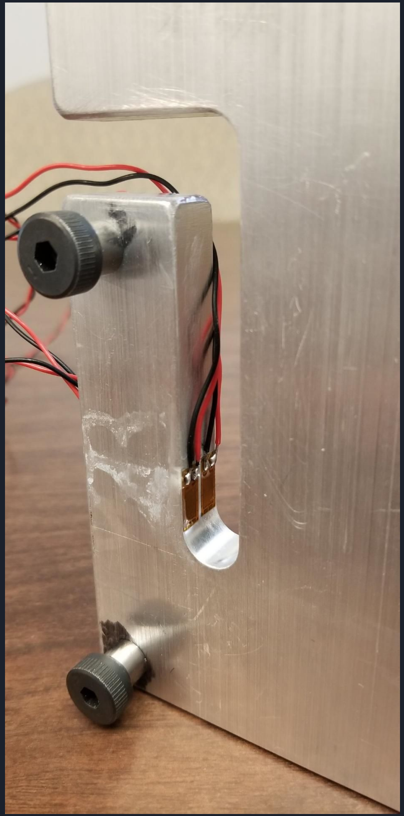


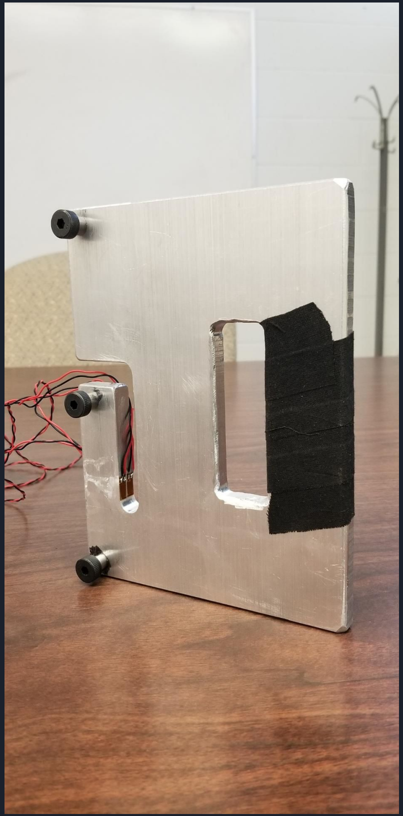


Construction

Final Product

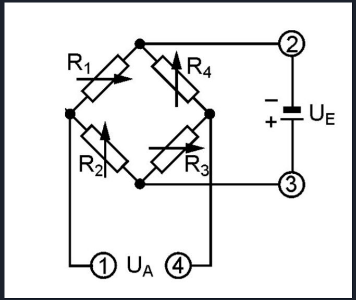


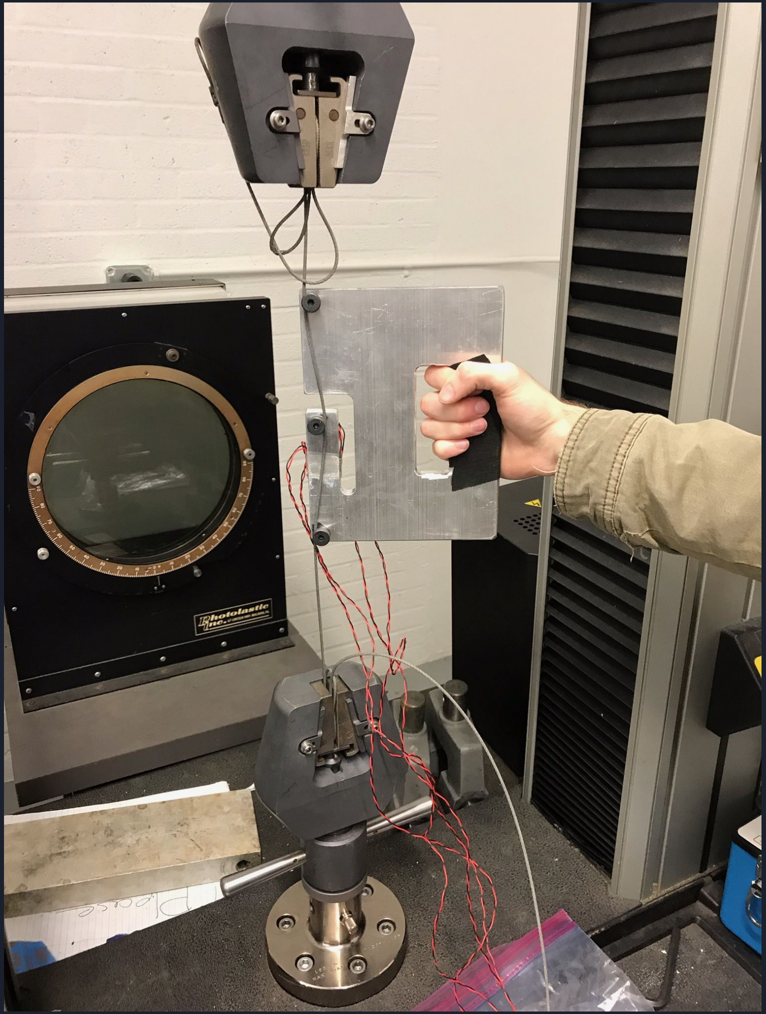




Procedure

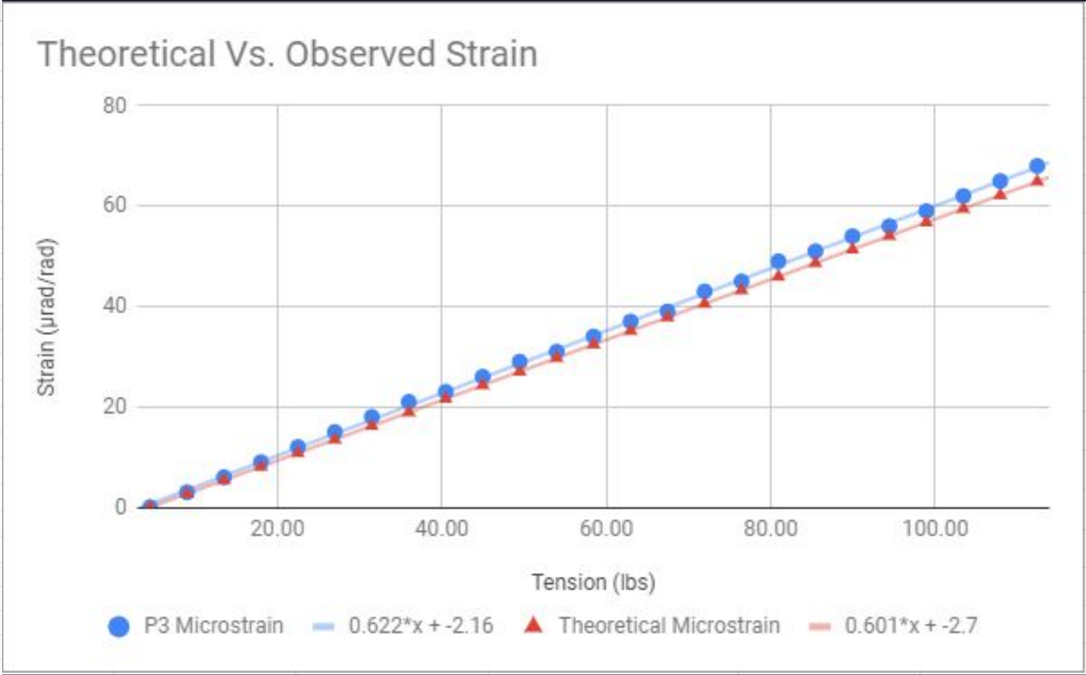
1. Turn on the Instron
2. Insert rigging cable into load cells
3. Thread cable through shoulder screws as shown
4. Zero the instron force and displacement values on adjacent monitor
5. Connect the four strain gages to the P3 indicator in full bridge formation as shown in the circuit diagram
6. Increase the load 20N and record strain
7. Repeat data collection for 25 data points





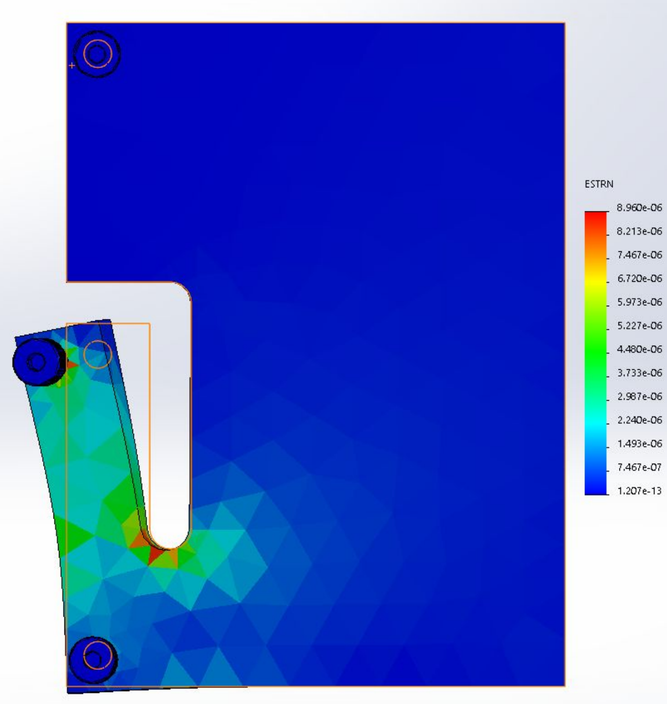
Theoretical Vs. Observed Strain

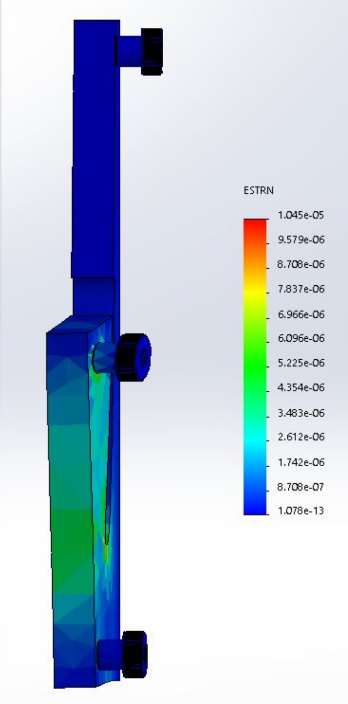
	A	B	C
1	**Input Parameter**		
2	L (in)	7.25	Outer pin center to center distance
3	D (in)	0.375	Pin diameter
4	d (in)	0.09375	Cable Diameter
5	t (in)	0.5	Plate thickness
6	r	2	Ratio of h/t
7	G (in)	0.492126	Effective strain Gage Length
8	T (lb)	4.5	Trial tension value
9	E (psi)	1.00E+07	Modulus of elasticity
10	σy (ksi)	36	Yield strength
11	x (in)	0.4063	Location of strain gage centroid
12		Note: x = 0.340 lines up the trendlines	
13	**Output Values**		
14	lc (in)	2.344	Length of cantilever
15	h (in)	1	Cantilever x-sect height
16	I (in^4)	0.04166666667	Moment of inertia
17	Θ (rad)	0.1296734537	Fixed cable deflection angle (assumes no cantilever deflection)
18	F (lb)	1.163793103	Pin load on cantilever, due to cable tension (assuming no cantilever deflection)
19	σ (ksi)	0.02705749138	Cantilever stress at strain gages
20	ε (με)	2.71	Micro strain = 1 million times stress/modulus
21	y (in)	0.000003	Cantilever deflection
22			
23	Θ' (rad)	0.129672627	Corrected cable deflection angle by adding deflection
24	% Error	0.00%	% difference of assumed cable deflection angle and corrected cable deflection
25			
26	S	1330.500285	Safety Factor



Theoretical Vs. FEA Strain at 10lbf Cable Tension

	A	B	C
1	**Input Parameter**		
2	L (in)	7.25	Outer pin center to center distance
3	D (in)	0.375	Pin diameter
4	d (in)	0.09375	Cable Diameter
5	t (in)	0.5	Plate thickness
6	r	2	Ratio of h/t
7	G (in)	0.492126	Effective strain Gage Length
8	T (lb)	10	Trial tension value
9	E (psi)	1.00E+07	Modulus of elasticity
10	σy (ksi)	36	Yield strength
11	x (in)	0.4063	Location of strain gage centroid
12			
13	**Output Values**		
14	lc (in)	2.344	Length of cantilever
15	h (in)	1	Cantilever x-sect height
16	I (in^4)	0.04166666667	Moment of inertia
17	ϴ (rad)	0.1296734537	Fixed cable deflection angle (assumes no cantilever deflection)
18	F (lb)	2.586206897	Pin load on cantilever, due to cable tension (assuming no cantilever deflection)
19	σ (ksi)	0.06012775862	Cantilever stress at strain gages
20	ε (με)	6.01	Micro strain = 1 million times stress/modulus
21	y (in)	0.000007	Cantilever deflection
22			
23	ϴ' (rad)	0.1296716166	Corrected cable deflection angle by adding deflection
24	% Error	0.00%	% difference of assumed cable deflection angle and corrected cable deflection
25			
26	S	598.7251284	Safety Factor





Uncertainty Analysis

- Zeroing the Instron is only relative, there is no way to know when there is exactly zero force
- Out of plane bending was not accounted for in the theory
- Modulus of Elasticity is an estimate based on generally accepted values and could differ in the materials used in this experiment
- The fillet at the base of the cantilever changes its stiffness characteristics
- Friction of the cable was not accounted for in the theoretical calculation

Conclusions/Recommendations

Purpose

- To design, construct, and calibrate a full bridge strain gage transducer suitable for measuring levels of force, pressure, displacement, temperature, vibration, velocity, acceleration, etc, and to become familiarized with the use of transducers and strain gages

Was the theory supported?

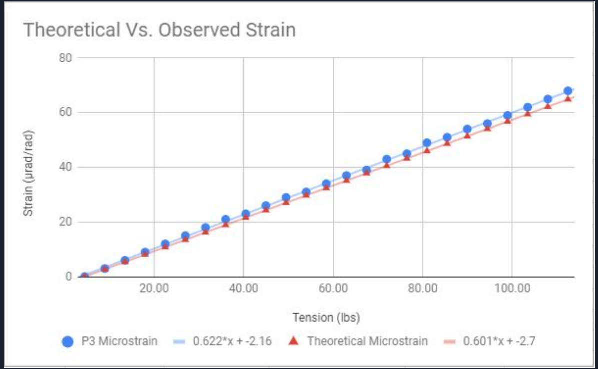
- Yes, low percent error for all calculated versus theoretical values shows that the results supported the theory

Goals Achieved

- Gained experience with several multidisciplinary engineering processes including milling, welding, CAD, finite element analysis, and circuitry
- Built a functioning tensiometer

Improvements

- Find a proper way to attach the ends of the cable to the instron; This would help ensure accuracy and eliminate erroneous readings due to securing the cables improperly



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