Morgun Werling

METC143

12/12/2018

Problem Statement: The task is to design a cable that will support a 60 ton vehicle. The cable is 25 foot long and can have an elastic deformation of no more than 10%. Using the Modulus of Elasticity for various metals design a cable. Use common cable sizes.

Introduction: The process began by taking the allowable deformation and calculating allowable strain. After calculating the allowable strain, the minimum cable diameter was calculated using the modulus of elasticity for each material. Stress calculations for the amount of stress caused by the 60 ton vehicle on all common cable diameters was then calculated for the purpose of constructing a plot. Finally, a thermal analysis was conducted for two of the more common materials (aluminum and steel), to show the change in length of the 25ft cable from zero to three hundred degrees Fahrenheit.

Results:

1) Material information

2014-T6 ALUMINUM		
ELEMENT		COMPOSITON
ALUMINUM		90.4 - 95 %
CHROMIUM		<= 0.10 %
COPPER		3.9 - 5.0 %
IRON		<= 0.70 %
MAGNESIUM		0.20 - 0.80 %
MANGANESE		0.40 - 1.2 %
OTHER		<= 0.05 %
OTHER, TOTAL		<= 0.15 %
SILICON		0.50 - 1.2 %
TITANIUM		<= 0.15 %
ZINC		<= 0.25 %

COPPER		
ELEMENT		COMPOSITON
COPPER	Cu	100%

1045 STEEL		
ELEMENT		COMPOSITON
CARBON	C	0.42 - 0.50 %
IRON	Fe	98.51 - 98.98 %
MANGANESE	Mn	0.60 - 0.90 %
PHOSPHOROUS	P	<= 0.040 %
SULFUR	S	<= 0.050 %

TITANIUM Ti-6Al-4V (GRADE 5) ANNEALED		
ELEMENT		COMPOSITON
ALUMINUM	Al	5.5 - 6.75 %
CARBON	C	<= 0.080 %
HYDROGEN	H	<= 0.015 %
IRON	Fe	<= 0.40 %
NITROGEN	N	<= 0.030 %
OTHER, EACH		<= 0.050 %
OTHER, TOTAL		<= 0.30 %
OXYGEN	O	<= 0.20 %
TITANIUM	Ti	87.725 - 91 %
VANADIUM	V	3.5 - 4.5 %

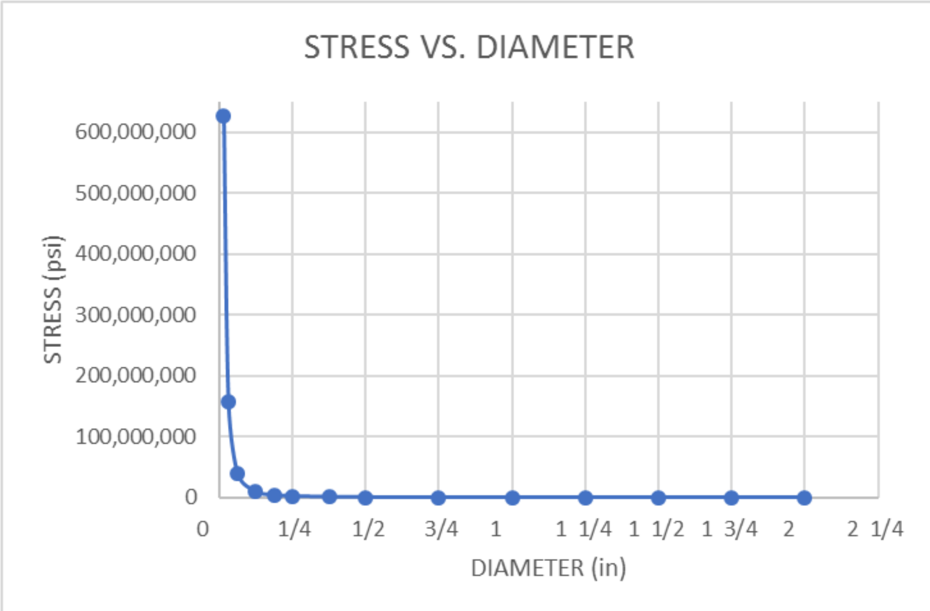
2) Calculated diameter required for each material based on modulus of elasticity.

DIAMETER REQUIRED FOR EACH MATERIAL, BASED ON MODULUS OF ELASTICITY					
INITIAL LENGTH	25	(ft)			
% DEFORMATION	10%				
MAX LENGTH TOTAL	27.5	(ft)			
LOAD	120000	(lbs)			
STRAIN	0.1	(in/in)			
MATERIAL	**MODULUS (psi)**	**AREA (in^2)**	**MIN. DIAMETER (in)**	**CABLE SIZE (in)**	
2014-T6 ALUMINUM	10,000,000	1.44	1.354055	1 1/2	
1045 STEEL	30,000,000	0.48	0.781764	1	
COPPER	15,000,000	0.96	1.1055813	1 1/4	
Ti-6AL-AV (ANNEALED)	12,000,000	1.2	1.2360774	1 1/4	

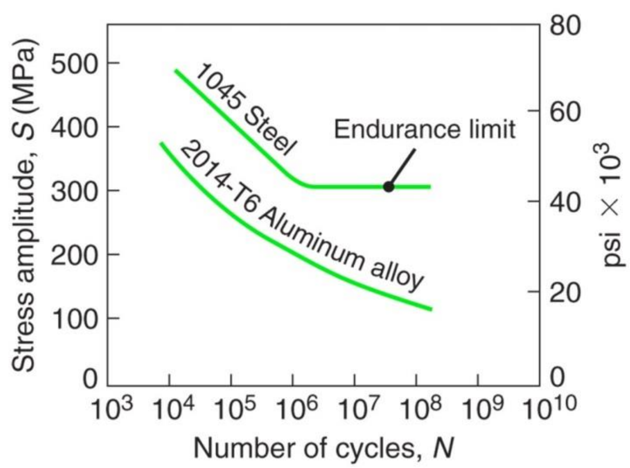
3) Stress calculations based on all common diameter sizes given in project instructions

STRESS CALCULATIONS FOR COMMON CABLE SIZES			
LOAD (lbs)	120000		
DIAMETER fractional (in)	**DIAMETER (in)**	**AREA (in^2)**	**STRESS (psi)**
2	2.000	3.141593	38,197
1 3/4	1.750	2.405282	49,890
1 1/2	1.500	1.767146	67,906
1 1/4	1.250	1.227185	97,785
1	1.000	0.785398	152,789
3/4	0.750	0.441786	271,624
1/2	0.500	0.19635	611,155
3/8	0.375	0.110447	1,086,498
1/4	0.250	0.049087	2,444,620
3/16	0.188	0.027612	4,345,991
1/8	0.125	0.012272	9,778,480
1/16	0.0625	0.003068	39,113,919
1/32	0.03125	0.000767	156,455,675
1/64	0.015625	0.000192	625,822,701

4) Stress vs diameter plot based on calculations



Fatigue Analysis:



a.

ALUMINUM CABLE DIAMETER	1.5	(in)
STEEL CABLE DIAMETER	1	(in)
LOAD	120000	(lbs)

MATERIAL	DIAMETER	RADIUS	AREA	STRESS
AL	1.5	0.75	1.767146	67,906
STL	1	0.5	0.785398	152,789

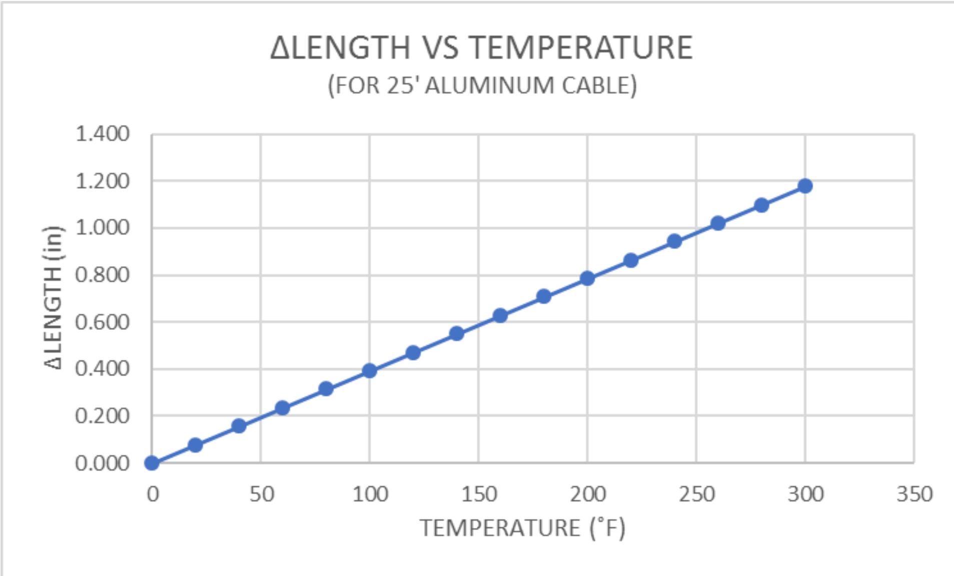
b. Given that there was no cycle requirement in the problem statement, the cable diameters that were chosen were the minimum diameter required. As a result, the selected diameters for aluminum and steel do not have a high fatigue cycle

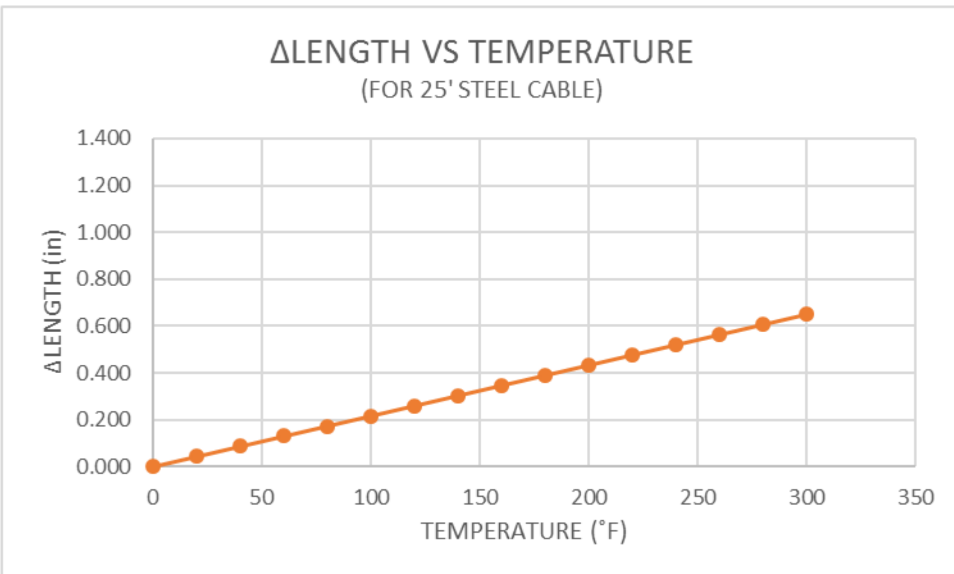
threshold. With that said, the aluminum cable will last only a few cycles (personally, I would treat this as a single-use-disposable part). The steel will last slightly longer, because the additional area added when rounding the diameter increases the fatigue cycles more than the rounding for the aluminum, since steel has a much higher modulus of elasticity. Given this, the steel cable should be able to sustain somewhere around 250 cycles (however I would suggest less than ten full cycles, without a more comprehensive study).
To summarize the point, the number of cycles that the cable can sustain is irrelevant. The project was to find the minimum diameter given certain criteria, not the minimum diameter with the given criteria, that will last X number of cycles. Final answer: The warning label on the cable should say “single use only, do not reuse”.

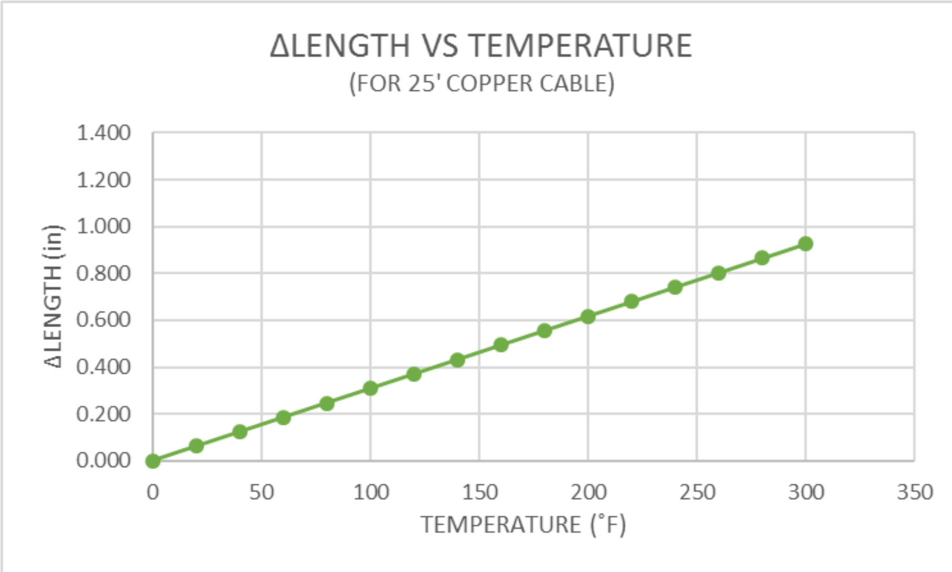
Thermal Analysis:

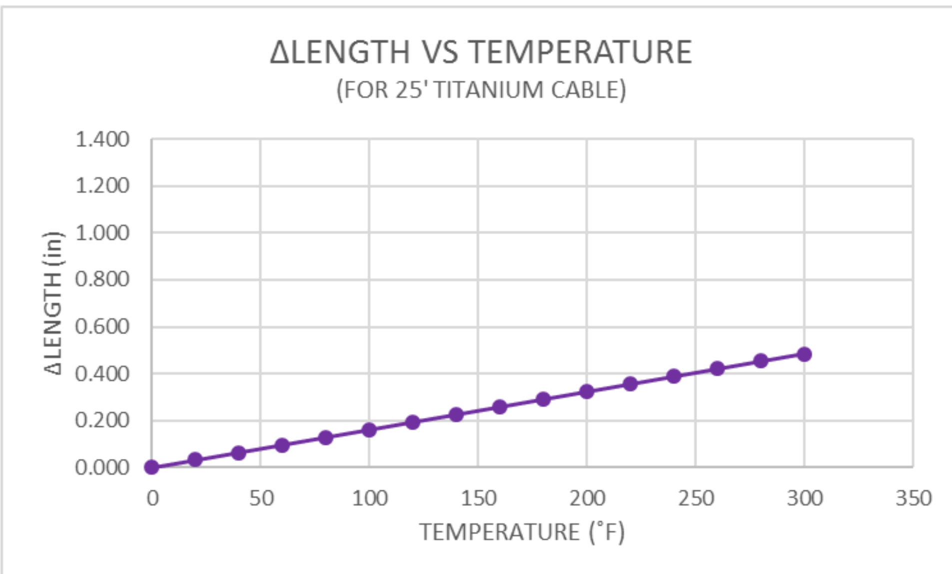
THERMAL EXPANSION COEFFICIENT	2014-T6 ALUMINUM	13.1E-6	(in/in-˚F)
	1045 STEEL	7.2E-6	(in/in-˚F)
	COPPER	10.3E-6	(in/in-˚F)
	Ti-6AL-AV (ANNEALED)	5.4E-6	in/in-˚F
CABLE LENGTH (L)		300	(in)
AMBIENT TEMPERATURE		70	(˚F)
TEMPERATURE INCREMENT		20	(˚F)

TEMPERATURE (˚F)	THERMAL EXPANSION (in)			
	ALUMINUM	STEEL	COPPER	TITANIUM
0	0	0	0	0
20	0.079	0.043	0.062	0.032
40	0.157	0.087	0.124	0.065
60	0.236	0.130	0.185	0.097
80	0.314	0.173	0.247	0.129
100	0.393	0.217	0.309	0.162
120	0.472	0.260	0.371	0.194
140	0.550	0.303	0.433	0.226
160	0.629	0.347	0.494	0.259
180	0.707	0.390	0.556	0.291
200	0.786	0.433	0.618	0.323
220	0.865	0.477	0.680	0.356
240	0.943	0.520	0.742	0.388
260	1.022	0.563	0.803	0.420
280	1.100	0.606	0.865	0.453
300	1.179	0.650	0.927	0.485


ΔLENGTH VS TEMPERATURE
(FOR 25' ALUMINUM CABLE)
ΔLENGTH (in)
TEMPERATURE (˚F)
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
50
100
150
200
250
300
350


ΔLENGTH VS TEMPERATURE
(FOR 25' STEEL CABLE)
ΔLENGTH (in)
TEMPERATURE (˚F)
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
50
100
150
200
250
300
350





Conclusion:

1) As a preface to the explanation of diameter choices, it is important to note that the problem statement stated that the cable only had to be able to support a 60 ton vehicle. There was no cycle requirement, cost requirement, or size requirement. The calculated diameters were found under the assumption of no outside forces other than the gravitational force of the vehicle. The cables are calculated to support the vehicle, without the intent to support it more than once.
   The cable with the smallest diameter is steel at 1". This is because it has the highest modulus of elasticity, at 30 million psi. The copper and titanium cables tied for the second and third smallest diameter at 1 ¼". The copper has a modulus of elasticity of 15

million psi, and the titanium has a modulus of elasticity of 12 million psi. Both materials required a cable size of larger than 1" and were able to be rounded up to 1 ¼". The aluminum cable required the largest diameter at 1 ½". Aluminum has a low modulus of elasticity for a structural material, at 10 million psi. Because of this, the aluminum cable required a minimum diameter of approximately 1.36" which is rounded up to 1 ½" to allow for a common cable size to be used.

2) Out of the four materials analyzed, the steel cable is the obvious choice. There are multiple reasons that steel is the most appropriate material. The first reason is availability. Steel is much easier to purchase in cable form than any metallic material available for structural purposes. The second is that steel is the cheapest of the four materials used in this project. Cost is always a consideration, and more expensive materials should only be used when there is a benefit. The third reason, is that there is no requirement for corrosion resistance. The fourth reason, is that the steel cable will work harden far slower than copper and aluminum, and titanium is too rigid. The appeal of a cable is that it can flex in multiple directions, while remaining lighter than a chain of the equivalent strength. If the material work hardens too easily, the flexible design of a cable becomes too brittle and rigid with use.