Project (#2): Metallic Materials – Stress and Strain Failure Analysis

Due Date: Upload zip folder to TED by 11:58 PM, Friday March 13, 2020

<u>Files in your MATLAB Folder:</u>
Download from TED: SE160A_2_Metallics_Input.xlsx
Download from TED: SE160A_2_Metallics_Output.xlsx
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<u>Your created (m) file:</u>
For Undergraduate Students: SE160A_2_LastName_FirstName.m
For Graduate Students: SE260A_2_LastName_FirstName.m

<u>Analytical Study answers are saved in a (pdf):</u>
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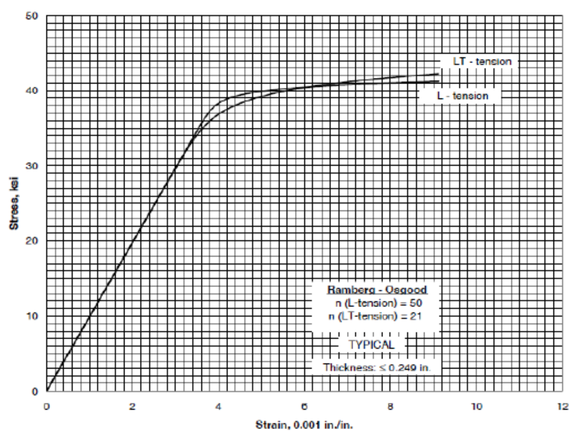
Metallic materials (for example, steel, aluminum, titanium) are used in the aerospace industry. These materials are characterized as being isotropic with a well-defined elastic (linear) region, a yield point (yield strength), followed by a plastic region before failure (ultimate strength). Since an aerospace structure must perform in the linear elastic region with an adequate safety margin for both yielding (permanent deformation) and breakage, the concept of a minimum allowable material strength is introduced. This allowable strength, along with one of the accepted failure criteria is used by aerospace structural engineers to determine the safety of the structure. Finally, this calculated margin of safety (*MS*) can be used to scale the applied loads so that (*MS*=0).



In this project, you will develop a MATLAB program that will:

1) Read in user-defined yield and ultimate, A-Basis and B-Basis, tension, compression, and shear strength properties.
2) Read in a user-defined yield and ultimate safety factors and determine the material allowable tension, compression, and shear stress (σ_T*, σ_C*, τ*) and tension, compression, and shear strain (ε_T*, ε_C*, γ*) properties.
3) Read in a user-defined three dimensional stress state and calculate the principal stresses (σ_{p1}, σ_{p2}, σ_{p3}), the maximum shear stress (τ_{max}), and draw the three-dimensional Mohr's circle. Then calculate the A-Basis and B-Basis Margins of Safety (MS) using the three different strength failure criteria (Rankine, Tresca, and von Mises). For the Tresca Criteria, if the stress element is in pure tension (σ_{p1}, σ_{p2}, $\sigma_{p3} > 0$), then the added shear stress equation involves checking (τ*) and (σ_T*/2), if the stress element is in pure compression (σ_{p1}, σ_{p2}, $\sigma_{p3} < 0$), then the added shear stress equation involves checking (τ*) and (|σ_C*|/2), if the stress element is in mixed tension-compression, then the added shear stress equations involves checking (τ*) and (σ_T*- σ_C*)/4. Finally, calculate the three-dimensional stress state at failure (*MS* = 0) by scaling the initial stress state.
4) Read in a two-dimensional strain states from a defined rosette, then calculate the two dimensional surface strains and apply the Saint Venant failure theory to calculate the margin of safety (MS).

ANALYTICAL STUDY (Use your MATLAB code to answer questions and submit using pdf file)

1.) A spinning engine rotor blade with centrifugal forces acting in the x-direction has stress state given by (σ_{xx} = 90,000 lb/in^2, $\sigma_{yy} = \sigma_{zz} = \tau_{xy} = \tau_{xz} = \tau_{yz}$ = 0 lb/in^2). The rotor is fabricated with Ti-6Al-4V (solution treated). The material stiffness properties were measured as (E = 16.0 x 10^6 lb/in^2, ν = 0.31) and 15 material coupon tests were performed to determine the A- and B-basis strength properties (see Table 1). The yield and ultimate safety factors are 1.10 and 1.50, respectively.
   a.) Calculate the A- and B-Basis allowable strength properties.
   b.) Calculate the Margin of Safety (*MS*) using the Tresca, Rankine, and Von Mises failure theories for both the A- and B-Basis allowable strength properties.
   c.) Scale the stress state so that (*MS* = 0) for the B-Basis strength properties based upon the Von Mises failure theory.

2.) Engineers at the aircraft engine company of problem (#1) are investigating the use of new nano-material technology to alter the stress state of the spinning rotor blade for the purpose of increasing the MS.
   a.) What is the MS if the spinning blade stress state is altered to (σ_{xx} = 90,000 lb/in^2, $\sigma_{yy} = \sigma_{zz}$ = -30,000 lb/in^2, $\tau_{xy} = \tau_{xz} = \tau_{yz}$ = -20,000 lb/in^2). Use B-basis allowables and the von Mises Failure Criteria.
   b.) What is the MS if the spinning blade stress state is altered to (σ_{xx} = 90,000 lb/in^2, $\sigma_{yy} = \sigma_{zz}$ = +30,000 lb/in^2, $\tau_{xy} = \tau_{xz} = \tau_{yz}$ = +20,000 lb/in^2). Use B-basis allowables and the von Mises Failure Criteria.

Table 1: Strength Properties for Ti-6Al-4V (solution treated) - Experimentally Measured

Property	A-Basis	B-Basis	S-Basis	Units
σ_{Ty}	136	143	145	Ksi
σ_{Tu}	151	158	160	Ksi
σ_{Cy}	-140	-150	-150	Ksi
σ_{Cu}	-155	-161	-165	Ksi
σ_{Sy}	86	89	91	Ksi
σ_{Su}	95	100	100	Ksi

3.) A uniform bar is subjected to an axial force and a shear force. Students apply four strain gage rosettes along the bar length and then measure strains (ε_a, ε_b, ε_c).
   a.) Calculate the structural strains (ε_{xx}, ε_{yy}, γ_{xy}) for the four gages.
   b.) It was suspected that maybe the 3rd and 4th gages were orientated incorrectly since their results did not closely matched the strain gage (#2) results. A visual examination revealed that both gages were incorrectly positioned, but the observed angle could not be determined. Calculate the mis-alignment angle of gages (#3) and (#4).

	Rosette Type			*Measured Strains (μ in/in)*		
(#)	θ_a	θ_b	θ_c	ε_a	ε_b	ε_c
1	0^o	45^o	90^o	1000.0	600.0	-300.0
2	0^o	60^o	120^o	1000.0	241.5	-191.5
3	0^o	60^o	120^o	946.7	362.6	-259.3
4	0^o	60^o	120^o	1033.5	123.7	-107.2