Project Points:	
Spar Analysis Function:	400 points
Write-Up:	200 points
Total:	600 points

MATLAB Project: Bending, Torsion, and Shear Analysis of a Thin-Wall Circular Spar
Due Date: Upload zip folder to Canvas by 11:58 PM, Wednesday February 21, 2024

Files in CANVAS ZIP folder. Extract and put into your MATLAB folder:

Spar_Analysis_Main.p	Kosmatka Spar Analysis Main Code (encrypted p-version)
Spar_Analysis_Function.p	Kosmatka Spar Analysis Function (encrypted p-version)
Spar_Analysis_Function (Student Skeleton).m	Recommended Spar Function Starter Code
Spar_Analysis_WriteUp.pdf	Project Write Up (Version 1)
SE160A_1_Spar_Analysis_Input.xlsx	Spar Analysis Excel Input File (Sample)
SE160A_1_Spar_Analysis_Input (BackUp).xlsx	Spar Analysis Excel Input File (Backup)
SE160A_1_Spar_Analysis_Input (Blank).xlsx	Spar Analysis Excel Input File (Blank)
SE160B_1_Spar_Analysis_Output.xlsx	Spar Analysis Excel Output File (Sample)
SE160B_1_Spar_Analysis_Output (Blank).xlsx	Spar Analysis Excel Output File (Blank)

On or before February 21st, 2024, you will load the following two files into a zip folder and then upload the zip folder to the SE-160A Canvas Gradescope Account.

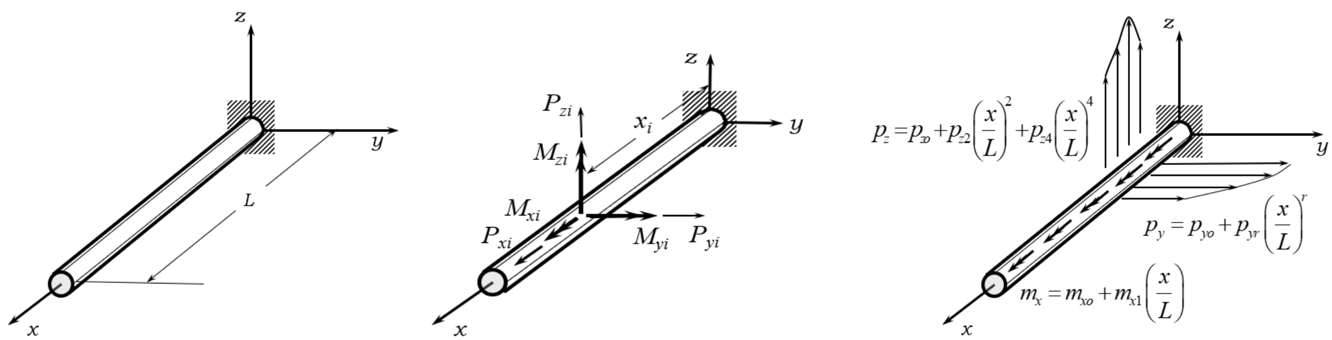
SE160A_1_LastName_FirstName.zip	Zip Folder
SE160A_1_LastName_FirstName.m	Your Spar Analysis Function
SE160A_1_LastName_FirstName.pdf	Your solutions to answered questions and design studies.

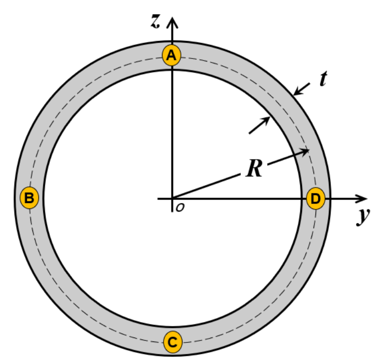
Introduction:

The success of human powered flight depends upon the development of an extremely lightweight efficient aircraft along with a pilot having outstanding pedaling power. These aircraft typically weigh less than 50 lbs. and past historical successes include crossing the English Channel (approx. 25 miles) or flying from the Greek island of Crete to Santorini (70 miles). US universities that have led this development include Caltech and MIT. The main wing is typically comprised of an advanced composite thin-wall main spar, small leading edge (*LE*) and trailing edge (*TE*) spars, numerous composite wing ribs, and a thin mylar skin. The main spar is designed to take both the aerodynamic lift and drag loads as well as any torsion loads that may result from the in-flight loads. Ideally one would strive to achieve an acceptable (*MS*> 0) along the spar length for the worst case load envelope. Successful aircraft have been built with a ***main spar having a thin-wall circular cross-section.*** YouTube video examples of human-powered flight.

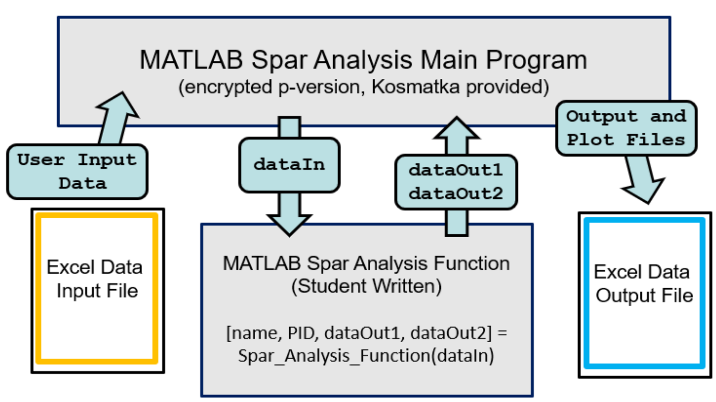
https://www.youtube.com/watch?v=4GTZE7Xxdt0
https://www.youtube.com/watch?v=OcxZ5seDlxI

In this MATLAB project, you will write a MATLAB function that will structurally analyze a wing spar that has a thin wall circular cross-section. This spar could be used in a UAV, or a small civil aviation aircraft, or a Martian glider, or even a world-record human powered aircraft. Your MATLAB function will be general enough that either concentrated loads could be applied at two locations, or an approximate aerodynamic loading that includes a distributed lift, drag, aerodynamic torque, and maneuvering load factors. The MATLAB function will calculate the displacement and stress distribution which will be plotted along the spar length. At the root, the stresses will be calculated along with the margins of safety (MS) at four locations around the circumference (points A, B, C, and D).





The project is developed using a Spar Analysis Main Program and a student programmed Spar Analysis Function. See below. The Main Program opens an Excel input file, an Excel output file, and the Spar Analysis Function. The main program, which is written in a MATLAB encrypted p-version, takes care of all of the data input and transferring the input data to the Spar Analysis Function. Next the Spar Analysis Function performs all the data analysis and organizes the data for output and plotting. The Main Program writes the calculated data to the Excel output file, as well as generating all of the needed plots and writing them to specific locations in the Excel output file. Thus, the student only needs to focus on performing the calculations and not worry about the cumbersome book-keeping effort of reading the input data from Excel and writing/plotting the calculated data to an Excel output file.



The six goals of this project include the calculation of:

- the modulus-weighted section properties (EA, EI_{yy}, EI_{zz}, GJ) of a thin-wall circular cross-section.
- the internal load distribution of a spar subjected to concentrated loads, aerodynamic loads, and maneuvering load factors.
- The axial, shear, bending moment, and torque diagrams.
- The allowable tension stress, compression stress, and shear stress
- The root normal stress (σ_{xx}), shear stress (τ_{xy}, τ_{xz}) and margins of safety (MS) at four cross-section points
- The spar axial and bending displacement distribution, twist distribution, and bending slope distribution.

FUNCTION INPUT

```
Input Data Array: dataIn (38)

        dataIn(01):     Number of Output Plot Data Points
        dataIn(02):     Spar Length (inch)
        dataIn(03):     Mean Cross-Section Radius (inch)
        dataIn(04):     Mean Cross-Section Thickness (inch)
        dataIn(05):     Material Density (lbf/in^3)
        dataIn(06):     Material Young's Modulus (Msi)
        dataIn(07):     Material Shear Modulus (Msi)
        dataIn(08):     Material Yield Strength - Tension (Ksi)
        dataIn(09):     Material Yield Strength - Compression (Ksi)
        dataIn(10):     Material Yield Strength - Shear (Ksi)
        dataIn(11):     Material Ultimate Strength - Tension (Ksi)
        dataIn(12):     Material Ultimate Strength - Compression (Ksi)
        dataIn(13):     Material Ultimate Strength - Shear (Ksi)
        dataIn(14):     Safety Factor - Yield
        dataIn(15):     Safety Factor - Ultimate
        dataIn(16):     First Load Location (x/L)
        dataIn(17):     Concentrated Force - X Direction (lb)
        dataIn(18):     Concentrated Force - Y Direction (lb)
        dataIn(19):     Concentrated Force - Z Direction (lb)
        dataIn(20):     Concentrated Torque - About X Direction (lb-in)
        dataIn(21):     Concentrated Moment - About Y Direction (lb-in)
        dataIn(22):     Concentrated Moment - About Z Direction (lb-in)
        dataIn(23):     Second Load Location (x/L)
        dataIn(24):     Concentrated Force - X Direction (lb)
        dataIn(25):     Concentrated Force - Y Direction (lb)
        dataIn(26):     Concentrated Force - Z Direction (lb)
        dataIn(27):     Concentrated Torque - About X Direction (lb-in)
        dataIn(28):     Concentrated Moment - About Y Direction (lb-in)
        dataIn(29):     Concentrated Moment - About Z Direction (lb-in)
        dataIn(30):     Aircraft Load Factor
        dataIn(31):     Drag Distribution - Constant (lb/in)
        dataIn(32):     Drag Distribution - rth order (lb/in)
        dataIn(33):     Drag Distribution - polynomial order
        dataIn(34):     Lift Distribution - Constant (lb/in)
        dataIn(35):     Lift Distribution - 2nd Order (lb/in)
        dataIn(36):     Lift Distribution - 4th Order (lb/in)
        dataIn(37):     Twist Moment Distribution - Constant (lb-in/in)
        dataIn(38):     Twist Moment Distribution - 1st Order (lb-in/in)
```

FUNCTION OUTPUT

```
Name:              Name of student author

PID:               UCSD Student ID number

dataOut1:          Packed calculated output variable data
  dataOut1(01):    Axial   Stiffness EA   (lb)
  dataOut1(02):    Bending Stiffness EIyy (lb-in^2)
  dataOut1(03):    Bending Stiffness EIzz (lb-in^2)
  dataOut1(04):    Bending Stiffness EIyz (lb-in^2)
  dataOut1(05):    Torsion Stiffness GJ   (lb-in^2)
  dataOut1(06):    Root Internal Force - X Direction (lb)
  dataOut1(07):    Root Internal Force - Y Direction (lb)
  dataOut1(08):    Root Internal Force - Z Direction (lb)
  dataOut1(09):    Root Internal Moment - about X Direction (lb-in)
  dataOut1(10):    Root Internal Moment - about Y Direction (lb-in)
  dataOut1(11):    Root Internal Moment - about Z Direction (lb-in)
  dataOut1(12):    Allowable Stress - Tension (lb/in^2)
  dataOut1(13):    Allowable Stress - Compression (lb/in^2)
  dataOut1(14):    Allowable Stress - Shear (lb/in^2)
  dataOut1(15):    Root Axial Stress - point A (lb/in^2)
  dataOut1(16):    Root Axial Stress - point B (lb/in^2)
  dataOut1(17):    Root Axial Stress - point C (lb/in^2)
  dataOut1(18):    Root Axial Stress - point D (lb/in^2)
  dataOut1(19):    Root Shear Stress xy - point A (lb/in^2)
  dataOut1(20):    Root Shear Stress xy - point B (lb/in^2)
  dataOut1(21):    Root Shear Stress xy - point C (lb/in^2)
  dataOut1(22):    Root Shear Stress xy - point D (lb/in^2)
  dataOut1(23):    Root Shear Stress xz - point A (lb/in^2)
  dataOut1(24):    Root Shear Stress xz - point B (lb/in^2)
  dataOut1(25):    Root Shear Stress xz - point C (lb/in^2)
  dataOut1(26):    Root Shear Stress xz - point D (lb/in^2)
  dataOut1(27):    Margin of Safety - point A
  dataOut1(28):    Margin of Safety - point B
  dataOut1(29):    Margin of Safety - point C
  dataOut1(30):    Margin of Safety - point D
  dataOut1(31):    Tip Displacement  - X Direction (inch)
  dataOut1(32):    Tip Displacement  - Y Direction (inch)
  dataOut1(33):    Tip Displacement  - Z Direction (inch)
  dataOut1(34):    Tip Twist (degree)
  dataOut1(35):    Tip Bending Slope (dv/dx) (inch/inch)
  dataOut1(36):    Tip Bending Slope (dw/dx) (inch/inch)

dataOut2:          Packed calculated output plot data
  column( 1):      X direction coordinate (inch)
  column( 2):      Applied distributed drag force (lb/in)
  column( 3):      Applied distributed lift force (lb/in)
  column( 4):      Applied distributed torque (lb-in/in)
  column( 5):      Internal axial force  - Vx (lb)
  column( 6):      Internal shear force  - Vy (lb)
  column( 7):      Internal shear force  - Vz (lb)
  column( 8):      Internal axial torque - Mx (lb-in)
  column( 9):      Internal bending moment - My (lb-in)
  column(10):      Internal bending moment - Mz (lb-in)
```

```
column(11):     Axial Stress - point A (lb/in^2)
column(12):     Axial Stress - point B (lb/in^2)
column(13):     Axial Stress - point C (lb/in^2)
column(14):     Axial Stress - point D (lb/in^2)
column(15):     Shear Stress - point A (lb/in^2)
column(16):     Shear Stress - point B (lb/in^2)
column(17):     Shear Stress - point C (lb/in^2)
column(18):     Shear Stress - point D (lb/in^2)
column(19):     Displacement - X Direction (inch)
column(20):     Displacement - Y Direction (inch)
column(21):     Displacement - z Direction (inch)
column(22):     Twist (degree)
column(23):     Bending Slope (dv/dx) (inch/inch)
column(24):     Bending Slope (dw/dx) (inch/inch)
```

<u>Running the MATLAB P-code</u>

1) In your MATLAB directory include the following files:

```
SE160A_1_Spar_Analysis_Input.xlsx            Excel Input File
SE160A_1_Spar_Analysis_Output.xlsx          Excel Output File
Spar_Analysis_Main.p                   Project Main Code p-code
Spar_Analysis_Function.m        (function that you will write)
```

2) Open MATLAB in that directory
3) Make sure both the Excel input and output files are closed
4) Run the p-code. Do not try and open a (*.p) code

```
>> run Spar_Analysis_Main.p
```

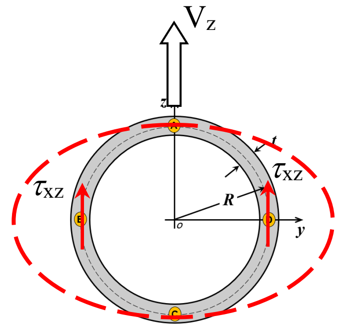
The main code will open the Excel input file, your Spar_Analysis_Function, and the Excel output file. Then the input data is passed to the function for calculation, followed by the calculated data being returned to the main program. Finally, the main program writes the data and plots to the Excel output file.

5) Open the Excel output file and review results.

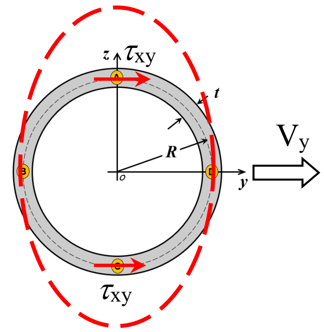
<u>Note:</u> It is recommended that you start with the Spar_Analysis_Function (student skeleton).m. This example function has lots of useful code.

<u>Note:</u> If you want to check your results, replace your Spar_Analysis_Function.m with the provided Spar_Analysis_Function.p, which was provided in your zip folder. Using the above command, run the main program, which will now call the p-version function. The correct answers are written to the output file. Save the output file for comparing with your function results.

Appendix: Additional Equation Summary



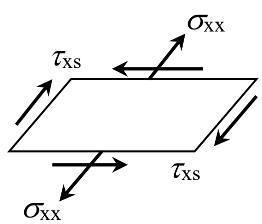
$$\tau_{xz}\Big|_b = -\frac{2\left(\frac{V_z}{2}\right)}{\pi r t}\cos\left(180^o\right) = \frac{V_z}{\pi r t}, \qquad \tau_{xz}\Big|_d = \frac{2\left(\frac{V_z}{2}\right)}{\pi r t}\cos\left(0^o\right) = \frac{V_z}{\pi r t}$$



$$\tau_{xy}\Big|_a = \frac{2\left(\frac{V_y}{2}\right)}{\pi r t}\sin\left(90^o\right) = \frac{V_y}{\pi r t}, \qquad \tau_{xy}\Big|_c = -\frac{2\left(\frac{V_y}{2}\right)}{\pi r t}\sin\left(270^o\right) = \frac{V_y}{\pi r t}$$

Von Mises Failure Criteria:

$$MS = \frac{\sigma_T^*}{\sqrt{\sigma_{xx}^2 + 3\tau_{xs}^2}} - 1$$



ANALYTICAL and DESIGN STUDIES

The analytical problems and design studies will be posted at the end of the 5^{th} week.