ME441 – Take Home Project

Spring 2023

Due Tuesday, May 9th at 5pm

Part A (20% of your grade)

Part A of this project is a conceptual quiz on content after L20. It can be found in BBlearn during finals week and before the final exam due date (shown above). You'll have 1hr to complete it whenever you like before that due date. It will be designed to be completed in 20min. **This part is an INDIVIDUAL assignment.**

Part B (80% of your grade)

This part can be worked on in teams of two students (ONLY). Please submit in your teams of two by only having one person submit into BBlearn.

You are to simulate a supersonic airfoil in MATLAB using the tools and knowledge gained in the course to date. The airfoil in question can be found in the figure below. It is a simplified airfoil for ease of programming. It is clearly an asymmetrical airfoil profile where the flow around the top needs to travel further than the flow around the bottom surface. Asymmetrical airfoils are great for gaining lift at low angles of attack for subsonic flight. We will be testing this asymmetrical airfoil's performance in supersonic flight. Hopefully through this project you will learn more about the behavior of asymmetrical airfoils in supersonic flight. Feel free to start by using the code that we have generated, or that I have shared with you, in class.

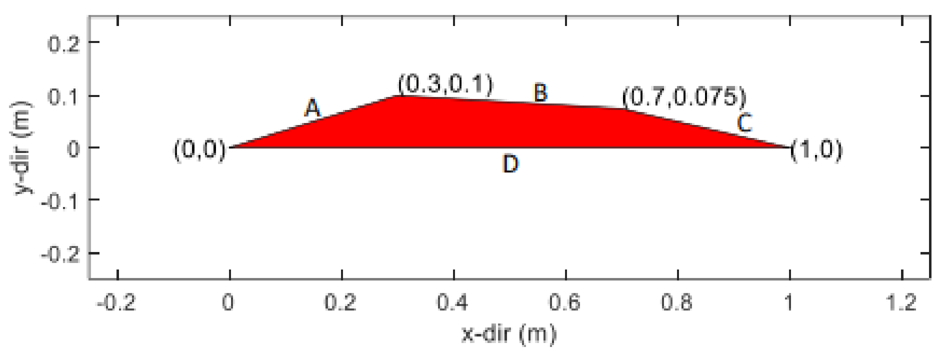

Figure 1:Simplified Airfoil

For this project, feel free to use functions built into the aerospace toolbox in MATLAB. We saw how useful the Prandtl-Meyer function was, feel free to explore some of the others (See below):

Gas Dynamics

`flowfanno`	Fanno line flow relations
`flowisentropic`	Isentropic flow ratios
`flownormalshock`	Normal shock relations
`flowprandtlmeyer`	Calculate Prandtl-Meyer functions for expansion waves
`flowrayleigh`	Rayleigh line flow relations

If you don't have access to the aerospace toolbox, let me know! Happy to copy over the few functions that might be useful.

I've also created a useful function called InvertTBM.m that inverts the theta-beta-mach equation for ease of use for this project. You can find it in BBlearn now.

Steps for a complete code:

1. (10%) Generate the geometry shown in the figure above in MATLAB using the coordinates given (no need to display the coordinates like I have once you've verified their locations) and then find the appropriate deflection angles for flow around the object, assuming a zero angle of attack (flow travels in the positive x-direction only). Pay special attention to what angle constitutes a shock wave vs an expansion fan. It is recommended that you use positive angles for shocks (flow turning into itself) and negative for expansion fans (flow turning away). Do this for the first three deflection angles now – *NOTE: you'll do the slip line angle (and corresponding deflection angles) later.*
2. (20%) Assume a freestream **Mach#=3** in the positive x-direction just before the airfoil, perform the following:
    a. solve for the flow in region "A", then add properties as a text above the surface in region "A" in your figure. These would be static pressure and static temp at least.
    b. solve for the flow in region "B", then add properties as a text above the surface in region "B" in your figure. These would be static pressure and static temp at least.
    c. solve for the flow in region "C", then add properties as a text above the surface in region "C" in your figure. These would be static pressure and static temp at least.
    d. solve for the flow in region "D", then add properties as a text above the surface in region "D" in your figure. These would be static pressure and static temp at least.
    e. Add oblique shocks as a single line and expansion fans as two lines (forward and rearward Mach lines) to your figure. Be careful to represent these lines appropriately – so perform your trig accordingly.

NOTE: I found it easier to place the properties at the top of the figure and to view the figure in full screen.

3. (10%) Take the properties that you found in each region and calculate the pressure forces acting on all surfaces per unit span. With those pressure forces per unit span, calculate the lift, drag, and resultant forces per unit span acting on the airfoil. Print these values to the screen and on the figure somewhere (perhaps in the title).
4. (10%) Find the properties behind the trailing edge of the airfoil by iterating to find the slip line angle that generates deflection angles for the flow coming off the top and bottom of the trailing

edge. Your convergence value should be based on the static pressure values and a nice check to validate could be to see if the flow directions are the same and parallel to the slip line. Note that the velocities can be different above and below the slip line due to the slip line.

5. (15%) Now that you have a functioning code for the above requirements, it is time to vary the angle of attack. It is recommended that you do NOT vary the angle of the airfoil in the figure, instead vary the angle that the flow comes in at. The goal here is to get an animation of the flow properties, shock waves, and expansion fans as the angle of attach (AoA) varies from -10 to 10 degrees. *Note: feel free to extend this range to test the limits of your code after you have a functioning project.* Useful comments:
    a. Keep track of when an oblique shock wave or an expansion fan occurs with the sign of the deflection angle. A (+) for an oblique shock and a (-) for an expansion fan.
    b. Careful with your trig of your lines coming off the corners. You will need to visualize how those lines should be represented as you code them.
    c. If it is easier for you, start a new code for just part five.
    d. If you planned ahead at the beginning of the project, this part will be easier to code.
6. (5pts) Generate the following plots:
    a. Plot the lift and drag forces per unit span as a function of the AoA.
    b. Plot the 2D lift and drag coefficients as a function of the AoA.
7. *Extra credit (10%) – pick an angle of attack (AoA) that is not zero and vary the Mach #. Animate your figure and show how the properties and shocks/exp.fans vary as the Mach# varies.*
8. (10pts) Summarize your results in a paper that introduces your figures and data in tables. Please be thorough with your explanation of what we are seeing. For animated images, take snapshots through time by picking a few AoA and/or Mach#'s to run the code just for that scenario so you get a good figure. Take some time to comment at the end on whether or not this airfoil would be a good one for supersonic flight and in what condition/application.
9. Appendix of online resources used to solve this problem.

Part B Submission Requirements:

1. Submit all MATLAB code and functions that were needed/generated.
2. Submit your report on your results as a PDF.

Other Project Rules:

1. Can share code within your group, can NOT share with other groups. Although allowed to discuss conceptual topics with other groups.
2. You can use online resources such as Mathworks and chatGPT. If you do, you must copy your quary and resulting code snippets and past them into the appendix. So effectively, cite your sources.
3. If you post this on help sites like Chegg or Coursehero (or the like), I can track down the person who submitted it and I can track down the people who viewed it. And you will fail the assignment at the very least.
4. Code must be able to generate what you submit to you will get a zero.