AE 244: Assignment 2

<u>Weightage</u>: 15% of the total grades

<u>Deadline</u>: 10th March. 2024 (Sunday) 11:59 PM
(Submissions after this deadline will attract 5% penalty for each 30 minutes delay. For example, 15% will be deducted from the assignment grades if the submission happens at 1:30 AM)

A note on plagiarism:

This is an individual assignment. While discussion is encouraged, simply copying someone else's work will attract zero marks for all involved.

Background

You are a part of a recreational vehicle design division in a startup. You have been asked to design a glider that can seat one person weighing up to 100 kgf. The glider is completely unpowered. It will be towed behind another aircraft before getting released at an altitude of 4000 meters.

Goal:

Simulating an airfoil in a CFD tool can take a significant amount of time and computational resources as noticed in the first assignment. Therefore, it is useful to have a tool that can give at least some approximate answers quickly, so that an iterative airfoil design process can be conducted efficiently.

The goal of the current assignment is to create a tool that can predict performance of any thin airfoil using the thin airfoil theory, and to compare its prediction capabilities against other tools. Later, use the tool to try out your own unique airfoil designs!

Tasks

1. Create a computer program comprising of the following functions to implement thin-airfoil theory (**In a team of 3**):
    a. A function to generate and plot points along the camber line based on user defined functions [y = f(x)], including the one for NACA airfoils.
    (Consider normalized airfoil with leading edge at x = 0 and trailing edge at x = 1.)
    b. A function to compute the slope of the camber line at any given point along the chord length.
    c. A function to compute C_l of the thin airfoil at a given α based on thin airfoil theory.
    d. A function to plot vector field around the airfoil based on circulation distribution, and compute circulation due to airfoil through line integral.
    e. A main function that takes user inputs and combines functionality of all the above functions.
2. Use the program to plot/find (**Individually**):
    a. Camber line ('y' vs 'x') for the NACA airfoil from assignment 1
    b. Slope of the camber line along x (dy/dx vs x)

   c. C_l vs α (α from -4⁰ to 10⁰) along with C_l vs α curves from CFD simulations from assignment 1 for the NACA airfoil on the same chart for comparison.
   d. Vector field plot around the airfoil in a domain 4 times the chord length along x and 3 times the chord length along y.
   e. Circulation around the entire airfoil using velocity line-integral approach
   f. Bound circulation by integrating circulation distribution along camber line.
3. Come up with 3 custom-designed airfoils and plot for each design (**Individually**):
   a. Camber line ('y' vs 'x') for the three custom designed airfoils
   b. C_l vs α of the three airfoils (α = -4^0 to 10^0)
   c. Vector field.

Report Structure

1. Program development team introduction and work share

1.1. Table containing team member names, roll numbers, and contribution by each in programing the functions [1]

2. Algorithm

Describe the algorithm for each function in a stepwise manner. Include equations wherever relevant (snipped images of equations are acceptable).
Examples of algorithm : https://www.programiz.com/dsa/algorithm#quadratic

2.1. Algorithm for plotting camber line [3]
2.2. Algorithm for plotting camber line slope [5]
2.3. Algorithm for computing C_l [10]
2.4. Algorithm for plotting vector field [5]
2.5. Algorithm for calculating circulation through line integral. [5]

3. Airfoil Simulation and Results.

3.1. Camber line ('y' vs 'x') for the NACA airfoil from assignment 1 [2]
3.2. Slope of the camber line along x (dy/dx vs x) [2]
3.3. C_l vs α for the NACA airfoil from the program and CFD simulations on same chart [5]
3.4. Comment on/discuss the results obtained in 3.3. [4]
3.5. Vector field plot around the airfoil (domain size: 4c times 3c) at α = 3^0 [5]
3.6. Comment on/discuss the plot obtained in 3.5 [4]
3.7. Circulation around the entire airfoil using velocity line-integral approach at α = 3^0 [3]
3.8. Bound circulation by integrating circulation distribution along camber line. α = 3^0 [2]
3.9. Compare and comment on the values obtained in 3.7 and 3.8. [2]

4. Novel Airfoil Properties

4.1. Camber line ('y' vs 'x') for your 3 airfoils and the NACA airfoil on same chart [3]

4.2. C_l vs α of the three airfoils along with that of the NACA airfoil on same chart [6]
4.3. Comment on/discuss the results obtained in 4.2 [2]
4.4. Vector field plot around the three airfoils (domain size: 4c times 3c) at $\alpha = 3^0$ [3]
4.5. Comment on/discuss the results obtained in 4.4 [2]

5. Conclusion

5.1. Overall take on your code's performance as compared to Ansys simulation, and possible reasons for deviations, if any [4]
5.2. Overall take on the performance of your airfoil as compared to the NACA airfoil [4]

6. Code (marks common to the team members)

6.1. Proper working of the camber line plotting code [2]
6.2. Proper working of the camber line slope plotting code [3]
6.3. Proper working of C_l and C_m code [6]
6.4. Proper working of vector field plotting code [4]
6.5. Proper working of circulation calculation [3]

7. Acknowledgement

Mandatory to acknowledge people you discussed with or took help for any part of the assignment.

8. References

List all references (books, paper, websites, etc.) used while doing the assignment