AE 244: Assignment 1

Weightage: 15% of the total grades

Deadline: 4tg February. 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:

Study flow over an airfoil in a simulation software in great detail and verify if the software is giving reasonable answers for the airfoil. Later, design your own airfoil and analyze it in the software.

Tasks

1. **Create an airfoil** based on your roll number using http://airfoiltools.com/airfoil/naca4digit. If your roll number is ABCDEFG, the NACA 4-series airfoil you create must have its maximum camber = F.G%, thickness = AB/2 %, and maximum camber position = (AB + FG)/2 % . Assume the chord length (c) to be 1 meter.
2. **Simulate the airfoil** using Ansys at 30 m/s free stream velocity for angle of attack (α) = -4^0 , -2^0 , 0^0 , 2^0 , 4^0 , 6^0 , 8^0 , 10^0
3. **Plot** C_l vs α , C_d vs α , and C_l vs C_d
4. **Report** lift curve slope, Y-intercept, stall angle, maximum C_l, and maximum C_l/C_d .
5. **Study the flow** at $\alpha = 3^0$ and $\alpha = 10^0$ by
    a. plotting streamlines, pressure coefficient contours, vorticity contours.
    b. plotting coefficient of pressure along blade surface
    c. plotting unseparated boundary layer velocity profile on the upper side of the airfoil
6. **Validate** mass and momentum conservation by tracking incoming and outgoing mass and momentum in control volume containing the airfoil.
7. **Design** your own airfoil with the aim to improve maximum C_l/C_d performance.
8. **Repeat tasks 2 and 3** and compare your airfoil's performance against the one based on your roll number.

Report Structure

1. Airfoil Creation and Simulation Mesh Generation

1.1. Mention the NACA airfoil based on your roll number [1]
1.2. Airfoil shape plot and image of airfoil CAD as required for Ansys simulation [3]
1.3. Image of structured mesh created for airfoil simulation based on best practices. [4]

2. Airfoil Simulation and Results.

Discussion/Interpretation is required for each plot and is worth 50% of the assigned marks.

2.1. C_l vs α plot [5]
2.2. C_d vs α plot [5]
2.3. C_m vs αplot [5]
2.4. C_l vs C_d plot [5]
2.5. Lift curve slope [2]
2.6. Y-Intercept [2]
2.7. Stall angle [2]
2.8. Maximum C_l [2]
2.9. Maximum C_l/C_d [2]

3. Flow Study (at $\alpha = 3^0$ and 10^0)

Discussion/Interpretation is required for each plot and is worth 50% of the assigned marks.

3.1. Streamline plots [4]
3.2. Velocity field magnitude contour plots [4]
3.3. Pressure field contour plots [4]
3.4. Coefficient of Pressure plots along airfoil surface [4]
3.5. Vorticity field contour plots [4]
3.6. Approximate location of stagnation and flow separation points in airfoil surface [4]
3.7. Upper surface boundary layer velocity profile at x/c = 10%, 30% and 70%
(plot three locations on the same chart) [6]
3.8. Estimate of boundary layer thickess at the three locations [3]
3.9. Verify validity of Bernoulli equation along a streamline
(a) far from the boundary layer [3]
(b) inside the boundary layer [3]

4. Conservation laws (at $\alpha = 3^0$)

Consider a rectangular control volume containing the airfoil.

4.1. Net mass flow rate into the control volume. [5]
4.2. Net rate of momentum change through the control volume. [5]
4.3. Comparison with lift and drag force reported in section 2 of the report. [2]

5. Airfoil Design

5.1. Suggest any change you can make to the airfoil shape to improve performance with reason [4]

5.2. Simulate the airfoil at an angle of attack of your choice (between -4^0 and 10^0) and report its C_l and C_d values. [5]

5.3. Comment on the performance of the new airfoil [2]

6. Acknowledgement

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

7. References

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