ASE 162M – Fall 2024

Laboratory 3

Diamond Airfoil Aerodynamics

Assignment (150 pts)

Due two weeks after the day of your scheduled lab 11:59 pm as a PDF uploaded to the assignment page on Canvas and this is the only lab assignment which you can do as a group.

Instructions:

The assignment should be typed and no hand-written work will be accepted (including equations). This is to be a full lab report (see formatting guidelines on Blackboard). The questions below do not have to be answered in order, but should be presented as a narrative within your report.

Points will be deducted for typos, grammatical errors, and formatting errors. Points will be deducted for using too many significant figures (more than three in most cases) when presenting data. All quantities determined through experimentation must be presented along with an uncertainty value, however, derivations of uncertainty equations are not required. Points will be deducted for the inclusion of gratuitous and unnecessary figures and tables, i.e. MATLAB code or figures and tables which are not necessary to make the point you are trying to make in the text.

Note: You must correct your images for distortion effects and you may use the distortion correction derived for the previous lab assignment. Additionally, all images should portray the flow moving from left to right (standard convention).

Questions

1. This report should be free of grammatical errors and typos. (10 pts)
2. This report should have acceptable and consistent formatting and contain at a minimum the following sections: Abstract, Introduction, Experimental Setup, Results and Discussion, Conclusion, References, and Appendix. If you are unclear on what is considered "acceptable" reference the template and guidelines provided on Canvas. (10 pts)
3. Write an abstract, providing a brief synopsis of the work conducted and the results. (3 pts)
4. Write an introduction, discussing at least five relevant publications and how they relate to this work, providing sufficient context for the work conducted. Lecture notes, websites, and textbooks will not count towards the five references (but should still be included if necessary). The introduction should conclude with a brief discussion of the current work with regards to how it relates to previous research. (15 pts)
5. Write a section on the theoretical concepts and equations used in generating this report including (but not limited to) Schlieren, shock-expansion theory, expressions for coefficients of lift and drag (in terms of angle of attack, pressure, and wedge angle), and center of pressure of an airfoil. Do not include derivations of equations in this section. (15 pts)
6. Include an "Experimental Setup" section in which you describe the equipment and experimental design you used to conduct this work. This should include a description of the wind tunnel used in the experiments, a description of the data acquisition system, a detailed schematic of the Schlieren system (including rays and with a description of the function of each part), and descriptions (preferably a diagram) of the model tested. Your description should be detailed enough that someone reading your report would be able to replicate your setup. Do not simply copy and paste from the description provided at the end of the lab handout. (10 pts)

7. Include a Results and Discussion section that answers the following questions:

    a. Present three images that have been corrected for distortion: Mach 2.25 & 2.5 at 0° AoA, Mach 3 at 7° AoA, and Mach 2 at 0° AoA. Label the flow features in all three images. How are the images different? How are they similar? What happens to the viscous structure downstream of the models as the Mach number is changed? Is this in agreement with shock-expansion theory? Also, compare the raw images to the corresponding images corrected for image distortion. Was there a noticeable effect? (10 pts)

    b. Compare the surface pressure measurements obtained during the experiment to the theoretical surface pressures obtained using shock-expansion theory for all cases. Calculate your theoretical pressures using the true Mach number you calculated from your stagnation and static pressure. If there is a discrepancy, explain why you think this is the case. (10 pts)

    c. Plot measured and theoretical CD vs. M, CL vs. AoA, and CD vs. CL for all runs. What trends do you see in your measured data? If there is a discrepancy between measured and theoretical values, comment on why you might think this is the case. (20 pts)

    d. Supersonic linearized potential theory for a thin airfoil predicts that:

    $$C_L = \frac{4\alpha}{\sqrt{M_\infty^2 - 1}} \text{ and } C_D = \frac{4\alpha^2}{\sqrt{M_\infty^2 - 1}} + \frac{2}{\sqrt{M_\infty^2 - 1}}\left[\frac{1}{c}\int_0^c \left(\left(\frac{dy_u}{dx}\right)^2 + \left(\frac{dy_l}{dx}\right)^2\right) dx\right]$$

    Where, for a diamond airfoil, C_D simplifies to:

    $$C_D = \frac{4\alpha^2 + 2\tan^2\theta}{\sqrt{M_\infty^2 - 1}}$$

    Using a plot, compare the theoretical trend for C_D and C_L to your results. Do they agree? Why or why not? (5 pts)

    e. Calculate the experimental center of pressure for each run, as well as the theoretical trend in center of pressure for the range of Mach numbers and angles of attack used in the study. Plot your theoretical and experimental values. Do the theoretical values change with angle of attack? With Mach number? Do the experimental values? By how much? Is this behavior we expect for a symmetric airfoil? How does the supersonic value of center of pressure compare to the value one normally expects for a subsonic airfoil? (20 pts)

8. Write a conclusion that summarizes the work performed and outlines the key findings of the experiment. (7 pts)

9. Include a properly formatted list of references. These references should be cited throughout the text. Feel free to choose any standard formatting style for the references (such as APA, MLA, or Chicago) as long as you are consistent for all references. (5 pts)

10. Include an appendix where you derive the equations used to calculate coefficient of lift and drag from the measured surface pressures (you should have provided these equations in the Theory section). Do not include derivations for Schlieren and shock-expansion theory equations. (10 pts)