Assignment 2 Boundary Layer Transition

Academic year: 2018-2019

Requirements

- Personal or group task: personal
- Minimum / Maximum number of pages: 6 / 10 (excluding Title page)
- Font size: 10 – 12

The aerodynamic characteristics and performance of any aircraft part exposed to the external flow is significantly influenced by the state of the boundary layer (BL), that can either be laminar or turbulent. In that respect the determination of the transition point location becomes an essential part of the flow analysis of airfoils. The so-called e^n-method is the best method in this respect as it allows a fast and quite accurate calculation of the transition point. Many airfoil design and analysis programs employ this e^n-method. In this assignment you will use the program XFOIL to determine the effect of the amplification factor n.

Since the stability of the BL is influenced by external factors like the ambient turbulence level, the default value of $n = 9$ very often does not lead to an acceptable result when comparing the predicted results with experimental data. For this reason, the n-factor should be selected by the user based on knowledge about the flow conditions for the particular airfoil.

In this assignment, your task is to get further insight in the influence of the n-factor on the behavior of the boundary layer and the airfoil characteristics.

Note: When discussing XFOIL results in your report, please do not use screen prints as they are hardly readable. Instead export the data and produce high quality graphs in Matlab, Excel or any other convenient program. Note that XFOIL also allows you to quickly generate high quality postscript files (hence pdf).

Tasks

Part 1

Investigate the effect of the n-factor by performing the following tasks:

- Download the XFOIL program and the manual either from the internet (https://web.mit.edu/drela/Public/web/xfoil/) and install it in a local directory. Before you start, make yourself familiar with the theoretical background of this solver.
- Calculate your personal 4-series airfoil shape that you are going to investigate in this assignment. The procedure for this can be found in Appendix A. Show the calculation and its results and clearly state what airfoil shape is used.

- For this airfoil, calculate the lift and drag polar between -2 and 10 deg. angle of attack for n-values between $n = 4$ and $n = 12$ and produce clear plots of the results (no screen prints). Use a chord-based Reynolds number of $Re = 3.0 \times 10^6$.
- Discuss the results (plots plus text) and explain:
  - How the lift and drag characteristics are affected by the changes in the n-factor
  - How the BL characteristics, like the wall shear stress is affected by the n-factor

Part 2

The transition location influences the occurrence of a so-called "laminar separation bubble". To analyze both the effect of the n-factor and a user defined transition location, perform the following tasks:

- Select a new <u>non-symmetrical NACA 4-series airfoil</u> and Reynolds number at which this airfoil produces a <u>clearly recognizable laminar separation bubble</u>. The length of the bubble will become larger when the Reynolds number is lowered. Therefore, you might want to lower the Reynolds number to $Re = 5 \times 10^5$.
- Check the effect of the n-factor (between 4 and 12) on the length of the separation bubble and the drag coefficients and explain the results by discussing lift and drag coefficient as well as the surface shear stress.
- For the same airfoil, perform calculations for user defined transition locations (simulation of roughness) between the leading edge (LE) and the location of natural transition (select one value of the lift coefficient between 0.0 and 0.4).
- Discuss how for the fixed lift coefficient the drag coefficient is influenced by the location of forced transition and explain how forced transition may have lowered the drag coefficient of the airfoil.

Appendix A. Airfoil selection

The airfoil that needs to be analyzed are all NACA 4-series. The form (NACA designation) is based on your **student number**. To find the airfoil shape that you need to investigate within this assignment do the following:

1. Take the <u>last 3 digits</u> of your student number, for example: 989, and take the sum, which we will denote N. In this example: N=9+8+9=26. This number determines the relative thickness of the airfoil you are going to investigate.
   a. In case your number is 5 or lower, use N=10
   b. In case your number is between 5 and 10, add a zero in front (so 9 becomes 09).
2. The first digit of the NACA designation is always 2
3. The second digit of the NACA designation is the second digit of your student number.

Some examples of this calculation are provided in the table underneath (check).

Student number	N	NACA Airfoil
4223977	23	2223
4218124	7	2207
4303784	19	2319
4712900	09	2709
4599667	19	2519
4391594	18	2318
4724143	8	2708
4221000	10	2210
4078005	10	2010

Please note that failure to work with the right airfoil shape will result in zero credits for Assignment #2.