TMMV01 Aerodynamics: Computer Lab

Introduction

In the computer lab you are going to familiarize with typical post-processing, i.e. handling and analysis of data, from flow simulations and measurements. From a post-processing perspective the data look rather similar, typically a property sampled over time. Apart from just the post-processing you are to compare the experimental results to theoretical values and comment on, with motivation, whether they are reasonable or not. The work consists of to parts: Boundary layer data (simulation) and Force measurements on a delta plate (experiment).

Data from simulations and experiments are available on the course web page. `Delta.zip` contains measurements of the normal force on a delta wing for different angles of attack and `Laminar.zip` and `Turbulent.zip` contain numerical data from a boundary layer.

The aim is to get knowledge of how the output from simulations and measurements typically looks and is handled, and to compare experimental to theoretical values with subsequent critical analysis. The work is presented by answering some questions.

Preparation

Read chapter 4, 3.14, 5.4.3, and 7.7 in the book, and see the lecture notes about boundary layers, separation, and delta wings.

Measurement of Forces on Delta Wings

The normal force has been measured on a delta plate (triangular plate) in a water tunnel with a sampling frequencuy of 1 kHz for a velocity of 0.18 m/s and temperature 20°C. The balence registers the "total" normal force, i.e. not just the aerodynamic part. Since we are only interested in the contribution of the aerodynamic force, you will have to use the available measurements to determine this. Thus, use the data set available on the course web page and calculate the aerodynamic normal force N and the the corresponding coefficient C_N. A drawing of the plate is available together with the data set. In addition, calculate the lift coefficient C_L using Eq. 7.62 in the course book, and compute the terms for potential flow lift and vortex lift separately. Show the coefficients in one plot and discuss the agreement of the results. Also, compare and contrast qualitatively with the performance of a trapezoidal wing (comparison of data not is not required).

Presentation

Show N, C_N, C_L and the terms for potential lift and vortex lift in a clear and illustrative way. Describe the assumptions on which the theoretical values are based and comment on their validity for this case. Explain similarities and differences between C_N and C_L, and discuss the different contributions to the lift force. Max 1 A4 page.

Numerical Simulations of Flow in a Boundary Layer

Numerical simulations of flow along (between) two infinitely wide flat plates have been carried out on a very powerful computer. Undisturbed, uniform, laminar flow with a velocity of 50 m/s reaches the plates, is parallel to them at the beginning, and continues to flow along them, see Fig. 1. For the first plate, the flow remains laminar along the entire surface, whereas for the second plate transition to turbulence is trigged 5 cm from the leading edge by a geometrical disturbance. This introduces disturbances in the flow, which in turn initiate the turbulence. The temperature of the freestream is 300 K and the temperature of the plate is 330 K and 350 K, for the laminar and turbulent case, respectively. The density and viscosity of the fluid are 1.225 kg/m^3 and 1.7894 $\cdot 10^{-5}$ kg/(m$\cdot$s), respectively.

(a)

(b)

Figure 1: Flow along two flat plates. The flow direction is from left to right. (a) Laminar flow along the entire plate. (b) A geometrical disturbande 5 cm from the left side (leading edge) introduces turbulence.

Instantaneous values of the u velocity (i.e. x component) have been monitored and are available on the course web page. `Laminar.zip` contains data from the laminar boundary layer and a prepared matlab file (must be completed), and `Turbulent.zip` contains data from the turbulent boundary layer. The data are monitored in points along lines normal to the surface located 0.1, 0.2, 0.3, 0.4, and 0.48 m from the leading edge (laminar plate) and at 0.05, 0.10, 0.15, and 0.20 m from the *transition* (turbulent part). See Fig. 2 for a schematic illustration. The sampling frequency is 200 kHz. y coordinates for both the laminar and the turbulent cases are available on the course web-page (note that there are different y-coordinates for the laminar and turbulent cases). There is also a Matlab file with useful commands.

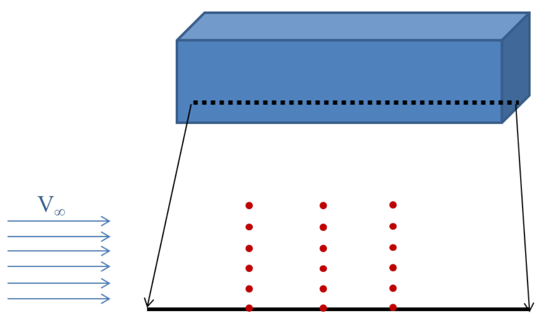

Figure 2: Schematic illustration of how the sampling points are located relative to the plates. Red dots illustrate their location. For the laminar and turbulent plates there are 46 and 51 points, respectively, in the wall-normal direction at each streamwise location.

Use the available data to compute time averaged velocity profiles at all streamwise locations. Furthermore determine skin friction coefficient and boundary layer thickness according to their definitions, and compare the results to theoretical estimates. Show skin friction in one plot and boundary layer thickness in another plot, both experimental and theoretical values.

Presentation

Show the velocity profiles (one plot for the laminar part and one for the turbulent), skin friction coefficients (one plot including both the laminar and turbulent part), and boundary layer thickness (one plot including both the laminar and turbulent part). All plots must include numerical and theoretical values for comparison. Explain how the boundary layer develops from the leading edge and downstream. Explain why the skin friction develops as it does. Discuss the accuracy of the numerical results. Comment on and if possible explain similarities and differences between theoretical and numerical data. Max 1 A4 page.

Submission

Upload the answers in Lisam, make sure both names and email addresses are written in the document. All answers must be prepared and formulated by the authors written on it, to submit copies of others' works, parts or in whole, is not allowed and will be a matter for the disciplinary board.
Good luck!