AerE 344: Undergraduate Aerodynamics and Propulsion Laboratory

Lab Instructions

Lab #11: PIV Measurements of the Unsteady Vortices in the Wake of An Airfoil

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Lab #11: PIV measurements of the flow field around an airfoil

Objectives:

1. To enhance the understanding of fundamentals and system setup of Particle Image Velocimetry (PIV) technique.
2. To get "hands-on" experiences on how to make PIV measurements.
3. To know how to do PIV image acquisition, image processing, and final result analysis and discussion of an experimental study.

The flow field to be measured:

The experiments will be performed in a closed-circuit low-speed wind tunnel located in the Aerospace Engineering Department of Iowa State University. The tunnel has a test section with a 1 ×1 ft (30 ×30 cm) cross section and all the walls of the test section optically transparent. The wind tunnel has a contraction section upstream the test section with honeycomb, screen structures and cooling system installed ahead of the contraction section to provide uniform low turbulent incoming flow to enter the test section.

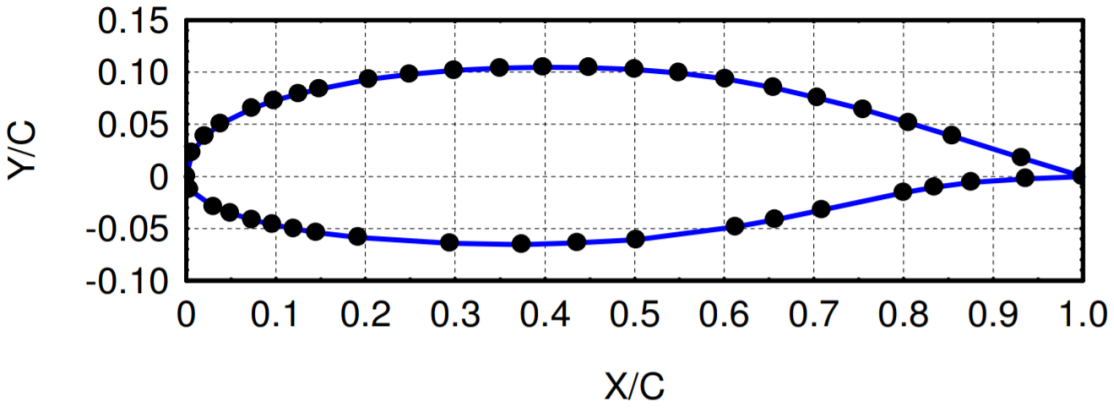

Figure 1. GA(W)-1 Airfoil geometry and pressure tap locations

Figure 1 shows the airfoil used in the present laboratory: GA(W)-1 airfoil. The chord length of the airfoil is 101mm, i. e., C = 101mm. For the present laboratory, the flow velocity at the inlet of the test section was set as U_∞=10.0 m/s, which corresponds to a chord Reynolds number of Re_c =68,000.

Figure 2 shows the experimental setup used for the PIV measurement. During the experiment, the test airfoil was installed in the middle of the test section. A PIV system was used to make flow velocity field measurements along the chord at the middle span of the airfoils. The flow was seeded with 1~5µm oil droplets. Illumination was provided by a double-pulsed Nd:YAG laser (NewWave Gemini 200) adjusted on the second harmonic and emitting two pulses of 200 mJ at the wavelength of 532 nm with a repetition rate of 10 Hz. The laser beam was shaped to a sheet by a set of mirrors, spherical and cylindrical lenses. The thickness of the laser sheet in the measurement region is about 0.5mm. A high-resolution 12-bit (1376 x 1040 pixel) CCD camera was used for PIV image acquisition with the axis of the camera perpendicular to the laser sheet. The CCD cameras and the double-pulsed Nd:YAG lasers were connected to a workstation (host computer) via a Digital Delay Generator (Berkeley Nucleonics, Model 565), which controlled the timing of the laser illumination and the image acquisition.

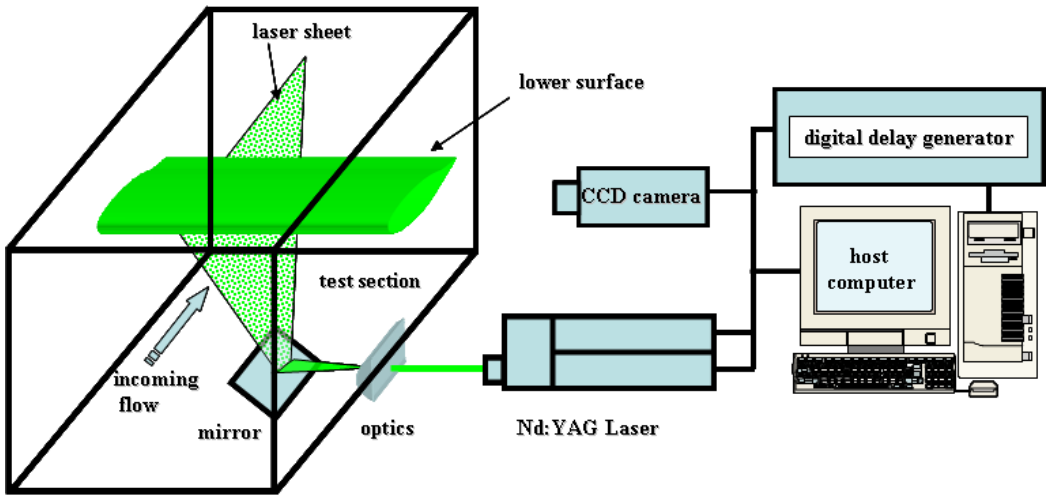

Figure 2: Experimental setup for the PIV measurements

What you will have available to you for this lab:

- A calibrated PIV system setup for acquiring image pairs of particle images in the wake of a GA (W)-1 airfoil.
- A computer software package for processing the image pairs, performing the cross-correlation analysis, and outputting text files containing the vector data (u,v) at each (x,y) analysis location.
- A MATLAB script for importing a sequence of PIV captures into the variables X, Y, Us, Vs.

What you will do during the lab time:

- Conduct the wind tunnel experiment at 10 m/s and at angles of attack of 4, 8, 12, 16 degrees.
- Import the captured images into the PIV software and compute the vector fields using cross-correlation.
- You will be given an exported data set of PIV wake measurements to perform post-processing and wake analysis.

Requirements for the Lab Report

1. You are required to prepare a formal lab report with following results included:

a. Instantaneous PIV measurement results
   i. Two frames of velocity vector fields
   ii. Corresponding vorticity distributions

b. Ensemble-averaged PIV measurement results based on 100 frames of instantaneous PIV measurements results.
   i. Velocity vectors of the mean flow field
   ii. Vorticity distribution of the mean flow field
   iii. *T*urbulent kinetic energy distribution
   iv. Wake profile at 1/2 chord downstream

2. Report requirement:

a. Discuss the relationship between the instantaneous PIV measurements and the ensemble average results. How is the uncertainty in the mean velocity field related to the number of instantaneous snapshots and the velocity fluctuations? Do certain regions in your average flow field have higher uncertainty than others?

b. A brief discussion about the measurement results you get, comparing the PIV wake measurement results to the previous wake measurements in the Pitot rake and hotwire experiments.

The Experimental Data Needed for Lab #11

1. The time delay between the two laser pulses. Δt =?
2. The repetition rate of the laser pulses (frame rate of the PIV measurements), f = ?
3. Scale ratio between the physical measurement window and PIV images. 1 mm = ? pixel
4. The angle of attack and chord length of the airfoil, a = ?, c = ?
5. 100 frames of instantaneous PIV image pairs saved as 8-bit TIF images.
6. 100 calculated instantaneous vector fields exported to text-format data.

Recommendations:

1. For the PIV image process, the interrogation window size is set as ~ 32 by 32 pixels.
2. For the PIV image process, use 50% overlapping to derive velocity vectors.