# AerE545/AerE445: Experimental Fluid Mechanics and Heat Transfer

## Lab # 04: PIV measurements of flow field around an airfoil

**Objectives:**

1. To enhance the understanding about 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 result analysis and discussion of an experimental study.

**Instructor:** Dr. Hui Hu
Department of Aerospace Engineering Iowa State University
Office: Room 2251, Howe Hall Tel: 515-294-0094
Email: huhui@iastate.edu

**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 of 0.45 m×0.6 m× 1.45 m (width × height × length) in dimension 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.

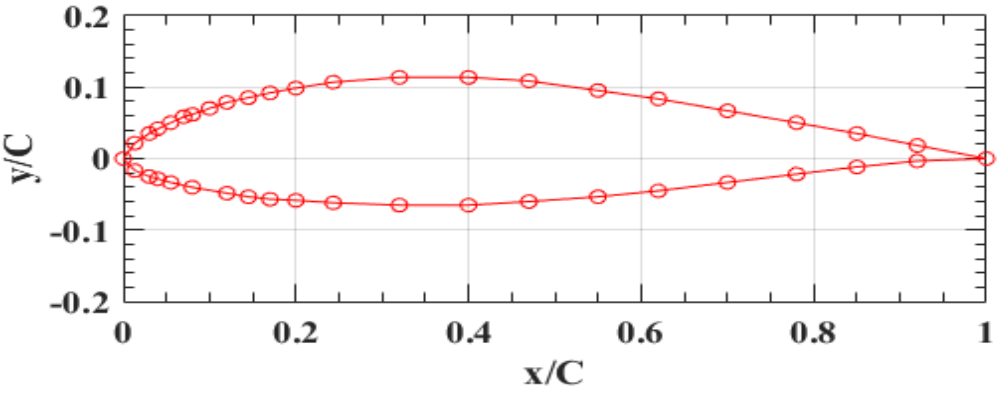


Figure 1. DU-96-W-180 airfoil and pressure tap locations.

Figure 1 shows the airfoil used in the present laboratory: DU-96-W-180 airfoil. The DU-96-W-180 airfoil has the maximum thickness of 18% of the chord length. Compared with standard NACA airfoils, the DU-96-W-180 airfoil was specially designed for wind turbine blade applications with a large leading-edge radius in order to flatten the peak in pressure coefficient near the airfoil nose to discourage flow separation. The chord length of the airfoil is 150 mm, i. e., $C$ = 150mm. For the present laboratory, the flow velocity at the inlet of the test section was set as $U_\infty = 25.0$ m/s, which corresponds to a chord Reynolds number of $\mathrm{Re}_c = 250,000$.

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.

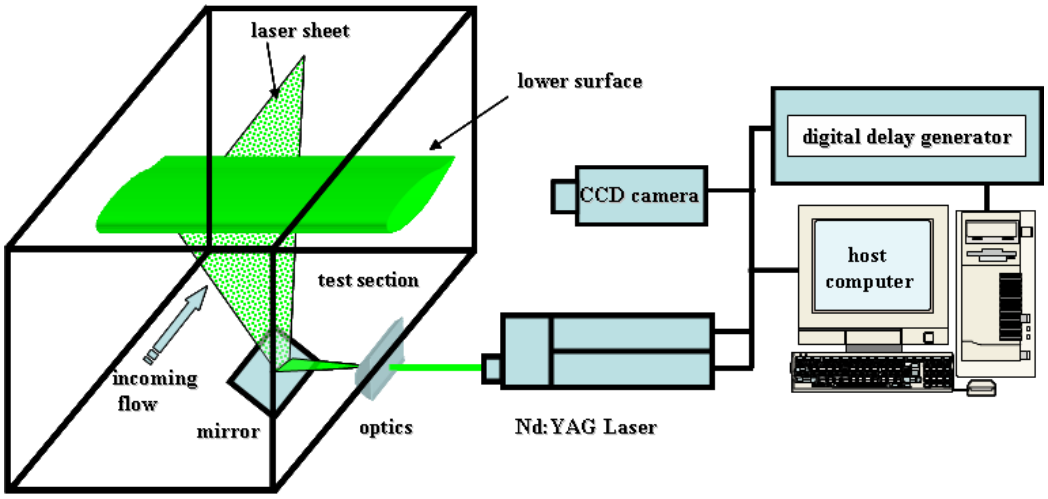


Figure 2. Experimental setup for the PIV measurements

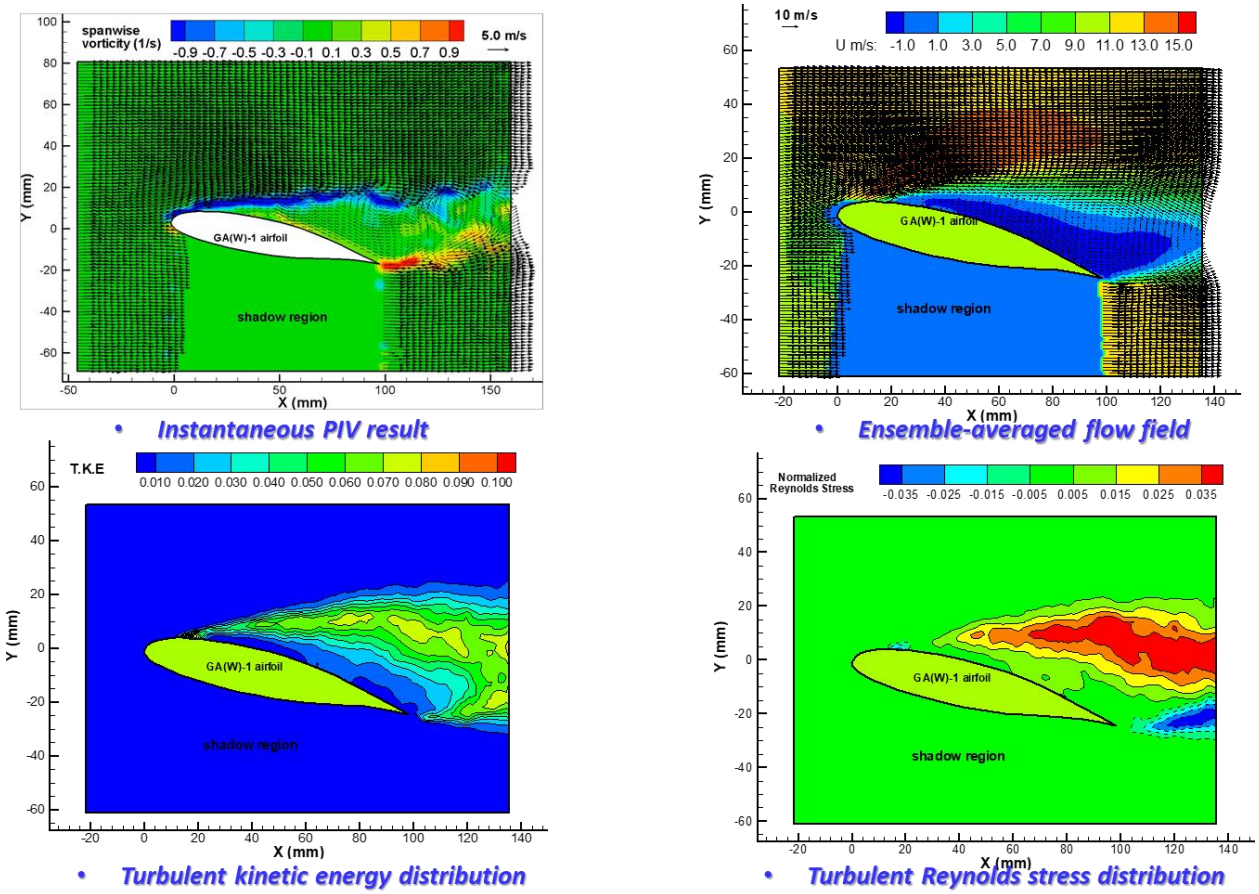


Figure 3. Typical PIV measurement results

## 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 150 frames of instantaneous PIV measurements results.
        i. Velocity vectors of the mean flow field
        ii. Turbulent kinetic energy distribution
        iii. Reynolds stress distribution

2. **Report requirement:**
    a. A brief introduction about the technical basis of PIV.
    b. A brief introduction about the experimental setup
    c. Using the PIV image processing software to do the PIV image processing.
    d. A brief discussion about the measurement results you obtain.

## The Experimental Data Needed for the PIV Laboratory

1. The time delay between the two laser pulses. $\Delta t$ =?
2. The repetition rate of the laser pulses (frame rate of the PIV measurements), f = ?
3. The scale ratio between the physical measurement window and PIV images. 1 mm = ? pixel
4. The angle of attack of the airfoil.
5. 150 ~ 200 frames of instantaneous PIV image pairs saved as 8-bit TIF images.

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.
3. For your information, the head length of the 8-bit TIF images acquired by the PIXELFLY camera used in the present Laboratory is 8502bit.

## The parameter setting for the PIV experiments:

| Group assignment | angle of attack | Airflow velocity |
|---|---|---|
| AerE445- section 01<br>Group #1 | AOA= 0,5,10,15 deg. | $U_\infty$ = 25 m/s |
| AerE445 - section 02<br>Group #1 | AOA= 1,6,11,16 deg. | $U_\infty$ = 25 m/s |
| AerE445 -section 02<br>Group #2 | AOA= 2,7,12,17 deg. | $U_\infty$ = 25 m/s |
| | | |
| AerE545 - section 01<br>Group #1 | AOA= 3,8,13,18 deg. | $U_\infty$ = 25 m/s |
| AerE545- Section 02<br>Group #1 | AOA= 4,9,14,19 deg. | $U_\infty$ = 25 m/s |