AerE545/AerE445: Experimental Fluid Mechanics and Heat Transfer

Lab#05: Stereoscopic Particle Image Velocimetry (SPIV) Laboratory to Quantify Flow Characteristics Behind an UAV Propeller

Objectives:

1. To get familiar with the experimental setup and the basic procedures to perform stereoscopic PIV measurements.

2. To understand the fundamental principles of stereoscopic PIV technique and to apply this technique to quantify the flow fields behind an UAV propeller.

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The experimental setup and test model:

The experimental study will be performed in the Advanced Flow Diagnostic and Experimental Aerodynamic Laboratory located at Iowa State University. Figure 1 shows the experimental setup to be used for the stereoscopic PIV measurements. As shown in the figure, one UAV propeller rotor with a diameter of D = 240 mm is installed on the test rig. For the test model of the present study, an aluminum rod was used as the tower to support the rotor blade and the nacelle.

As shown clearly in Fig. 1, illumination source for the SPIV measurememnts was provided by a double-pulsed Nd:YAG laser (NewWave Gemini 200), emitting two pulses of 200 mJ with the wavelength of 532 nm at a repetition rate of 2 Hz. Using a set of high-energy mirrors and optical lenses, the laser beam was shaped into a thin light sheet with thickness of about 2.0 mm in the measurement interest. The illuminating laser sheet was aligned along the spanwise direction, normal to the induced flow direction. During the test, two high resolution 14-bit high-resolution CCD cameras (PCO2000, Cooke Corp.) were used for the SPIV image acquisition. The two cameras were arranged with an angular displacement configuration of about 35 degrees to get a largely overlapped view. With the installation of tilt-axis mounts, laser illumination plane, the lenses and camera bodies were adjusted to satisfy the Scheimpflug condition. The CCD cameras and double-pulsed Nd:YAG laser were connected to a Digital Delay Generator (Berkeley Nucleonics, Model 565) to control the timing of the laser illumination and image acquisition. A general in-situ calibration procedure was conducted to obtain the mapping functions between the image planes and object planes for the SPIV measurements.

The instantaneous flow velocity vectors were obtained by using a frame-to-frame cross-correlation technique with an interrogation window size of 32 pixels ×32 pixels. An effective overlap of 50% of the interrogation windows was employed in the PIV image processing. The instantaneous 2D velocity vectors were then used to reconstruct all three components of the flow velocity vectors in the laser illuminating plane by using the mapping functions obtained through the calibration procedure.

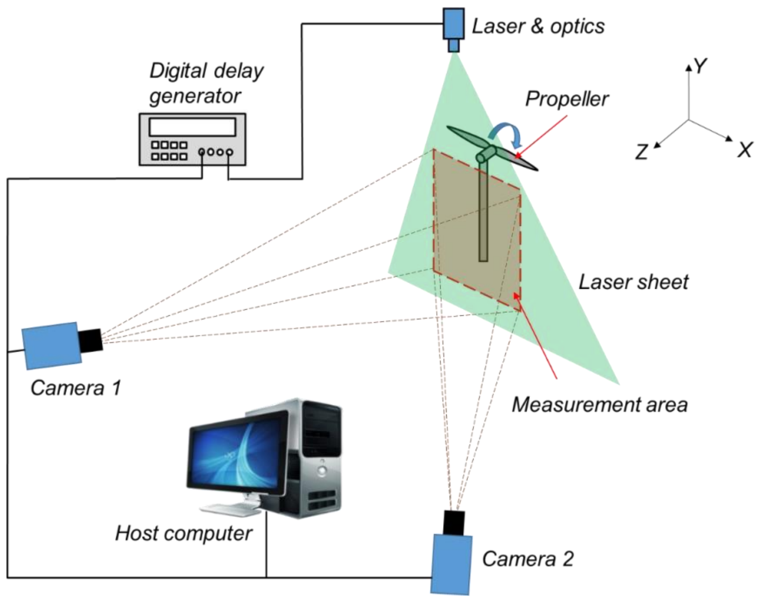

Figure 1. Experimental setup used for the Stereoscopic PIV measurements.

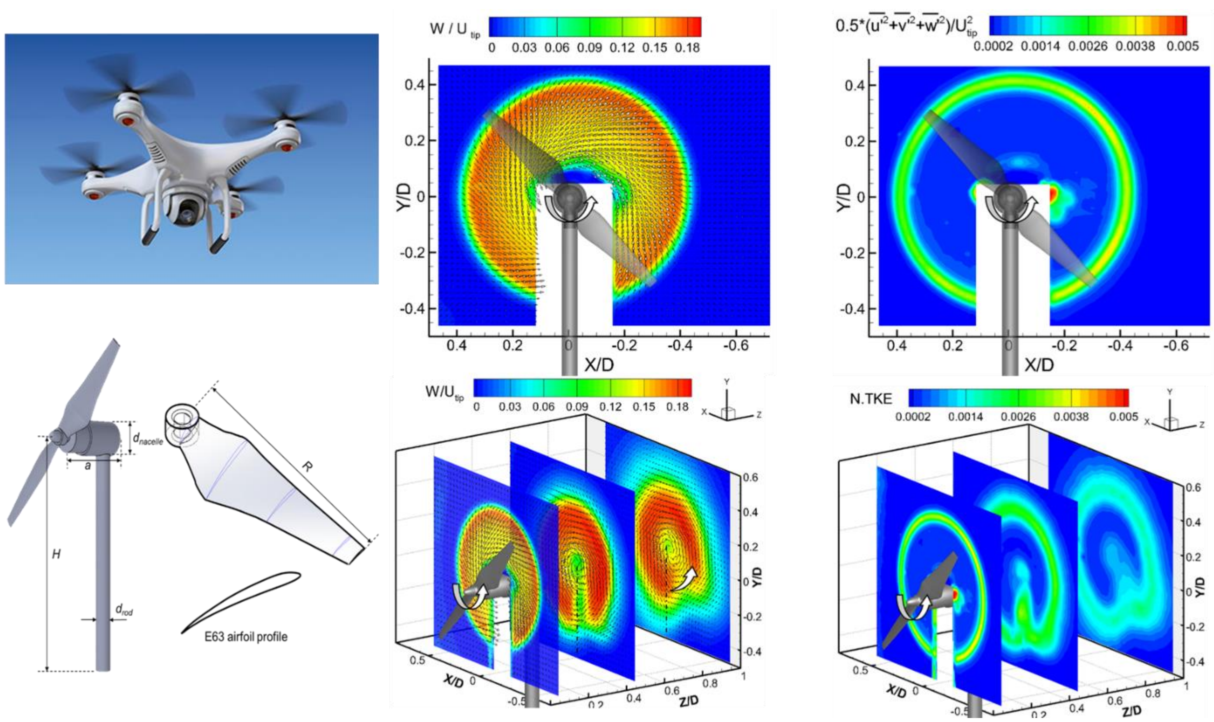

Figure 2. Typical results of Stereoscopic PIV measurements

Experiment procedure:

1. Turn on the power for UAV propeller rotor. The output voltage should be 11.1 V. If everything correct, you will hear a power-on sound from it.
2. Set the duty cycle to 65 for the present laboratory.
3. Turn on the Laser systems and smoke generator to acquire instantaneous SPIV images.

What you need to know before you came to the lab:

1. You should review and understand the basis of SPIV technique.
2. You should review and know how to compute the ensemble-averaged velocities (*U*, *V*, *W*), turbulence kinetic energy ($0.5\left(\overline{u'^2}+\overline{v'^2}+\overline{w'^2}\right)$), and streamwise vorticity ($\omega_z=\frac{\partial v_i}{\partial x}-\frac{\partial u_i}{\partial y}$).

The test conditions for the experiments:

Each group needs to perform the SPIV experiments at,

1. *Z*=0.5*D* downstream

2. *Z*=1.0*D* downstream

Requirements of the lab report

Each group is required to prepare a formal lab report with following results included:

1. Instantaneous SPIV measurement results

a). Instantaneous velocity vector fields (u_i, v_i, w_i)

b). Corresponding instantaneous vorticity fields ($\omega_z = \frac{\partial v_i}{\partial x} - \frac{\partial u_i}{\partial y}$)

2. Ensemble-averaged SPIV measurement results based on 150 ~ 200 frames of instantaneous measurements results.

a). Velocity vectors of the mean flow field (*U*, *V*, *W*)

b). Turbulent kinetic energy distribution (i.e., including three components fluctuations)

c). Reynolds stress distributions

3. Reconstructing the flow fields behind the rotor at *Z*=0.5*D*, 1.0*D*. A brief discussion about the flow fields characteristics and evolutions of vortex structures should also be included in the lab report.