Particle Image Velocimetry Experiments for Flow Around an Airfoil

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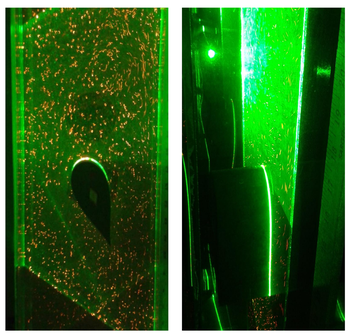
Introduction

Particle Image Velocimetry (PIV) is a technique to quantitatively analyze the flow of a fluid. Experiments recorded with a high speed camera investigate water circulating through a flow cell around an airfoil at varying angles of attack. The velocity field of the flow can be approximated using the data from videos.

Experimental Set Up

Water flows primarily vertically through a 16 cm x 18 cm x 90 cm flow cell. The 3D printed Joukowski airfoil is approximately 4.5 cm at its widest point.

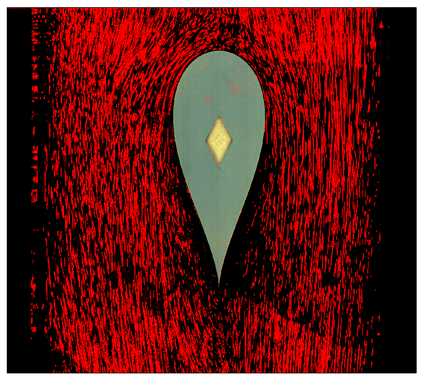


The water is seeded with fluorescent red microspheres (212 - 250 µm diameter) which are illuminated by two 100 mW green line lasers aligned to form a plane in the middle of the cell.

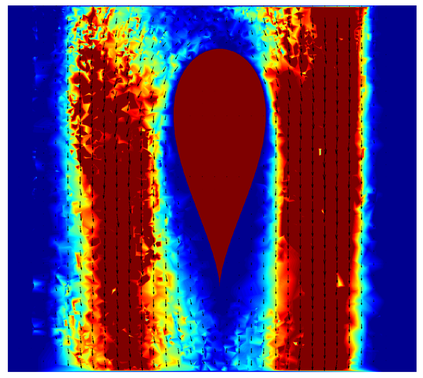
Phantom v9.1 High Speed Color Camera

- 3 GB of RAM
- 1344 x 1200 pixels
- 50 fps
- 2 ms exposure time
- 25 s record time

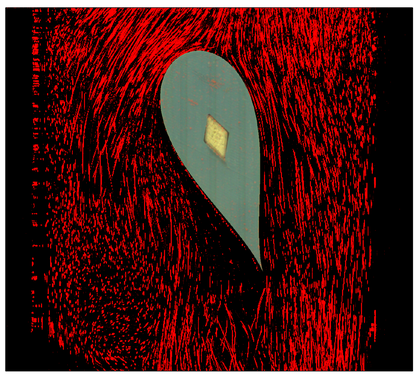
The videos record the movement of the particles around the airfoil. Experiments were run with the airfoil at varying angles of attack. Data from these videos will be used to analyze the flow around an airfoil.



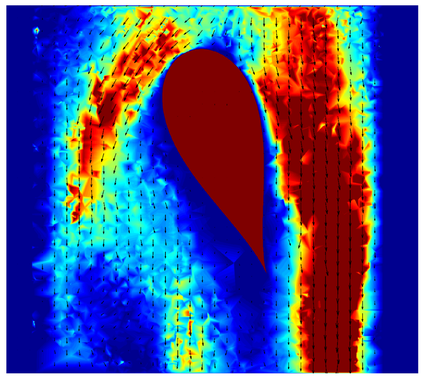
0°
Over 460,000 data points



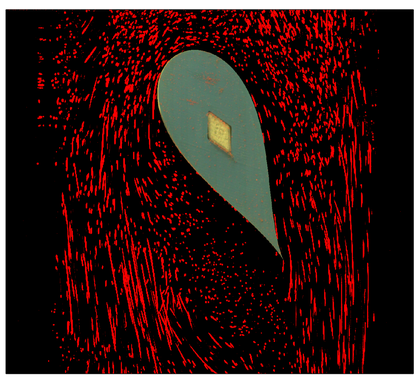
0.25 cm/s
Re = 111



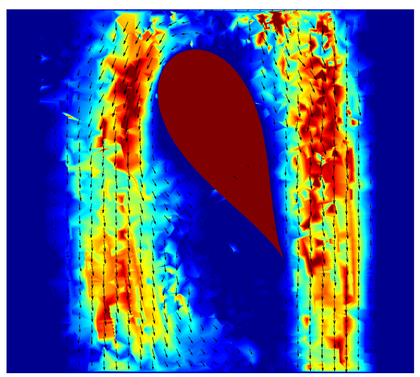
19°
Over 250,000 data points



0.19 cm/s
Re = 84



27°
Over 420,000 data points



0.16 cm/s
Re = 73

$$Re = \frac{\rho V L}{\eta}$$

- Density of fluid (ρ)
- Velocity scale (V)
- Length scale (L)
- Viscosity of fluid (η)

Data Analysis

The data is analyzed in MATLAB and Mathematica. Subtracting the green and blue components (laser and airfoil) from each image and overlaying the intensified red component (particles) from all 1,248 frames into one image shows the motion of the particles in the video. The average velocities of particles within the top and bottom 50 pixels of the video are averaged to find the average velocity of the flow. Velocity includes speed and direction. The velocity field images represent the speed (color) and the direction (vectors) of the velocity of the flow. Cooler colors and shorter vectors represent slower flow speed. Warmer colors and longer vectors represent faster flow speed.

Reynolds Number

The Reynolds Number is a dimensionless quantity (no units) that relates specific parameters of a flow. Using the known values of the density and viscosity of water, the width of the airfoil, and the average velocity, the Reynolds Number can be calculated for each flow. Two flows with parameters related by a fixed ratio have the same Reynolds Number and are considered dynamically similar. The findings from the experiments around an airfoil at varying angles of attack can model comparable flows.

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