PARTICLE IMAGE VELOCIMETRY

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Contents

Methods

Particle Image Velocimetry (PIV) is a common optical method for quantitatively measuring fluid flow. We use this method to measure fluid properties relevant to solving the Naiver-Stokes equations and some resulting fluid forces. In this experiment, we conducted a Particle Image Velocimetry (PIV) on a water tunnel, with a 0.5″ diameter cylinder stretching across the entire test section width of 30.48 *cm*. Thereafter, we had water flowing at rate of 16 *gpm* in the test section with a depth of 14.9 *cm*. The water was seeded with 60μm hollow grass spheres tracer particles which were designed to be neutrally buoyant in water. Our tracer particles faithfully followed the flow dynamic of our fluid, subsequently aligning with the free-stream. We had a 532 *nm* Class IV laser connected to a cylindrical lens send a planar sheet of light beam illuminating our tracer particles, which in turn reflected the laser light and the reflected light was captured by a camera centered on the cylinder, as shown by figure. 1. The laser illuminated the test section, particularly flashing about in a pre-programmed interval with continuous sequence of image being taken at a frequency of 10 *Hz*. And the laser flashes and image acquisition were synchronized through a programmable timing unit (PTU) .

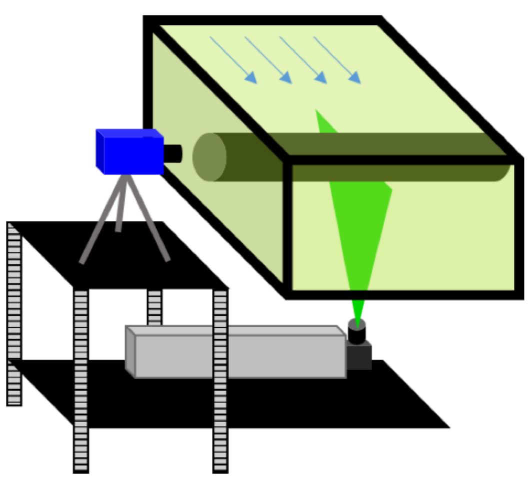

Figure 1: Schematic of PIV setup.

Results

We performed our analysis on Matlab with the PIVlab tool and obtained the following figures.

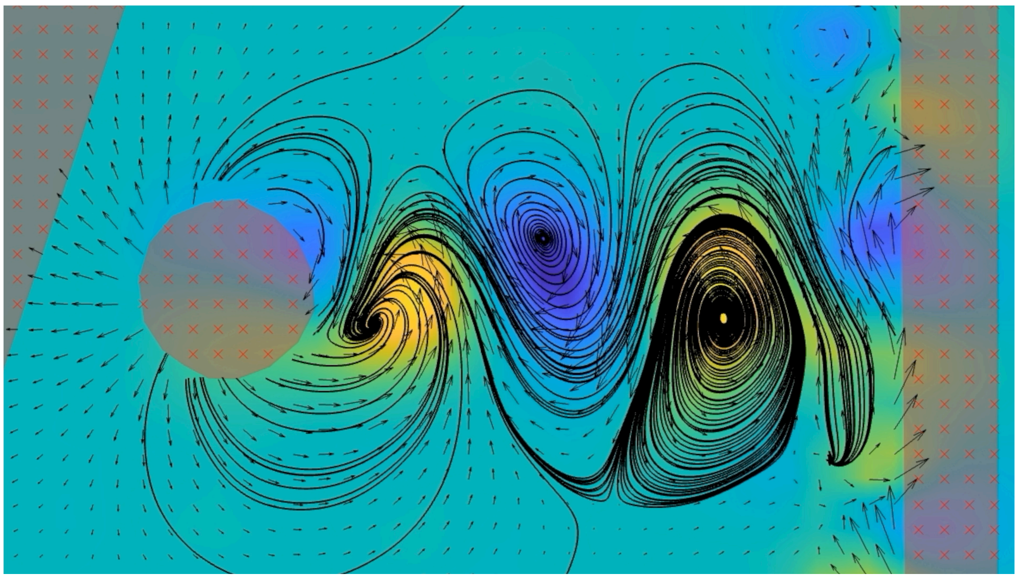

Figure 2: Streamlines (black) and vorticity gradients (*yellow/blue*) from 2C-PIV of a cylinder in free-stream of a cylinder in a free-stream. (Bondo 2021)

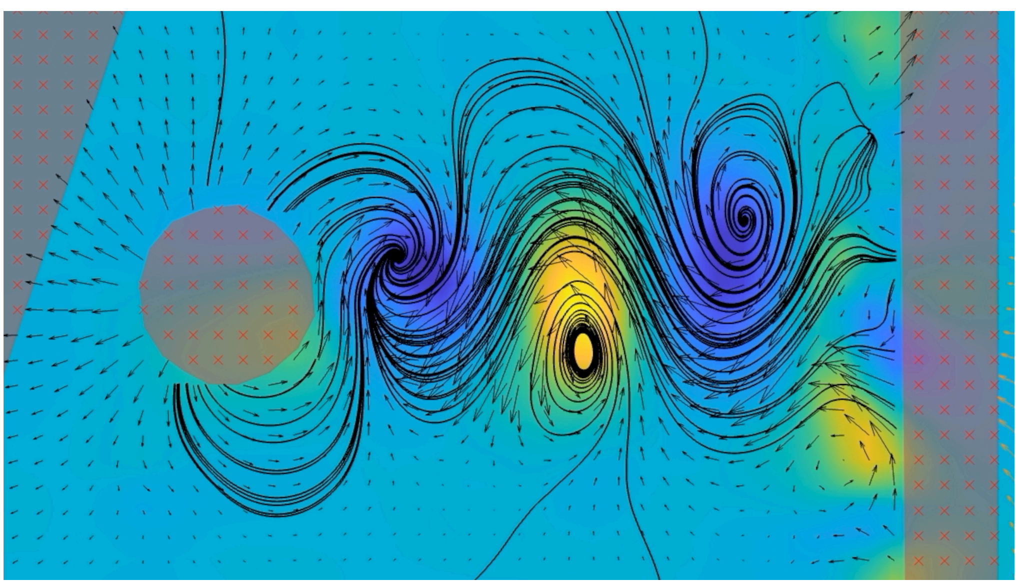

Figure 3: Streamlines (black) and vorticity gradients (*blue/yellow*) from 2C-PIV of a cylinder in free-stream of a cylinder in a free-stream. (Bondo 2021)

Discussion

1. Measured $\boldsymbol{u}$= ***0.026559 m/s***

$$1m/s \approx \frac{gal/m \times 6.309 \times 10^{-5}}{Width \times Depth} \longrightarrow \textbf{\textit{Conversion factor.}}$$

$$\text{Predicted } \boldsymbol{u} \approx \frac{16\, gal/m \times 6.309 \times 10^{-5}\, m^3/s}{\left(30.48 \times 10^{-2}\, m \times 14.9 \times 10^{-2}\, m\right)} = \boldsymbol{0.02223\, m/s}$$

$$\delta = \left| \frac{\nu_M - \nu_P}{\nu_P} \right|$$

$$\delta = \text{Relative Error}$$
$$\nu_M = \text{Measured Value}$$
$$\nu_P = \text{Predicted Value}$$

$$\delta = \left| \frac{0.02656 - 0.02223}{0.02223} \right| = \boldsymbol{0.1949}$$

2. From our experimental results, we observed the development of oscillating vortices on the wake region of our cylinder. Vortices formations are dependent on the Reynolds number of the local flow condition. For external flow, at a low Reynolds number of Re < 4, the flow around the cylinder is relatively laminar and steady, but as we increase the Reynolds number to the range of 40 < Re < 90, the flow separates from the trailing edge of the cylinder and unsteady vortices are shed off the trailing edge of the cylinder. Notably, the flows separation from the trailing edge of the cylinder happens due to boundary flow separation which was brought about by the viscous

effect within the boundary layer. Similarly, in our results figures, we can observe formations of alternating blue and yellow vortices shed down stream of our cylinder signifying the positive and the negative pressure gradient in the top and bottom of our cylinder respectively.

References

Wikimedia Foundation. (2021, August 22). *Kármán vortex street*.Wikipedia. Retrieved September 18, 2021, from https://en.wikipedia.org/wiki/K%C3%A1rm%C3%A1n_vortex_street.