Particle Image Velocimetry Laboratory
Fluid Mechanics

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1 Introduction

In the first laboratory experiment, CFD techniques were used to simulate the flow of water through two infinite parallel plates. The issue with computational simulations is that it is not possible to know if they are correctly calibrated unless they are verified with experimental results. So, how can we study a fluid like air or water if they are transparent?

Throughout history, various techniques have been developed to achieve this goal, starting with observation:

In 1968, Porsche engineers set out to win Le Mans with their new prototype, the Porsche 917, but things did not go as expected. The car turned out to be unstable and difficult to drive. It was observed that the rear part of the car did not get dirty, which caught the attention of the engineers, as this meant that the air was not passing correctly through that area. This led to the decision to cut off the rear part of the car, giving birth to the Porsche 917K, one of the most dominant cars in the history of motorsports. More information. There's also the wind tunnel, which began its development in 1871 when Francis Herbert Wenham, an aeronautical engineer, built a wind tunnel to study the behavior of airplane wings. Wind tunnel history.

Nowadays, techniques such as PIV (Particle Image Velocimetry) and PTV (Particle Tracking Velocimetry) are being implemented in the industry to study the behavior of fluids in different situations. This laboratory experiment aims to study an incompressible Newtonian fluid using the PIV technique, where data such as velocity profile and shear stress will be obtained.

2 Development

For this exercise, you must develop a Python code, which, based on .txt files, should be able to obtain the velocity profile and shear stress from the PIV data obtained in the laboratory. This curve should be compared with a theoretical calculation, where you should base it on Poiseuille's Law, which allows identifying the velocity profile in a laminar flow through a tube.

$$u(r) = u_{max}(1 - \frac{r^2}{R^2}) \tag{1}$$

$$u_{max} = 2 \cdot u_{avg} \tag{2}$$

If you need more information, consult the following link.

You should calculate the shear stress profile using the following formula:

$$\tau = \mu \frac{du}{dy} \tag{3}$$

Likewise, the theoretical shear profile should be calculated and compared.

3 Questions

In addition to the development, you must answer the following questions throughout your report:

What is the difference between PIV and PTV techniques?

How can AI (Artificial Intelligence) be implemented in PIV or PTV techniques?

What advantages does PIV or PTV have over the wind tunnel? Why is the wind tunnel still used in the industry?

Besides the techniques mentioned in this guide, what other techniques are used to study fluid behavior?

Why would be your argument to explain de differences between theoretical and experimental results?

What would be expected if the fluid velocity is increased? Conversely, what would be expected if the fluid viscosity is increased?

Why in the observed case, does the shear stress only have one component?

Mention the assumptions of the Poiseuille equation to derive the three given equations.

4 Recommended Readings

Grant 1997

Hammad 1999

Nezu 2011

5 Data

Dimensions: 8.5 cm in width, 5.3 cm in height, flow rate of 90 L/min.

The txt files with the necessary information to run the codes are available at the following link.

Additionally, you can find a video of the data collection here.

6 Additional Requirements

You must attach your code in the report. You can do this through Google Colab or GitHub (I am sharing a guide of the most important commands with you).

The code should generate the average curve from the provided txt files, both for speed and shear rate.

Remember to include the assumptions made when analyzing the txt files and explain the rationale behind the selected data.

Good luck, and let me know if you need anything!