

LDV Probe Specification

Characterization Sheet _ MiniLDV

Part Number	MiniLDV-G5-100	
Serial Number	P002317	
Fringe Separation	3.52	um
Frequency shifting	N/A	[Hz]
Drive Used for fshift		
Probe volume distance	90	mm
Prower in the probe volume	35	mW
Transmission efficiency	63%	%
Wave length	658	[nm]
Probe volume size at FWHM	70 X70	um
Probe volume length at FWHM	500	um

Tabel 2 Measured value of velocity as function of vertical distance from the cylinder.

Position	Velocity	RSM Velocity
Above the cylinder		
Close to Cylinder		
5		
7.5		
10		
20		
25		
Below the cylinder		
Close to Cylinder		
5		
7.5		
10		
20		
25		

4.0 Lab Reports Analysis

Based on the measurements obtained in Section 3:

1. Calculate Drag coefficient (C_D)
2. Compare the measured ratio of $\frac{U_{2\infty}}{U_{1\infty}}$ with theoretical value from the equation (16).

APPENDIX A: Specification of MiniLDV

Specification for hardware and instrumentation with MiniLDV system are given in Table A.1 and Table A.2 gives the specification of the probe

8. Run the NI scope and set proper Timeperiod and Voltage. Doppler bursts should start appearing on the oscilloscope. Calculate the frequency from the plot on the scope and enter the frequency value into the software under **Acquisition** → **Expected Frequency**
9. Calculate the velocity of the flow using the frequency.

$$U = f * 3.52$$

Compare this value to the value of velocity generated using the software.

10. Obtain the velocity profile by positioning the probe using the traverse at locations indicated in the Table 1 and establish the average freestream velocity by placing the probe
11. Acquire the data using Single Point Acquisition mode. Press **Acquire** button to record the data. Check the 'Save' checkbox to save the file. Record the values U_{bar} and U' into the Table 1.(Refer Appendix B)
12. Using the profile acquisition measure the velocity profile above and below the cylinder and record your data in Table 2.

Table 1 Measured value of velocity as function of distance from the cylinder.

Ambient Temperature, T_a (°C)	
Water density (kg/m ³)	
Reynolds number	
Viscosity of water (μ)	

Position	Velocity	RSM Velocity
Downstream		
Close to Cylinder		
5		
7.5		
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		
Upstream		
Close to Cylinder		
5		

chamber further improves the flow quality by accelerating the flow to test speed. Flow speed in the test section can be continuously varied from zero to more than 2.5 ft/s by varying the valve.

B. 3-D Traverse

The 3-D traverse allows ease of positioning and test area traversal for the miniLDV probe. Automatic traverse allows the miniLDV software, Burst Processor (BP- miniLDV), to automatically move the miniLDV probe vertically, a particularly useful technique for obtaining velocity profiles. The automatic traverse system comes with a traverse controller that should be connected to a personal computer USB port with an USB cable.

C. MiniLDV System

The miniLDV system includes a miniLDV probe, driver electronics, band-pass filter, and BPminiLDV acquisition hardware and processing software to make accurate measurement of fluids of varying temperature, pressure, and density. See the Appendix I for specification of the miniLDV System.

D. Tracer particles/Seeding of the water flow

The tap water used to fill the tunnel should naturally contain the seeding particles needed to perform LDV measurements. However, these particles have a tendency to settle out over time which will lead to reduced samples and poor measurement. If the number of samples are less than 5 samples per second seeding should be added to the system.

E. Cylinder Model

A circular cylinder is manufactured from brass and spans the entire test section width (that means ,of course that the end of the cylinder are in the boundary layers on the side walls of the water tunnel test section).

$$U_{1\infty}h - \int_0^h U_2 dy = 0 \quad (12)$$

add and subtract $U_{2\infty}h$ where $U_{2\infty}$ is the freestream flow located downstream of the cylinder:

$$U_{1\infty}h - U_{2\infty}h + \int_0^h (U_{2\infty} - U_2) dy = 0 \quad (13)$$

This can be re-written as

$$(U_{1\infty} - U_{2\infty})h + U_{2\infty} \int_0^h \left(1 - \frac{U_2}{U_{2\infty}}\right) dy = 0 \quad (14)$$

The displacement thickness/fringe spacing is given as

$$S \equiv \int_0^h \left(1 - \frac{U_2}{U_{2\infty}}\right) dy \equiv \text{Displacement thickness (Fringe Thickness)} \quad (15)$$

The relationship between the freestream velocities upstream and down stream of the object, the displacement thickness, and the height of the apparatus can be given as

$$U_{1\infty} = U_{2\infty} \left(1 - \frac{S}{h}\right) \quad (16)$$

Eq. (16) can be used calculate the the change in the free stream velocity from state 1 ahead of the cylinder to state 2 in the wake of the cylinder. However, unless boundary layer effects at the water tunnel walls are taken into effect, this relationship will not be very accurate.

The Drag force on the cylinder can be calculated from the momentum loss of the the fluid entering and exiting the control volume.

In general for a flow with uniform loss in flow velocity the drag would be given as

$$\text{Drag} = m \cdot \Delta U \quad (17)$$

where m is the mass flow rate around an object and is the change in free-stream flow speed around this object. Again, this form assumes that the flow field is uniform in the direction transverse to the mean flow vector.

In this case, the drag is given by momentum-balance arguments in terms of an integral

$$\text{Drag} = \iint \rho U_2 \cdot da \cdot (U_1 - U_2) \quad (18)$$

The drag per length b of the cylinder is given by

$$\text{Drag} = b \int_0^h \rho U_2 \cdot (U_1 - U_2) dy \quad (19)$$

Assuming the velocity ahead of the cylinder is uniform and setting $b=1$, the Drag per $U_1 U_1$ unit length of cylinder is

$$\text{Drag} = \frac{1}{2} \rho U_{1\infty}^2 \int_0^h 2 \left(\frac{U_2}{U_{1\infty}} \right) - \left(\frac{U_2}{U_{1\infty}} \right)^2 dy \quad (20)$$

With the assumption that $U_{2\infty} \cong U_{1\infty}$

1.2 A. Flow Over a Cylinder

A circular cylinder is one of the most basic shapes available. The study of flow over a stationary circular cylinder is a classic fluid mechanics problem. In general, the pressure distribution along the upper and lower surfaces of a circular cylinder is equal and no lift is generated. This means the velocity fields above and below the cylinder are symmetric about a horizontal axis.

A circular cylinder will experience finite drag from both skin friction and pressure effects (flow separation). Viscous effects cause skin friction and flow separation/flow reversal (recirculation) over the rear of the cylinder. The flow separation causes the bulk of the drag.

For incompressible viscous flow the drag coefficient (C_D) is a function of **Reynold's number (Re)**. **Remember $Re = \rho_\infty U_\infty d / \mu_\infty$ and ∞ represents free stream values.** Thus the important parameters of the problem are density (ρ_∞), free stream velocity (U_∞), cylinder diameter (d), and fluid viscosity (μ_∞). For water flows at fixed temperature, density and viscosity are essentially constant. Re can be varied by changing the free stream velocity or cylinder diameter.

- For a very low Reynold's number (approx. 0 – 4), the flow remains attached to the cylinder. This viscous regime is called Stokes flow.
- For Re between about 4 – 40, the flow separates behind the cylinder and forms two separate, stable (attached) vortices.
- For higher Re, the flow behind the cylinder becomes unstable and vortex shedding occurs. The shedding occurs alternately from above and below the cylinder, forming a distinct pattern in the wake flow, called a von Karman vortex sheet.
- At even higher Re (around 105) the vortex sheet becomes a turbulent, distinct wake. The laminar boundary layer on the surface of the cylinder separates on the forward face, at about 80 degrees from the stagnation point.
- At Re between about 3×10^5 to 3×10^6 , the flow reattaches on the back face of the cylinder. This happens because transition to turbulent flows takes place in the free shear layer over the top of the separated region. The flow separates again at about 120 degrees from the stagnation point. The pressure drag in this regime is reduced from that in the lower Re regime noted above.
- For Re greater than 3×10^6 the boundary layer transitions to turbulent on the front face before separation and the more energetic boundary layer stays attached until a bit less than 120 degrees from the stagnation point.

The wake region downstream of a cylinder, or any other solid body, is an area of reduced velocity, relative to the freestream velocity. The height of the wake region increases further downstream of the body. The wake is a result of the drag force between the body and the flow.

The **Strouhal number** is a dimensionless parameter describing the oscillating frequency of a flow. Usually it is defined as:

1.0 Theoretical Background

Conventional instrumentation like a Pitot static probe and static pressure ports cannot measure velocity fluctuations associated with turbulence or unsteadiness. Furthermore the time average velocities they can measure are inaccurate in regions where the flow is highly turbulent, reversing or of unknown direction (as in the center of the wake of a circular cylinder). Unfortunately such regions are often of the greatest engineering interest. Study of such regions is done using more sophisticated measurement techniques like PIV, LDV and hot-wires anemometry.

In this lab session study of flow over a cylinder is done using Laser Doppler Velocimetry technique.

A laser Doppler anemometer measures the velocity at a point in a flow using light beams. It senses true velocity component, and measures that component in a sequence of near instantaneous samples. These characteristics confer several advantages - an LDA does not disturb the flow being measured (like a Pitot does), it can be used in flows of unknown direction and it can give accurate measurements in unsteady and turbulent flows where the velocity is fluctuating with time. Among the disadvantages of LDAs are expense (typically \$40,000 for a simple system), the need for a transparent flow through which the light beams can pass, and the fact that they do not give continuous velocity signals.

Basic principles of LDV

In this lab session a miniLDV sensor ("One component dual-beam system") system is used. Figure 1 shows a "One-component dual-beam system". *One component* because it measures one specific velocity component (U in the diagram). *Dual beam* because it uses two laser beams of equal intensity. The beams are generated from a single laser using a half silvered mirror (the 'beam splitter'). They are then focused using a lens (called the *sending* lens). The lens also changes the direction of the beams causing them to cross at the point where they are focused. The region where the beams intersect is where the velocity measurement is made. It is called the *measurement volume*.

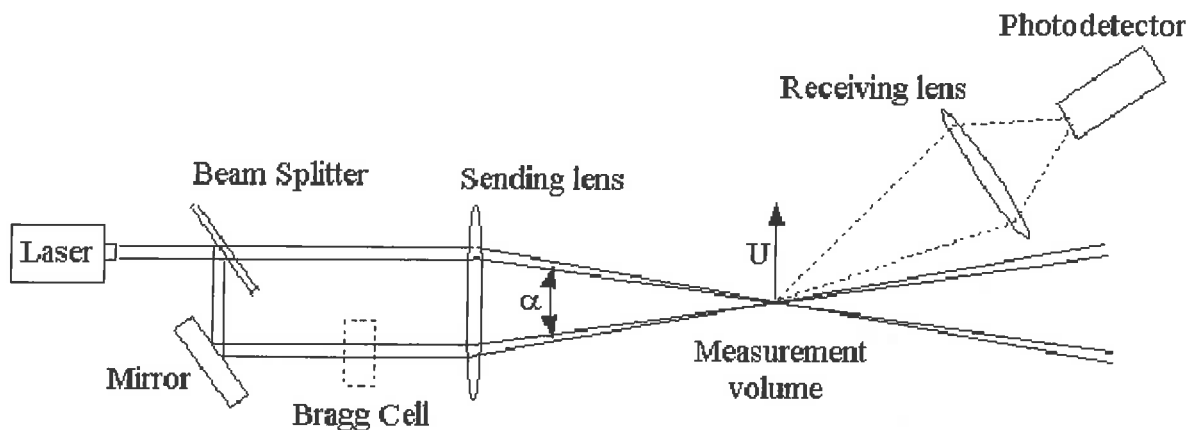


Figure 1. A single-component dual-beam LDV system in forward scatter mode

The interference of the light beams in the measurement volume creates a set of equally spaced fringes (light and dark bands) as shown in Figure 2. these are parallel to the bisector of the beams. A measurement is made when a tiny particle being carried by the flow passes through these fringes. As it does so the amount of light received by the particle fluctuates with the fringes. The amount of light scattered (i.e. reflected) by the particle